Lecture Notes in Energy 67

Adele Manzella
Agnes Allansdottir
Anna Pellizzone *Editors*

Geothermal Energy and Society

Springer

Lecture Notes in Energy

Volume 67

Lecture Notes in Energy (LNE) is a series that reports on new developments in the study of energy: from science and engineering to the analysis of energy policy. The series' scope includes but is not limited to, renewable and green energy, nuclear, fossil fuels and carbon capture, energy systems, energy storage and harvesting, batteries and fuel cells, power systems, energy efficiency, energy in buildings, energy policy, as well as energy-related topics in economics, management and transportation. Books published in LNE are original and timely and bridge between advanced textbooks and the forefront of research. Readers of LNE include postgraduate students and non-specialist researchers wishing to gain an accessible introduction to a field of research as well as professionals and researchers with a need for an up-to-date reference book on a well-defined topic. The series publishes single and multi-authored volumes as well as advanced textbooks.

More information about this series at http://www.springer.com/series/8874

Adele Manzella · Agnes Allansdottir
Anna Pellizzone
Editors

Geothermal Energy and Society

Springer

Editors
Adele Manzella
National Research Council
Institute of Geoscience
and Earth Resources
Pisa, Italy

Anna Pellizzone
National Research Council
Institute of Geoscience
and Earth Resources
Pisa, Italy

Agnes Allansdottir
Fondazione Toscana
Life Sciences
Siena, Italy

ISSN 2195-1284 ISSN 2195-1292 (electronic)
Lecture Notes in Energy
ISBN 978-3-319-78285-0 ISBN 978-3-319-78286-7 (eBook)
https://doi.org/10.1007/978-3-319-78286-7

Library of Congress Control Number: 2018945440

Printed on acid-free paper

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Keywords Geothermal energy • Public engagement • Social aspects
Energy transition

Genesis of the Book

Once upon a time, the scientist or the innovator conducted experiments in the lab, and shared results, models, and theories with other experts before presenting them to the whole society. The white coats were the unquestioned leading actors of techno-scientific development and the place of research and innovation was first of all the laboratory. In this context, the public was not part of the process of research and innovation. The public «could chose to learn the results of the laboratory sciences or remain indifferent to them, but it could certainly not add to them, dispute them, and even less contribute to their elaboration» (Latour 2004, p. 17).

Today the story has changed place, protagonists, and narrative. The public has become a major actor in the techno-scientific realm. This is not only because citizens pay taxes and want to have a voice on how public money are invested ("no taxation without representation" becomes here "no innovation without representation", Latour 2004) but also because citizens are end users of scientific and technological developments, making their views and needs extremely important—we would say founding—in the innovation process, also from the innovators perspective. Moreover, key enabling technologies (KET) such as information and communications technologies (ICT), 3D printing, and distributed energy resources (DER) are encouraging experiences of civic codesign, bringing social intelligence directly into the innovation process and fostering the development of bottom-up and frugal innovation.

The key role of the public is particularly important for energy technologies and energy transition, dealing with the so-called trilemma of (1) climate changes, (2) energy security, (3) energy justice (meaning here as socioeconomic challenges and inequalities, see also Chilvers and Longhurst 2016). Energy-related issues are characterized by high levels of complexity and thus require a sustained and reasoned public dialogue. First, "they bring into play multiple interconnected elements combining technical, behavioural and institutional issues" (Pidgeon et al. 2014); second, they have different scales of analyses (local as well as global); third, the level of uncertainty and/or ignorance, for instance to our energy and climate future, is high. Finally, research on energy and climate is not happening in a closed site, as the laboratory may be, but across the entire planet.

The complexity of the energy issue, and the transitions towards a low carbon future, brings into play a complex system of values and of powers, requiring a continuous, alert, public scrutiny. The debate about the connection between energy transition and democracy is becoming lively and several actors (academic, professional, civic groups, decision makers) are suggesting new frameworks to reshape the discussion around and the governance of our energy future. This is because the energy system—and the way it is organized—has profound implications on individual and social dimensions such as happiness, freedom, equity, welfare, and due process (Sovacool et al. 2015), becoming a matter of values, social justice, democracy, and power (Stirling 2014). The distributed nature of renewable energy sources (RES) requires a profound change of infrastructures and in the economical and political organization of our society, which is currently based on a fossil-fuel centralized system. The current situation is often described as "carbon lock-in" inertia, meaning that in order to introduce alternative energies we need a process of technological, social and institutional co-evolution (Lehman et al. 2012).

In this framework, the development of participative governance in the energy realm is becoming a pressing issue and geothermal energy makes no exception. Understanding the behavior of social and political actors and facilitating and enabling public participation in the energy transition are described as two key actions towards the strengthening and the acceleration of the energy transition in the European Strategic Energy Technology Plan (see Annex IV: Research and innovation actions, Part IV: cross-cutting aspects).[1] At a global level, at the 21st Meeting of the Conference of the Parties of the United Nations Framework Convention on Climate Change in Paris, a coalition of 38 countries and over 20 development and industry partners joined forces in the Global Geothermal Alliance (GGA), a platform for enhanced dialogue and knowledge sharing within the constituency as well as for coordinated action to increase the share of installed geothermal electricity and heat generation worldwide.[2] In September 2017, the governments reaffirmed their commitment to work together to identify and implement measures that will significantly increase the speed of geothermal energy development around the world, under the terms of the Florence Declaration promoted by GGA.[3]

---

[1] https://www.sintef.no/globalassets/project/eera-ccs/ir—annex-i-_-part-iv—detailed-contributions-from-the-stakeholders—v2014-10-20.pdf.

[2] http://www.globalgeothermalalliance.org/.

[3] http://www.globalgeothermalalliance.org/assets/pdf/Florence_Geothermal_Declaration_September2017.pdf.

Considering the old habit of humankind to make use of hot fluids naturally flowing at surface for heating, cooking, healing purposes, there should be no doubt that the use of geothermal energy is ancient. Thanks to technological optimization, the geothermal energy applications widened in number of use and scale. But there were two main applications that marked the uplift of geothermal energy as a global energy source: the production of electrical power, tested and proved in Tuscany (Italy) in 1904 and then launched at the industrial level on 1913, and the geothermal district heating, whose concept was born in Boise (Idaho, USA) on 1890 and adopted in Reykjavik (Iceland) in 1930. Both geothermal electrical power and geothermal district heating can be considered as important revolutions in the energy field and are among the first attempts to not rely solely on fossil fuels for two of the most demanding energy demands, e.g., electricity and residential heat.

Such a pioneering past of geothermal energy among renewable energies is not only unknown to most people, but, in a certain way, it represents a disadvantage. After a golden age in the 1970s and 1980s, with a jump in technological development and production similar to what we see now in solar and wind technologies, the interest in geothermal energy declined in parallel to oil price reduction. Geothermal technology was considered mature and it did not receive attention and research funding for about two decades. Moreover, those early brave attempts and consequent technological development were pursued with a trial-and-error logic, in years when environmental concerns were minimum, monitoring was based on opinions more than on data, and numerical simulation and effect forecast were partial. Some negative effects of the early deployment, also due to the wild, and often inconsiderate approach in some areas, and the lack of baseline data for environmental assessment remain impressed in the geothermal Curriculum Vitae.

To assist the current energy transition to low carbon technologies, any energy source, including geothermal, is under the critical lens of environmental groups and citizens living in the surroundings of operative or proposed energy plants. The geothermal sector is under public scrutiny and needs to proceed in a sustainable and responsible way. Geothermal plants, in operation or planned, have faced opposition in various countries. The matter goes beyond the technical issues, and requires social science studies and public engagement.

Such a topic is relatively new in geothermal practice, and still very restricted in literature but geothermal energy is well positioned in number of scientific publication in social related topics with respect to other energy sources. It seems that the geothermal sector pays more attention to social issues than other technologies, as shown by the results of a preliminary analysis, synthetized in Table 1. Searching in ScienceDirect[4] the number of papers related to various energy technologies and, for comparison, to leading topics of public interest (genomics and geo-engineering) in the last decade (2008–2018) we found that, in general, social science and public engagement represent a very minor part of the technology-related literature (as also

[4] A leading search engine of peer-reviewed scholarly literature with over 3800 journals and more than 37,000 book titles.

Table 1 Results of a desk research in ScienceDirect in the timeframe 2008–2018.

Technology		Number of publications	Social/Total rate %
Energy	Total	387,437	0.14
	Social related issues	528	
Geothermal	Total	4666	0.43
	Social related issues	20	
Solar energy	Total	26,422	0.06
	Social related issues	17	
Wind energy	Total	11,486	0.37
	Social related issues	43	
Biomass	Total	52,159	0.12
	Social related issues	61	
Nuclear energy	Total	11,329	0.23
	Social related issues	26	
Hydroelectric	Total	1064	0.28
	Social related issues	3	
CCS	Total	4777	2.22
	Social related issues	106	
Genomics	Total	31,641	0.04
	Social related issues	14	
Geo-engineering	Total	142	4.23
	Social related issues	6	

We searched articles containing—in keywords, in abstract or in title—the word "geothermal" together with one of the following: "public engagement" or "social aspects" or "public perception" or "social acceptance". Data Source: Science Direct 2008–2018

highlighted in Sovacool 2014). Within this restricted domain, geothermal energy scores third for rate of social topic over the total number of publications, after geo-engineering and carbon capture and storage (CCS) technologies.

Beyond a still scarce presence of social studies accompanying energy research and innovation, it is also important to stress that scholars consider public engagement from different perspectives, e.g., behavior change, social acceptance, public consultations, activism—as the emergent social movement "energy democracy" (Burke and Stephens 2017)—grassroots innovation, that results in a rather fragmented and inhomogeneous picture. This is also the case for public engagement with geothermal energy as it is fragmented and underexplored both in terms of conceptual frameworks and in policy making and energy governance. Our tentative approach to this issue is to consider the engagement of the public not only as consumers (becoming *prosumers* in the case of distributed renewable energy technologies) but as codesigners and as citizens.

When contacting our colleagues across the globe to ask for their interest in contributing to the book *Geothermal Energy and Society*, we told them that the book would have been focused on the social issues connected to geothermal energy.

At a first sight, this book could be described as something building bridges between different disciplines (i.e., earth sciences, engineering, and social sciences) and actually the interdisciplinary approach of this book is evident starting from the multidisciplinary expertise of the authors of the volume. However, as you are going to understand from the following chapter, the ambition of this book goes a little bit further than linking separated fields of study and/or different countries in the globe. By adopting a systemic approach, our goal is to focus on the interaction between the energy and the society realms as an emerging disciplinary domain in itself, contributing to the development of new tools for a participated governance of geothermal energy (and for energy innovation).

How This Book is Organized

This book is composed of two main sections or blocks, as described by Fig. 1. The first block introduces to the main topics treated by the book, so that readers will be able to understand the whole content of the book regardless of their background.

Geothermal terminology and technology is briefly explained in Chapter "General Introduction to Geothermal Energy", with some detail regarding environmental aspects. Chapter "Policy and Regulatory Aspects of Geothermal Energy: A European Perspective" describes policy and regulation adopted in Europe and regarding geothermal applications, as a proxy of global inhomogeneous situation and complexity. The point of view of geothermal energy companies is described in Chapter "Business Strategies in Geothermal Energy Market: A Citizens-Based Perspective", where the Corporate Social Responsibility approach is described, while Chapter "Geothermal Energy and Public Engagement" expands the perspective to incorporate any societal actor in the process of technological innovation.

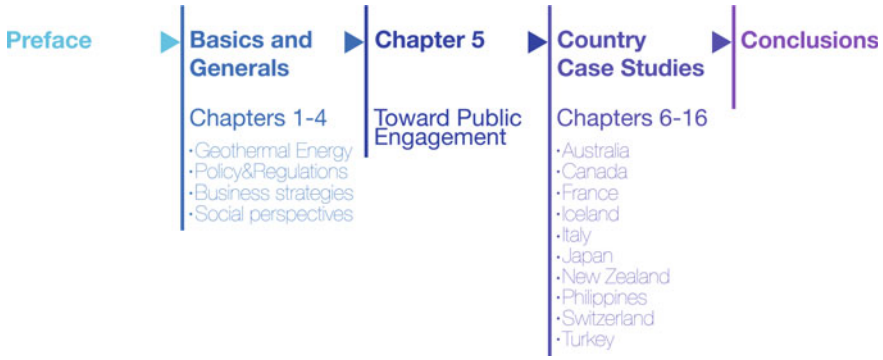


Fig. 1 Book's structure

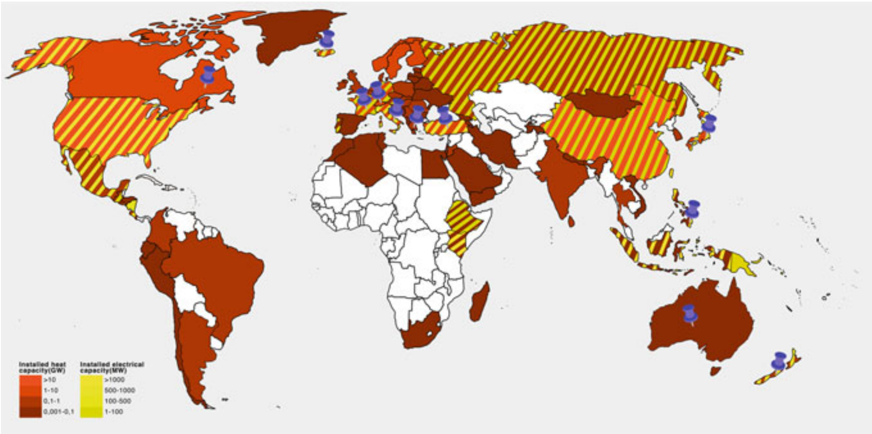


Fig. 2 Global distribution of geothermal applications (heat producing countries in red, electricity producing countries in yellow. Stripes indicate production of both heat and electricity). Countries described in our case studies are highlighted by purple pins. *Data Source* Lund and Boyd 2015, Bertani 2016

Chapter "Drawing the Picture: Public Engagement Experiences as Tools Towards an Emerging Framework" introduces the readers to the second block, where country Profiles with case studies from eleven countries around the Globe are presented. These chapters have been written following a common framework, so that analogies and peculiarities of each country can be easily retrieved.

The eleven cases described in this book, although partial with respect to the many countries using geothermal energy (Fig. 2), refer to cases of large geothermal production and potential and/or to extensive social engagement studies and policies.

The final chapter, conclusions, attempts to bring together all the country profiles and cases studies by comparing and contrasting what kinds of public engagement mechanisms and processes were put in place; what and who prompted social scientific research on geothermal energy and society in that particular country; what were the results and if and how they were implemented in policymaking for energy innovation and finally levels of knowledge about geothermal energy of the general public. From this synthesis, we attempt to derive input into policymaking and to propose steps towards an action plan for the future.

We hope you will enjoy the book as we enjoyed organizing, reading, and analyzing it. We are happy to have had the occasion to include so many case studies in a book, and we are sure that many will discover something new in the following chapters, either in the details or in the comparison of the different cases.

The multi- and interdisciplinary approach of the book will be evident proceeding with the reading. We believe that it will result in a mutual learning process and will help to build a framework for researchers, operators, and policymakers.

Acknowledgements

We acknowledge all the authors who joined us in this adventure, and contributed to the quality of this edited volume, and Springer Nature publishing, and Anthony Doyle in particular, for giving us the opportunity to publish it. We also thank Niccolò Abate for producing the graphic of Figs. 1 and 2.

Pisa, Italy — Adele Manzella
Siena, Italy — Agnes Allansdottir
Pisa, Italy — Anna Pellizzone

References

Bertani R (2016) Geothermal power generation in the world 2010–2014 update report. Geothermics 60:31–43

Burke MJ, Stephens JC (2017) Energy democracy: goals and policy instruments for sociotechnical transitions. Energy Res Soc Sci 33:35–48

Chilvers J, Longhurst N (2016) Participation in Transition(s): reconceiving public engagement is energy transition as Co-produced, emergent and diverse. J Environ Policy Plann 18(5):585–607

Latour B (2004) Which protocol for new collective experiments? In: Henning Schmindgen (ed) Experimental cultures, KadmosVerlag, Berlin, p 17

Lehmann P, Creutzig F, Ehlers MH, Friedrichsen N, Heuson C, Hirth L, Pietzcker R (2012) Carbon lock-out: advancing renewable energy policy in Europe. Energies 5:323–354

Lund JW, Boyd TL (2015) Direct Utilization of Geothermal Energy 2015 Worldwide Review. In: Proceedings World Geothermal Congress 2015, Melbourne, Australia [Online]. Available at: https://pangea.stanford.edu/ERE/db/WGC/papers/WGC/2015/01000.pdf Accessed 26 March 2018

Pidgeon N, Demski C, Butler C, Parkhill K, Spence A (2014) Creating a national citizen engagement process for energy policy. PNAS 111(4):13606–13613

Sovacool BK (2014) Diversity: Energy studies need social science. Nature 511:529–530

Sovacool BK, Ryan SE, Stern PC, Janda K, Rochlin G, Spreng D, Pasqualetti MJ, Wilhite H, Lutzenhiser L (2015) Integrating social science in energy research. Energy Res Soc Sci 6:95–99

Stirling A (2014) Transforming power: Social science and the politics of energy choices. Energy Res Soc Sci 1:83–95

Acknowledgements

As editors we would like to express our warmest thanks to all those who have contributed to this book. We also want to thank the production team at Springer Nature, in particular Saranya Kalidoss for her kind assistance and patience.

Contents

General Introduction to Geothermal Energy 1
Adele Manzella

Policy and Regulatory Aspects of Geothermal Energy: A European Perspective 19
Philippe Dumas

Business Strategies in Geothermal Energy Market: A Citizens-Based Perspective 39
Michele Contini, Eleonora Annunziata, Francesco Rizzi and Marco Frey

Geothermal Energy and Public Engagement 55
Agnes Allansdottir, Anna Pellizzone and Alessandro Sciullo

Drawing the Picture: Public Engagement Experiences as Tools Towards an Emerging Framework 67
Anna Pellizzone and Agnes Allansdottir

An Application of Social Science to Inform the Stakeholder Engagement of an Emerging Geothermal Industry in Australia 71
Simone Carr-Cornish, Lygia Romanach and Cameron Huddlestone-Holmes

Public Perception Regarding Deep Geothermal Energy and Social Acceptability in the Province of Québec, Canada 91
Michel Malo, Frédéric Malo, Karine Bédard and Jasmin Raymond

Geothermal Energy in France. A Resource Fairly Accepted for Heating but Controversial for High-Energy Power Plants 105
Philippe Chavot, Anne Masseran, Cyrille Bodin, Yeny Serrano and Jean Zoungrana

Social Aspects of Geothermal Energy in Greece 123
Spyridon Karytsas, Olympia Polyzou and Constantine Karytsas

Taming the Elements—The Use of Geothermal Energy in Iceland 145
Örn D. Jónsson, Bjarni F. Karlsson and Rögnvaldur J. Saemundsson

Geothermal Resources in Italy: Tracing a Path Towards Public Engagement 159
Anna Pellizzone, Agnes Allansdottir and Adele Manzella

Issues Around Geothermal Energy and Society in Japan 179
Kasumi Yasukawa

New Zealand's Public Participation in Geothermal Resource Development 193
Katherine Luketina and Phoebe Parson

The Philippine Experience in Geothermal Energy Development 217
Marnel Arnold Ratio, Jillian Aira Gabo-Ratio
and Anna Leah Tabios-Hillebrecht

Geothermal Energy in Switzerland: Highlighting the Role of Context 239
Olivier Ejderyan, Franziska Ruef and Michael Stauffacher

Turkey—Pitching Forward to Energy Independency 259
Melek Akca Prill

Conclusions 279

Editors and Contributors

About the Editors

Adele Manzella is a Senior Scientist at the Italian National Research Council (CNR), working as a geophysicist and conducting field and theoretical investigations of geothermal systems in Italy and abroad. She coordinated for CNR the most recent national geothermal evaluation projects and led the CNR participation in many EU funded projects in the geothermal sector related to geothermal exploration, research coordination and outreach. She is President of the Italian Geothermal Association (UGI) and participates in the Steering Committee and Secretariat of the European Technology and Innovation Platform for Deep Geothermal (ETIP-DG). Nowadays, her activity tackles all fields of research, training, information, and promotion of geothermal energy.

Agnes Allansdottir is a social psychologist researcher who studied at the London School of Economics and Political Science. She has extensive experience of empirical research on societal dialogues on science and technology. From 1996, she lectured on psychology of communication, science communication, bioethics and science in society at the University of Siena. She has been a principal investigator on a series of EC funded international research projects on life sciences and society, climate change, public engagement, ethically sensitive technologies, and public ethics. She has repeatedly given advice to international and national policymaking bodies and has presented and published widely in high-level international journals, including *Nature*, *Nature Biotechnology*, *Plos One*, *PNAS* and *Energy Policy*.

Anna Pellizzone is a science writer and researcher. In 2017, she got a scholarship at the Italian National Research Council, Institute of Geosciences and Earth Resources. Natural scientist, she holds a master in Science Communication and a Ph.D. in Earth Sciences, obtained with a thesis on the social aspects of geothermal technologies in collaboration with the Italian National Research Council. Since 2012, she has been conducting research activities for the CNR and has participated in several projects (VIGOR, ATLANTE, GEOELEC, ETIP-DG) on geothermal energy, with contributions aimed at deepening the relationship between innovation, research, and society. Her research interests are focused on Responsible Research and Innovation (RRI) and she is author of several academic papers related to public engagement with geothermal energy. Since 2010 she has been writing also for generalist newspapers, magazines, and websites and since 2016 Anna has been collaborating with Fondazione Bassetti on the SMART-map project (www.projectsmartmap.eu) and with Fondazione Eni Enrico Mattei.

Contributors

Agnes Allansdottir Fondazione Toscana Life Sciences, Siena, Italy

Eleonora Annunziata Sant'Anna School of Advanced Studies, Institute of Management, Pisa, Italy

Karine Bédard Institut national de la recherche scientifique, Centre Eau Terre Environnement, Quebec City, QC, Canada

Cyrille Bodin LISEC, University of Strasbourg, Strasbourg, France

Simone Carr-Cornish CSIRO, Dutton Park, Australia

Philippe Chavot LISEC, University of Strasbourg, Strasbourg, France

Michele Contini Sant'Anna School of Advanced Studies, Institute of Management, Pisa, Italy

Philippe Dumas EGEC, European Geothermal Energy Council, Brussels, Belgium

Olivier Ejderyan Department of Environmental Systems Science, Transdisciplinarity Lab, ETH Zurich, Zurich, Switzerland; Swiss Competence Center for Energy Research-Supply of Electricity (SCCER-SoE), ETH Zurich, Zurich, Switzerland

Marco Frey Sant'Anna School of Advanced Studies, Institute of Management, Pisa, Italy

Jillian Aira Gabo-Ratio Rushurgent Working Group, National Institute of Geological Sciences, University of the Philippines, Quezon City, Philippines

Cameron Huddlestone-Holmes CSIRO, Queensland Centre for Advanced Technology, Pullenvale, Australia

Örn D. Jónsson School of Business, University of Iceland, Reykjavik, Iceland

Bjarni F. Karlsson School of Business, University of Iceland, Reykjavik, Iceland

Constantine Karytsas Center for Renewable Energy Sources & Saving, Pikermi, Greece

Spyridon Karytsas Center for Renewable Energy Sources & Saving, Pikermi, Greece

Katherine Luketina Waikato Regional Council (WRC), Hamilton, New Zealand

Frédéric Malo Université Laval, Hautes Études Internationales, Quebec City, QC, Canada

Michel Malo Institut national de la recherche scientifique, Centre Eau Terre Environnement, Quebec City, QC, Canada

Adele Manzella National Research Council, Institute of Geosciences and Earth Resources, Pisa, Italy

Anne Masseran CREM, University of Lorraine, Metz Cedex 01, France

Phoebe Parson Te Piringa - Faculty of Law, Research Centre for Environmental, Energy and Resources Law, University of Waikato (Te Whare Wananga o Waikato), Hamilton, New Zealand

Anna Pellizzone National Research Council, Institute of Geosciences and Earth Resources, Pisa, Italy

Olympia Polyzou Center for Renewable Energy Sources & Saving, Pikermi, Greece

Melek Akca Prill Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe, Germany

Marnel Arnold Ratio Laboratory of Geothermics, Department of Earth Resources Engineering, Graduate School of Engineering, Kyushu University, Fukuoka, Japan

Jasmin Raymond Institut national de la recherche scientifique, Centre Eau Terre Environnement, Quebec City, QC, Canada

Francesco Rizzi Department of Economics, University of Perugia, Perugia, Italy

Lygia Romanach CSIRO, Dutton Park, Australia

Franziska Ruef Department of Environmental Systems Science, Transdisciplinarity Lab, ETH Zurich, Zurich, Switzerland; Swiss Competence Center for Energy Research-Supply of Electricity (SCCER-SoE), ETH Zurich, Zurich, Switzerland

Rögnvaldur J. Saemundsson Faculty of Industrial Engineering, Mechanical Engineering and Computer Science, University of Iceland, Reykjavik, Iceland

Alessandro Sciullo Department of Culture, Politics and Society, University of Torino, Turin, Italy

Yeny Serrano LISEC, University of Strasbourg, Strasbourg, France

Michael Stauffacher Department of Environmental Systems Science, Transdisciplinarity Lab, ETH Zurich, Zurich, Switzerland; Swiss Competence Center for Energy Research-Supply of Electricity (SCCER-SoE), ETH Zurich, Zurich, Switzerland

Anna Leah Tabios-Hillebrecht Freshfields Bruckhaus Deringer LLP, Munich, Germany

Kasumi Yasukawa Advanced Industrial Science and Technology (AIST), Koriyama, Japan

Jean Zoungrana SAGE, University of Strasbourg, Strasbourg, Cedex, France

Summary

This book explores the diverse aspects of the relationship between the technological harnessing of geothermal resources and the societies and local communities in which these developments take place. The responsible use of geothermal energy can help with mitigating the effects of climate change and contribute to the development of a renewable and sustainable energy mix in the transition toward a low-carbon society. As with all other developments in the energy sector, a sustained societal dialogue is essential as society plays an active role in either accelerating or preventing the development of new energy technologies. This volume introduces a theoretical framework for a social scientific approach to the field and represents the first tentative collection of empirical case studies on geothermal energy and society from across the globe. It is organized in two sections. The first section is introductory to the issue of geothermal energy and the related policy and societal aspects, and is followed by a selection of eleven case studies constituting the second section. A conclusive chapter brings together the various contributions and sets out the lessons learned for this sector.

The book will be of interest to researchers from a range of disciplines involved with questions relating to energy and society.

General Introduction to Geothermal Energy

Adele Manzella

Abstract This chapter describes geothermal energy as a source of renewable energy, its use in the production of heat and electricity, and the main applications and technologies. Geothermal energy is the thermal energy stored underground, including any contained fluid, which is available for extraction and conversion into energy products. Electricity generation, which today produces 73.7 TWh (12.7 GW of capacity) worldwide, usually requires geothermal temperatures of over 100 °C. For heating, geothermal resources that span a wider range of temperatures can be used in various heat applications such as; space and district (and cooling, with the appropriate technology), spas and swimming pools, greenhouses and soil, aquaculture ponds, industrial processes and snow melting. The geothermal heat produced worldwide is 164.6 TWh, with a capacity of 70.9 GW. Geothermal resources are immune from weather and seasonal variations, and can produce a base-load (continuously) or adapt to the energy demand, providing a flexible and "smart" renewable energy source. To guarantee a sustainable use of geothermal energy, the consumption rate should not exceed the generation rate, so that the heat removed from the resource is replaced within a similar time scale, and geothermal plants typically produce energy below a certain level. In addition, any impact on the environment should be controlled, mitigated and managed. Any non-sustainable use of geothermal technologies can create a misperception of geothermal energy and social resistance to geothermal development.

Keywords Geothermal energy · Technological applications · Environmental performance · Economic aspects

A. Manzella (✉)
National Research Council, Institute of Geosciences
and Earth Resources, Via Moruzzi 1, 56124 Pisa, Italy
e-mail: manzella@igg.cnr.it

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes
in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_1

1 Introduction to Geothermal as a Source of Energy

The term "geothermal" refers to the thermal energy stored beneath the surface of the solid Earth. This energy is huge, and derives principally from planetary and geological processes. Our planet has been slowly cooling since its formation, and this primordial heat moves from the Earth's interior towards the surface, where it dissipates. Geological processes, and in particular the decay of long-living radioactive isotopes contained by crustal rock minerals, add to this continuous release of heat. Depending on the geological conditions, the amount of heat released at the Earth's surface varies from place to place and over time. On average, the amount of heat that is released from the interior through a unit area in a unit of time, known as the Earth's *heat flow*, amounts to 57 mW/m^2 in the continental crust and 99 mW/m^2 in the oceanic crust (Barbier 2002). If we were able to use all such heat, we would meet any energy demand. However, this is not possible since the energy is too dispersed.

The term geothermal energy refers to the portion of the Earth's thermal energy that we can access, bring to the Earth's surface, and use for our purposes.

The continuous release of heat produces a general decrease in temperature from the inner part of the planet toward the surface. Since we access the underground from above, we tend to think of the temperature as increasing as we go deeper. The *geothermal gradient*, i.e. the variation in temperature with depth, depends on the heat flow and thermal conductivity of the rocks. The highest values, 40–80 °C km^{-1}, are observed in volcanic areas or where the crust is particularly thin and hot, e.g. in mid-oceanic ridges or where magma is close to the surface (Arndt 2011). In subduction zones or stable continental areas, the gradient is the lowest possible, on average around 20–30 °C km^{-1}.

At the surface there is, however, a very limited but important portion of underground that is influenced by the outer temperature. Within a depth of a few meters, the ground is affected by seasonal changes in air temperature, and the gradient fluctuates correspondingly. Just below this depth, the ground temperature is essentially stable and the same as the average air temperature, which is the effect used in cellars for storing food and wine. Further below, the "planetary" geothermal gradient takes over (Fig. 1).

Technologies that take advantage of the thermal stability of the shallow underground for heating and cooling purposes are defined as shallow geothermal technologies. Technologies developed to access great depths to retrieve and use temperatures above the annual mean air temperature are referred to as deep geothermal. The threshold between these two general realms has been thinning over time, with hybrid technological solutions that optimise the energy production.

Water as a carrier of heat is mostly used to extract energy from underground. As the crust is highly fractured and thus permeable to fluids, surface water, essentially rainwater, penetrates at depth and exchanges heat with the rocks. The warm or hot water circulating in the underground rocks is reached by wells and extracted, and their heat used. Large production requires access to a large quantity of heated water

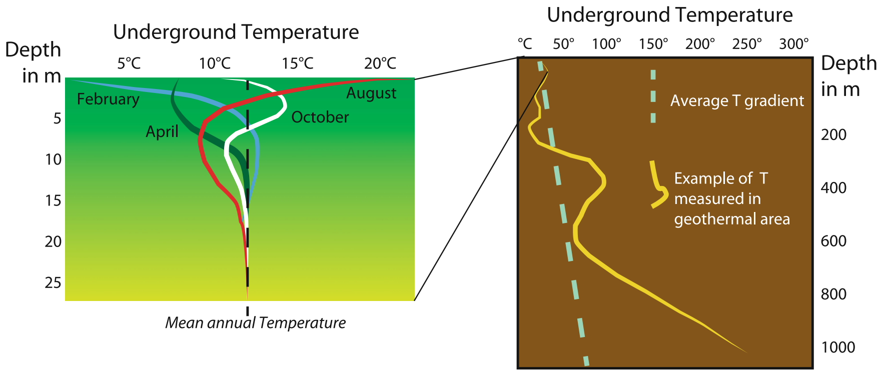


Fig. 1 Temperature variation with depth: shallow distribution, with seasonal changes and thermal stability (an example from the northern hemisphere, mid latitude condition) (left); average (30 °C km^{-1}) and actual temperature gradient as could be recorded in geothermal wells (right)

that circulates in hydrothermal reservoirs, however new technologies are expanding this concept, and currently geothermal energy does not rely solely on hydrothermal reservoirs.

Section 2 describes various technologies that have been designed to optimize the extraction and concentration of energy, and to use the heat in various processes and/or to generate electricity. Section 3 investigates geothermal as a renewable energy, in the sense that it is continuously generated underground. Renewability does not automatically imply sustainability, i.e. the ability to be sustained, which is linked more to the scope of geothermal technologies.

2 Technologies for Heating, Cooling and Electricity Production

For centuries of geothermal surface water was used for heating and therapeutic purposes, or for extracting elements and minerals. In the last hundred years, geothermal technologies have revolutionized this concept. Today, depending on the temperature of the fluid, geothermal waters are used for many different applications, including electricity generation, which is the most important use of high-temperature geothermal resources (usually higher than 120 °C).

2.1 Heating and Cooling Production

Geothermal energy can be employed directly as heat without further conversion into other types of energy. The heat demand represents a significant share of the final energy consumption for space heating, especially in cold countries, as well as for agricultural and industrial processes. Geothermal heat production could meet the demand simply by providing fluids at the required temperature. After extraction from the ground, fluids are directly circulated in the heating system or, more frequently, exchange heat with clean water through a *heat exchanger*. Geothermal fluids are then re-injected into the subsurface in a typical doublet or triplet system (as in Fig. 2).

The main types of geothermal heat production technologies are used for space heating and cooling (including heat pumps), bathing and swimming (including balneology for therapeutic purposes), agricultural (greenhouses and soil heating), industrial processes (food and drink preparation being the most common), and aquaculture (mainly fish farming).

Geothermal technologies mainly involve the optimal location, access and extraction of fluids from the ground, managing the heat exchanger and the heat production as a function of heat demand, and reinjecting the fluid into the ground. Any interference with other aquifers, and extensive cooling of the original, geothermal aquifer have to be avoided. Geothermal systems are usually capital

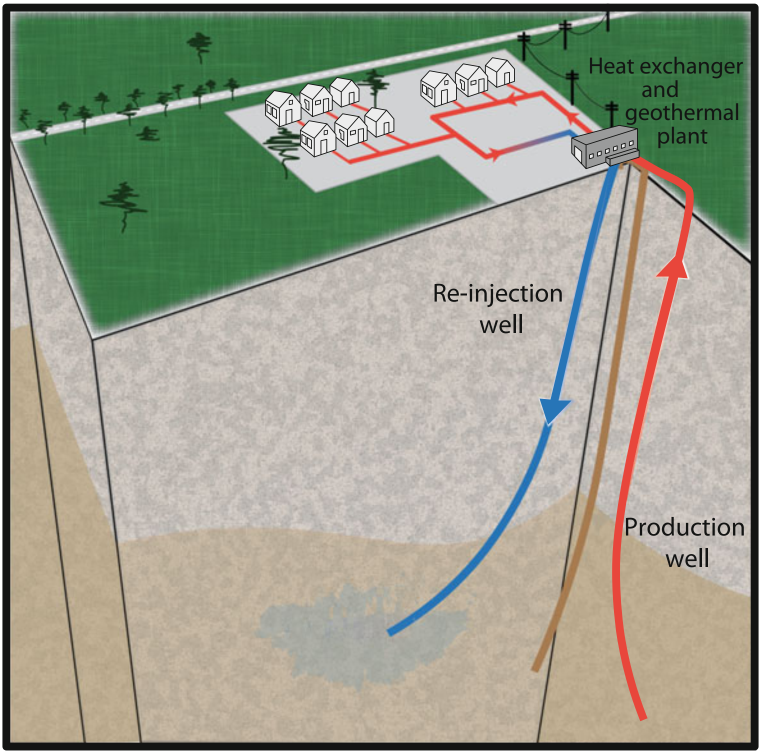


Fig. 2 Doublet-Triplet system used for heating purposes. Production well in red, injection well in blue. A third well, in brown, can be optionally used for injection and production, alternatively

intensive, the main costs being the initial investment in production and injection wells, and down-hole pumps. Operating expenses, however, are lower than conventional systems, considering that the energy source is free of charge and production can be adjusted to the energy demand.

The most important thermal application of geothermal energy is for district heating, where a doublet-triplet system is added to a district heating system (Fig. 2). The operation temperature is usually in the range of 70–90 °C, and entails accessing a depth of 1–3 km.

The agricultural applications of geothermal fluids, usually at an operational temperature of a few tens of °C, consist of a plant-growing temperature control in open fields (seldom used) and greenhouses. Soil heating is provided by burying thin pipelines where warm fluids are circulated. Greenhouse can be heated by the forced circulation of air in heat exchangers, hot-water circulating pipes or ducts located in or on the floor, finned units located along the walls and under benches, or a combination of these methods.

Geothermal heat can be used in animal husbandry, in particular in aquaculture, in the controlled breeding of aquatic forms of life. The size of the installation depends on the temperature of the geothermal source (usually a few tens of °C), the temperature required in the fish ponds, and the heat losses from these ponds.

Industrial applications mainly include process heating, evaporation, drying, distillation, sterilization, washing, de-icing, and salt extraction. Other minor applications for the bottling of water and carbonated drinks, production of paper and vehicle parts, oil recovery, food processing and milk pasteurization, leather industry, chemical extraction, CO_2 extraction, laundry use, pulp and paper processing, and borate and boric acid production have also been reported. The operational temperature spans a large range, from a few tens up to 100 °C.

The described way of using the fluids at the required temperature, known as passive or "free" heating and cooling (H&C), is one of the most environmental friendly forms of H&C available, and the basis of most thermal uses of geothermal energy until recently. However, the passive use has a limitation: it must adapt to the temperature of the natural groundwater available, which is not always what we need. Thanks to improvements in absorption machines and heat pumps, which are readily available on the market and are able to heat and cool the fluids efficiently, geothermal applications are becoming increasingly flexible. *Geothermal or ground-source heat pump (GSHP)* systems mostly exploit groundwater or ground-coupled temperatures, also at a shallow depth (10–200 m depth). The associated heat pump systems exploit the physical property of fluids to absorb and release heat when they vaporize or condense, respectively, and move heat from a space (to keep it cool), discharging heat at higher temperature (heating mode). Common air conditioning systems work this way and exchange heat with the external air. If a specific reverse system is installed, the heat pump system may be used for both heating and cooling. In GSHP the refrigerant fluid exchanges heat with the ground or the water extracted from the ground.

GSHP systems used in shallow geothermal application for heating and cooling take advantage of the stable temperature throughout the year at shallow depths. In the cold season the ground has a higher temperature than the air temperature, and the heat exchange is more efficient than with traditional, air-air heat pumps. With the right technology, the process can be reversed, and the heat pump can also work as a refrigerator in the hot season, using the cool temperature of the ground to chill the space. By combining doublet-triplet systems for fluid extraction at deep depths with geothermal heat pumps, numerous technical options are possible, ranging from the supply of heat and cold to single houses to providing heat to whole cities or areas through large district heating networks. Heat pumps require electricity, whose cost must be considered in the total balance, but provide the main advantages. First of all, GSHP systems are much more efficient than usual air source heat pump systems, since the heat source has a temperature closer to the required one. In addition, the combination of GSHP to deep geothermal technologies, increases the temperature of the produced fluids and contributes to the flexibility of the system, making the geothermal production potentially possible in any place.

At the 2015 World Geothermal Congress, 83 countries were reported to be using geothermal energy for thermal uses with overall installed capacity of 70.3 GW and a total production of 58.7 EJ (Lund and Boyd 2015). Globally, the main share of installed thermal potential is for geothermal heat pump systems (55%), bathing and swimming including balneology (20%) and space heating (15%, of which 89% is for district heating), while greenhouses, open ground heating and agricultural drying amount to 5%, and aquaculture, industrial processes and de-icing to 4%.

There are numerous elements to consider in the cost estimate of a geothermal system for thermal application which are often more complicated than for other forms of energy. Plant installation and operating costs need to be evaluated carefully before a geothermal project is launched. The overall cost depends on the resource (amount of heat, fluid discharge rate, depth to drill), the cost of installation and operation, the tariffs and incentives available, the price of other available energy sources, the plant efficiency, and the load time. The cost varies widely depending on the application (Table 1). District space heating *levelized costs* (i.e. the ratio between the cost of generating an asset through its whole lifetime and the energy produced) range from US$45/MWh to US$85/MWh, and costs of heating

Table 1 Investment costs and calculated levelized cost of heat (at discount cost of 10%) for various thermal applications

Heat application	Investment cost US$2005/kWh	Levelized cost of heat US$2005/GJ
Space heating (building)	1660–3940	28–77
Space heating (district)	570–1570	15–38
Greenhouses	500–1000	9.3–16
Uncovered aquaculture ponds (fish farming)	50–100	8.6–12
GSHP (residential and commercial)	940–3750	19–68

Based on data from: IPCC 2012

greenhouses vary between US$40/MWh and US$50/MWh (IEA 2011). IPCC (2012) estimates of costs are more comprehensive (Table 1), however still with a large margin of uncertainty, due to the lack of measuring standards and a complete dataset.

2.2 *Electricity Production*

Most power plants produce electricity through a generator activated by turbines rotated by a flux of steam. Fossil fuel plants boil water for steam, whereas geothermal power plants use steam produced from or heated by underground hot fluids. There are three main types of technology (Fig. 3).

In *dry steam plants*, which are used when geothermal fluids are in a vapour state when they reach the surface, the steam is piped directly from underground wells to the power plant, where it is moved into a turbine/generator unit. Fluids can be in a total vapour state already in the reservoir, which is rare, or derive from a mixture of liquid and vapour in the reservoir which, due to the pressure drop caused by the well, totally vaporize before reaching the surface. The fluids used in these plants have temperatures above 250 °C and the average size of dry steam plants is around 45 MW. After expanding in the turbine, producing kinetic energy which drives a generator to produce electricity, the vapour is sent to a condenser and cooled by spraying cooling water (wet coolers). The cooling water and condensed steam are then mixed and pumped directly to injection wells. The geothermal fluid in dry

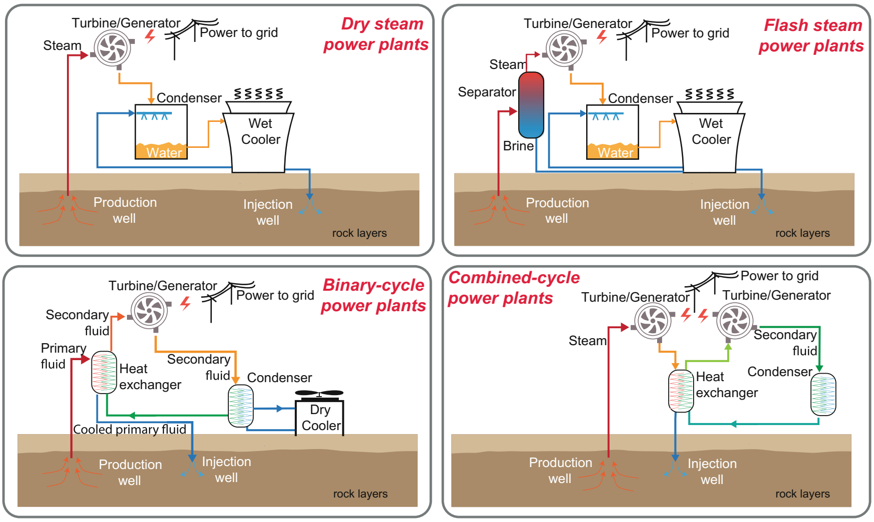


Fig. 3 Simplified flow diagram for dry steam (top left), single flash (top right), binary-cycle (bottom left) and combined-cycle (bottom right) geothermal power plants

steam plants is then partially lost in the atmosphere and partly condensed and reinjected.

In the *flash steam systems*, the fluid produced at the surface, after the pressure drop, is only partially vaporized (or flashed, thus the name). In this case, the liquid phase is separated from the vapour and the latter is sent to the turbine, while the liquid is reinjected back into the subsurface together with the condensed fluid obtained from the wet cooler as in dry steam plants. Flash steam plants reinject most (60–90%) of the geothermal fluid. Depending on the thermodynamic condition of the fluids, it may be economical to obtain, by pressure changes, a second and sometimes even a third flash from the separated fluid, producing more steam from its boiling. Flash steam technology generally uses fluids with temperatures above 180 °C. Plants have an average size of 30, 37 and 90 MW for single, double and triple flash technologies, respectively.

In *binary cycle technologies* were originally applied to produce electricity from fluids at lower temperatures (as low as about 110 °C). In binary plants the geothermal fluid exchanges heat with a working fluid, usually an organic fluid with a low boiling point and high vapour pressure at low temperatures compared to steam. The working fluid is vaporized in a heat exchanger and sent to an axial flow turbine, after which it is cooled and condensed, and the cycle begins again. The geothermal water is totally re-injected into the ground. This closed-loop technology attracts increasing interest, since it guarantees both production flexibility and a minimum interaction of geothermal fluids with surface environment. The main drawback is its efficiency, i.e. the ratio between the net electricity produced and the energy input, which is lower than for other technologies, being around 12% for steam plants (flash and dry) and between 2 and 10% (from 80–90 to 160–200 °C resources) for binary systems.

Today, global power production has a total capacity of 12.7 GW (IRENA 2018). Single flash power plants are most commonly used for geothermal power, comprising 41% of the installed capacity globally, dry steam follows at 22% and double flash ranks third at 21% of the globally installed capacity. Lastly, binary constitutes 12% of globally installed capacity (Bertani 2016). The remaining 3% of power plants are triple flash, flash/binary hybrid, and other geothermal technologies. The annual electricity generation reached 80.9 terawatt-hours (TWh) in 2015 (most recent data), amounting to approximately 0.3% of global electricity generation (IRENA 2017).

The upfront cost of geothermal power production plants is high, and varies depending on the phase of the project (Fig. 4).

The cost varies considerably and generally depends on the geology of a country or region, the quality of the resource (e.g., temperature, flow rate, chemistry), and the infrastructure in place. IEA (2011) estimates a cost ranging from US$2.8 million to US$5.5 million per MW, for a reference plant of 50 MW installed capacity. IRENA (2017) reports costs for geothermal power plants ranging from US$1.9 million to US$5 million per MW, with binary plants typically more expensive than direct dry steam and flash plants. The investment cost breakdown of utility scale geothermal power development shows variable figures (e.g., data from Iceland in

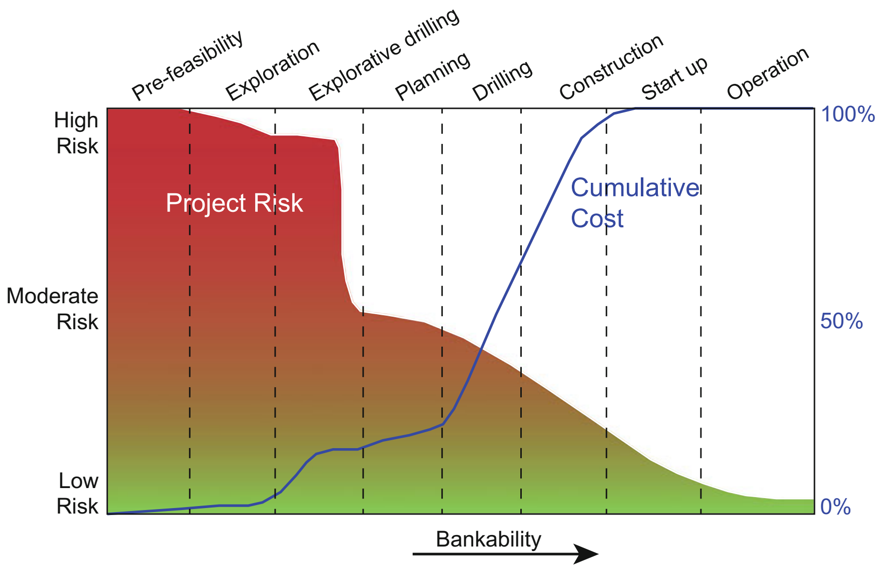


Fig. 4 Risk and cost development during the various phases of geothermal electricity production. *Modified from* Gehringer and Loksha 2012

Table 2 Investment costs reported for Europe (Data Source: Gehringer and Loksha 2012) and Indonesia (Data Source: IRENA 2014)

	Gehringer and Loksha 2012 (%)	IRENA 2014 (%)
Power plant construction	35	42
Drilling (exploratory, production, injection wells)	35	23
Steam gathering system, interconnection, early development (including exploration costs), miscellaneous and infrastructure	30	35

Gehringer and Loksha (2012) and from Indonesia in IRENA (2014), summarized in Table 2). In the case of low temperature or deep resources, or low productivity per well, the drilling quota may increase significantly. IRENA (2017) assessed the flash and binary plants in Europe and found that roughly 55% of the total installed costs corresponds to the power plant and other infrastructure, while exploration, drilling and field development costs amount to 20% for flash plants and 35% for binary plants.

Risk analysis is a key topic in renewable energies, which, in contrast to fossil fuel electricity production, requires large upfront investments but low operational and management capital. Since investments have to be made before the systems become operational, from the investors' point of view the risk is higher, and as a consequence, the rate of return of their investment increases. The resulting

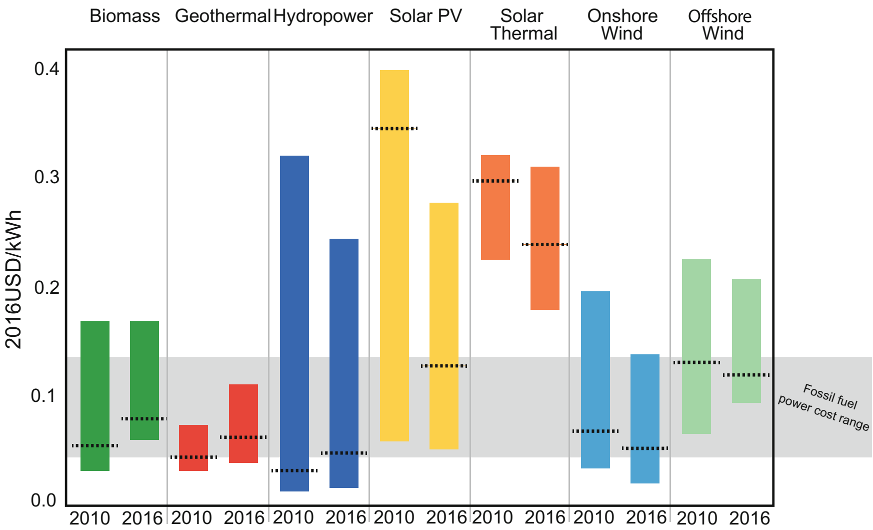


Fig. 5 Levelized cost of electricity produced by renewable energy sources and comparison with fossil fuel cost range. Modified from IRENA web page (https://irena.org/ourwork/Knowledge-Data-Statistics/Data-Statistics (Accessed Mar 2018))

increased upfront cost is often crucial for geothermal energy, which to the usual uncertainty of a plant construction, adds the risk of not finding the expected resource before drilling the first wells, i.e. before spending almost one third of the total cost of the plant. The risk levels in the various phases of geothermal projects are depicted in Fig. 4.

Since geothermal energy is constantly provided, geothermal has a base-load production, and the Capacity Factor (CF, i.e. the actual produced energy with respect to the full capacity energy) is much higher than for other renewable energies. The resulting Levelized Cost of Energy, i.e. the ratio between the cost of generating an asset during its whole lifetime and the electricity produced, is comparable to or lower than other energy sources (Fig. 5).

2.3 *Combined Applications and Hybrid*

In order to improve energy efficiency, some plants combine different technologies. For example, in most flash plants, the steam frequently exits the turbine at temperatures that are suitable for other uses. Some power plants combine dry or flash steam technology with a binary cycle to produce electricity from what otherwise would be wasted heat (Fig. 3). Hybrid power plants combine the stand-alone type of geothermal power plant with a different heat source, e.g. concentrating solar power or biomass, to increase the temperature of the geothermal fluid and, therefore, produce more power.

Another important way to improve efficiency and optimize the economic profile of geothermal projects is by using various applications for the combined production of power and heating and/or cooling (CCHP, Combined Cool, Heat and Power). Various projects in Europe (e.g. in Bavaria, Germany) and around the world produce both heat for district heating and power, and CCHP is expected to increase, especially in Europe and other areas with by a high population density.

The sequential operation of geothermal heat by integrating different technologies that use progressively lower temperatures, known as cascade applications, has also been applied in various places, and is expected to be developed further in the near future, since it improves energy efficiency and provides benefits to the local community. Typical examples are the combination of power or district heating plants with greenhouses or fish farming projects, or also with hydrotherapy and therapy centres, such as the famous Blue Lagoon in Iceland.

2.4 Technological Frontiers and Future Perspectives

Today the global installed capacity of geothermal energy amounts to about 60 GW worldwide with shares of 18, 26, and 56% for power generation, thermal applications, and ground source heat pumps (GSHP), respectively. Lead markets for geothermal energy are in America, Europe and Asia (Sigfusson and Uihlein 2015). However, this constitutes only a minor part of the geothermal potential, as estimated in many countries. To obtain a full and responsible deployment of geothermal potential, technologies need to be improved and new ones developed in order to reduce costs and increase the performance of geothermal projects. Research and innovation are thus focused on optimizing technologies for improving heat extraction from underground and increasing energy production, while reducing the risk of drilling without reaching commercially-viable geothermal resources.

Since most of the geothermal potential is heat stored in rocks whose permeability does not allow enough water to flow through them to produce hot water, many projects are aiming to overcome this limitation. This is achieved by improving permeability by enlarging or re-opening natural fractures between the production and injection wells, usually through hydraulic and chemical stimulation, i.e. pumping water and chemical additives, and also inserting special materials called proppants to prevent these fractures from closing again when the injection pressure is reduced. This approach, which requires further technological development to become economically productive, would increase the share of geothermal energy used enormously. The technology is known as *EGS* (Enhanced or Engineered Geothermal Systems) or *Petro-thermal* (in some European countries), and requires validation and deployment, cost reductions, and better performance.

While achieving cost-competitive electricity generation from EGSs is a long-term goal, in the short term, research and demonstration projects will move the industry along the learning curve toward technological readiness. Once technical and economic challenges for EGSs have been overcome, or when other methods of exploiting hot rock resources become available (e.g. without fracturing the underground bedrock), geothermal deployment could be pursued wherever rock temperatures and other underground properties would provide energy at a sufficiently low cost. This would mean that advanced geothermal systems could be deployed wherever there is a demand for electricity and heat.

Another important goal of research and innovation in geothermal energy is the development of *thermal energy storage* underground. By this technology the heat captured and stored in thermal banks in the summer can be retrieved efficiently in the winter. The Underground Thermal Energy Storage (UTES) concept goes beyond geothermal energy and considers, for example, the storage of thermal energy co-produced by solar sources or waste heat from industrial processes. Heat storage efficiency increases with scale; thus, this advantage is most important in commercial or district heating systems. This concept, used to date mostly at shallow levels, is currently being expanded to include deep aquifers and large thermal storage in order to optimize the response to the high demand for thermal and waste heat.

Future perspectives have been presented by IEA (2011). The estimated global geothermal electrical power installed capacity by 2050 amounts to 200 GWe, including 100 GWe hydrothermal electricity capacity and 100 GWe from EGSs. This latter technology is assumed to become commercially viable soon after 2030. This power production is expected to prevent around 760 megatonnes (Mt) of CO_2 emissions per year worldwide. Most of this increase is expected to happen in Pacific Asia, mainly Indonesia; the East-African Rift Valley; Central and South America; as well as in the United States, Japan, New Zealand, and Iceland.

The estimated global sum of annual geothermal heat use by 2050 amounts to 5.8 EJ (about 1600 TWh thermal energy), excluding energy from ground-source heat pumps and assuming full use of the potential of CHP generation via EGS technology. Under these assumed conditions, the use of heat from deep rock formations should theoretically become possible wherever rock temperatures and the properties of the underground allow energy to be sold at a sufficiently low price. The largest potential for geothermal heat is found in regions with a high heat demand: Europe, China and North America.

3 Environmental Aspects for a Sustainable Use of Geothermal Energy

3.1 Environmental Issues

The exploitation of geothermal energy may have an impact on the environment. The degree to which geothermal exploitation affects the environment would seem to be proportional to the scale of its exploitation and the depth of the resource.

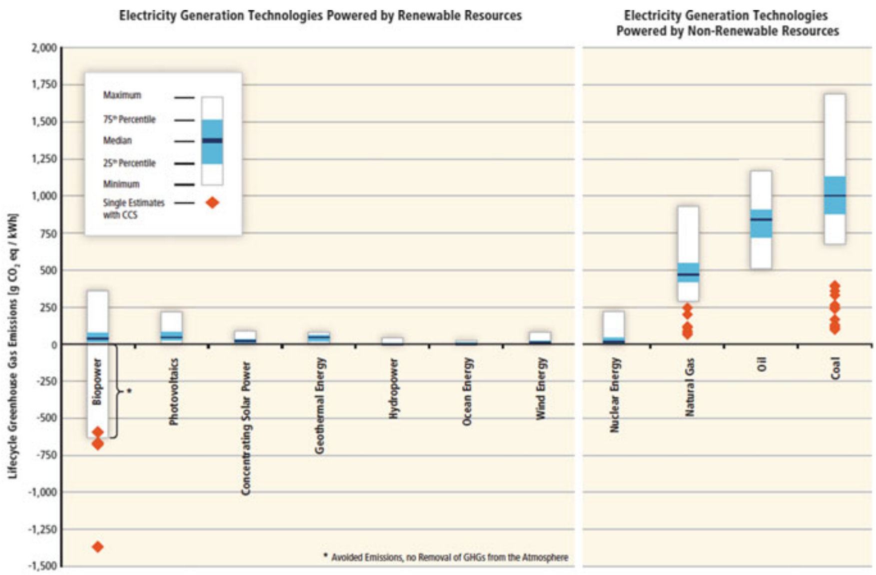
Shallow geothermal systems can easily avoid environmental impacts by adapting the most elementary precautions. The most critical potential risk is thermal pollution, when the boreholes are incorrectly located or the rate of extraction is too high. The first effect of an incorrect design is, however, the low efficiency of the plant, for which there is usually a technical solution. Electricity generation in binary cycle plants and heat production have a very limited environmental footprint because the fluid extracted from underground is totally reinjected after the heat exchange at the surface. The effects are potentially greater in the case of steam and flash power production systems, where part of the fluid is released in the environment, but can be kept within acceptable limits. The following description essentially refers to geothermal energy deployment from deep resources, and involves potential problems for both power and heat production.

Any modification to the environment must be evaluated carefully, in compliance with the regulations (which in some countries are very severe), but also because an apparently insignificant modification could trigger a chain of events whose impact is difficult to fully assess beforehand. For example, a mere 2–3 °C increase in the temperature of a body of water as a result of discharging the waste water from a utilization plant could interfere with and damage its ecosystem.

The most perceptible effect on the environment is derived from drilling, whether the boreholes are shallow for geoexchangers or deep for producing and injecting wells. Installing a drilling rig plus the accessory equipment entails constructing a drilling pad and access roads with an impact on the surface morphology of the area and possible damage to local flora and wildlife. In the case of fluid blow-outs from the wells, a problem related only to high temperature and pressure resources, fluids can pollute the surface water and air. This can be solved by blow-out preventers, where high temperatures and pressures, and aggressive chemicals are anticipated. During flow-tests, undesirable gases may be discharged into the atmosphere, but only for a very limited time. Noise can be annoying, but drills can be equipped with silencers. The best solution, in fact, is to avoid being too close to urban areas and to keep the drilling time as short as possible. The impact on the environment caused by drilling is temporary, and mostly ends once drilling is completed.

Installing pipelines that transport the geothermal fluids, and the construction of the utilization plants, may also affect animal and plant life as well as the surface morphology. The landscape is modified, although in some areas the network of pipelines criss-crossing the countryside and the power-plant cooling towers have become an integral part of the panorama and are indeed a famous tourist attraction in many geothermal areas. Power plants can have interesting designs, as in some Italian areas, or be partially hidden by vegetation (usually outside the facility to ease maintenance).

Exploiting deep, high temperature geothermal resources, especially in volcanic and magmatic areas, may lead to environmental problems. Some geothermal fluids, such as those used for district-heating in Iceland, are freshwaters, however this is very rare and deep geothermal fluids (steam or hot water) often contain gases such as carbon dioxide (CO_2), hydrogen sulphide (H_2S), ammonia (NH_3), methane (CH_4), and trace amounts of other gases, as well as dissolved chemicals whose concentrations usually increase with the temperature. For example, sodium chloride (NaCl), boron (B), arsenic (As) and mercury (Hg) are a source of pollution if discharged into the environment. The wastewater from geothermal plants also has a higher temperature than the environment and therefore constitutes a potential thermal pollutant. Geothermal fluids, however, can be treated and the chemicals separated. Various processes can be adopted to reduce gas emissions, e.g. for hydrogen sulphide. Carbon dioxide may also be present in the fluids used in the geothermal power plants, although much less CO_2 is discharged from these plants than from fossil-fueled power stations (see Fig. 6).



	Biopower	Photovoltaics	Concentrating Solar Power	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Nuclear Energy	Natural Gas	Oil	Coal
Count of Estimates	222(+4)	124	42	8	28	10	126	125	83(+7)	24	169(+12)
Count of References	52(+0)	26	13	6	11	5	49	32	36(+4)	10	50(+10)

Fig. 6 Lifecycle emission levels of renewable and non-renewable energy sources. *Source* IPCC 2012, Fig. 9.8, page 732. Original figure caption: Estimates of lifecycle GHG emissions (g CO_2 eq/kWh) for broad categories of electricity generation technologies, plus some technologies integrated with CCS. Land-use related net changes in carbon stocks (mainly applicable to biopower and hydropower from reservoirs) and land management impacts are excluded; negative estimates for biopower are based on assumptions about avoided emissions from residues and wastes in landfill disposals and co-products. References and methods for the review are reported in Annex II. The number of estimates is greater than the number of references because many studies considered multiple scenarios. Numbers reported in parentheses pertain to additional references and estimates that evaluated technologies with CCS. Distributional information relates to estimates currently available in LCA literature, not necessarily to underlying theoretical or practical extrema, or the true central tendency when considering all deployment conditions. Note: 1. ‘Negative estimates’ within the terminology of lifecycle assessments presented in this report refer to avoided emissions. Unlike the case of bioenergy combined with CCS, avoided emissions do not remove GHGs from the atmosphere

Wastewater is also a potential source of chemical pollution, although the low-to-moderate temperature of the geothermal fluids used in most thermal applications generally contains low levels of chemicals and the discharge of spent geothermal fluids is seldom a major problem. Spent geothermal fluids with high concentrations of chemicals such as boron, fluoride or arsenic found in deep high temperature fluids should be treated and re-injected into the reservoir, or elements extracted for mineral use. To prevent discharge into surface waters after cooling, the waters can be cooled in special storage ponds or tanks to avoid modifying the ecosystem of natural bodies of waters (rivers, lakes and even the sea).

The extraction of large quantities of fluids from geothermal reservoirs reduces pore pressure and the land surface may tend to subside and gradually sink. This is an irreversible phenomenon, a slow process distributed over vast areas. Over a number of years, the lowering of the land surface may reach detectable levels, in some cases in the order of a few tens of centimetres and even meters, and should be monitored systematically. In fact, Wairakei in New Zealand registered a 4.5 m localized subsidence between 1964 and 1974; water-dominated systems such as Wairakei subside more than vapour-dominated systems. Subsidence is controlled by topographic monitoring by high-resolution GPS remote control. Subsidence is prevented or mostly reduced by re-injection of spent fluids.

The withdrawal and/or re-injection of geothermal fluids may trigger or increase the frequency of seismic events in tectonically active areas, such as those close to plate boundaries where high temperature geothermal areas are located. In these areas, the injection of fluids tends to release the accumulated tectonic stress. These small events, most of which are detected by specific instruments, have increased in number. Correlation studies in geothermal areas operated for many decades have shown, however, that the magnitude of events has not increased with respect to the maximum magnitude registered so far.

The exploitation of hydrothermal resources has never triggered a major seismic event, and is unlikely to do so in the future. EGS demonstration projects and hydraulic stimulations, however, have been associated, in some cases, with seismic events felt by the local population and leading to damage. Various research projects are currently focused on this aspect, and fluid injection underground is usually carefully monitored. Protocols for seismic alert management are set up at the beginning of projects.

The noise from the occasional vent discharge associated with operating power generation geothermal plants is not negligible, although normally acceptable. At the power plant, the main noise pollution comes from the cooling tower fans, the steam ejector, and the turbine ‘hum’. The noise generated in thermal applications is usually negligible.

The sustainable development of geothermal energy implies that it is produced and used in a way that is compatible with the well-being of future generations and the environment. Shortall et al. (2015) have reviewed these aspects, and proposed a comprehensive assessment framework for geothermal energy projects, taking into account environmental as well as economic, social and policy aspects.

3.2 Environmental Performance

Geothermal energy is generally not affected by the weather or seasonal variations, therefore producing almost constantly unlike some other renewable technologies whose power and heat production varies over time.

Geothermal heat pumps can reduce energy consumption by up to 44% compared to air source heat pumps and up to 72% compared to electric resistance heating with standard air-conditioning equipment. The use of geothermal heat not only increases the share of green energy and reduces air pollution emissions, but in the long term, it also contributes to the energy efficiency of the plant since it forces the heating system to reflect the true temperature level required by the process.

When considering the lifecycle, the geothermal environmental performance is among the best, also in comparison to other renewable energy sources. The greenhouse gas (GHG) emissions released by geothermal power plants, as reported by IPCC in (2012), are among the lowest of all energy sources (see Fig. 6). Since heat and electricity production from geothermal energy does not require combustion, the overall emission rate is particularly low. This applies to all heating and cooling applications and most power production. The only apparent exception is related to the use of geothermal fluids which are naturally rich in gases, as in some areas with high temperature resources. In these cases, although the gases do not derive directly from industrial processes and are fewer than for any fossil fuel energy (apart a few exceptions as related to the best natural gas technologies), there has been some recent debate in Europe. Additional lifecycle assessments will be necessary to clarify the matter.

4 Conclusions

Geothermal energy has been used for centuries for heating and therapeutic purposes, and for one century in large scale plants, however many barriers still hinder its potential. Some of the technologies are still immature, in particular for EGSs. The limited amount of research and innovation funds in the sector, with respect to other energy sources, have led to many demonstration projects where technologies are still under development. This means that the costs, although relatively low, have increased in the last few years, unlike for many other renewable energies (Fig. 4).

Stable, long-term research funding is necessary.

The mitigation of investment risks requires new policies, for instance providing long-term stable policy schemes, financial risk-sharing and clarity on grid processes, and improving the structure and quality of the public administrative system and permit procedures. Reducing the risk perception of investors, along with a reduction in technical risks and the development of more efficient technologies, is the only way to reduce overall costs and create the condition for a complete deployment of geothermal potential, while contributing to energy efficiency.

Finally, the general public know very little about geothermal energy. There is currently no detailed, complete and uniform data collection, nor is there a standard method for measuring production, especially of heat and cool, comparable to and compatible with the production from other energy sources.

Geothermal plants may have both a positive and negative impact on the environment, but a sustainability assessment framework is still lacking. The little information available on geothermal energy makes it difficult, especially for the general public, to evaluate the pro and cons of geothermal energy in terms of different sites and technologies, and to compare geothermal with other energy sources.

This lack of knowledge is one of the main reasons for the increasing debate on geothermal plants in many countries in the last few years. Moreover, there has been little engagement with the public, as social studies are still very limited in the geothermal sector and public involvement in geothermal development is still in its infancy in many countries.

Acknowledgements The author acknowledges the projects GEMex and DG-ETIP, co-funded by the European Union's HORIZON2020 research and innovation programme (GA. No. 727550 and 773392, respectively).

References

Arndt N (2011) Geothermal Gradient. In: Gargaud M et al. (eds) Encyclopedia of astrobiology. Springer, Berlin, Heidelberg

Barbier E (2002) Geothermal energy technology and current status: an overview. Renew Sustain Energy Rev 6:3–65

Bertani R (2016) Geothermal power generation in the world 2010–2014 update report. Geothermics 60:31–43

Gehringer M, Loksha V (2012) Geothermal handbook: planning and financing power generation. In: Prepared for the World Bank, ESMAP Technical Report 002/12 [Online]. Available at: https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_Geothermal%20Handbook_TR002-12_Reduced.pdf. Accessed 26 Mar 2018

IEA (International Energy Agency) (2011) Technology roadmap: geothermal heat and power [Online]. Available at: http://www.iea.org/publications/freepublications/publication/Geothermal_roadmap.pdf. Accessed 26 Mar 2018

IPCC (International Panel on Climate Change) (2012) Working Group III special report on renewable energy sources and climate change mitigation (SRREN). Available at http://www.ipcc.ch/pdf/special-reports/srren/SRREN_Full_Report.pdf. Accessed 26 Mar 2018

IRENA (International Renewable Energy Agency) (2014) Renewable power generation costs in 2014, IRENA, Abu Dhabi. Available at http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Power_Costs_2014_report.pdf. Accessed 26 Mar 2018

IRENA (International Renewable Energy Agency) (2017) Geothermal Power: technology brief. IRENA, Abu Dhabi. ISBN 978-92-9260-036-5

IRENA (International Renewable Energy Agency) (2018), Renewable power generation costs in 2017, IRENA, Abu Dhabi, ISBN 978-92-9260-040-2. Available at https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf. Accessed 26 Mar 2018

Lund JW, Boyd TL (2015) Direct utilization of geothermal energy 2015 worldwide review. In: Proceedings World Geothermal Congress 2015, Melbourne, Australia [Online]. Available at: https://pangea.stanford.edu/ERE/db/WGC/papers/WGC/2015/01000.pdf. Accessed 26 Mar 2018

Shortall R, Davidsdottir B, Axelsson G (2015) Geothermal energy for sustainable development: a review of sustainability impacts and assessment frameworks. Renew Sustain Energy Rev 44:391–406

Sigfusson B, Uihlein A (2015) JRC geothermal energy status report. In: Publications Office of the European Union 2015. Available at: https://setis.ec.europa.eu/sites/default/files/reports/2015_jrc_geothermal_energy_status_report.pdf. Accessed 26 Mar 2018

Adele Manzella is a Senior Scientist at the Italian National Research Council (CNR), working as a geophysicist and conducting field and theoretical investigations of geothermal systems in Italy and abroad. She coordinated for CNR the most recent national geothermal evaluation projects and led the CNR participation in many EU funded projects in the geothermal sector related to geothermal exploration, research coordination and outreach. She is President of the Italian Geothermal Association (UGI) and participates to the Steering Committee and Secretariat of the European Technology and Innovation Platform for Deep Geothermal (ETIP-DG). Nowadays her activity tackles all fields of research, training, information and promotion of geothermal energy.

Policy and Regulatory Aspects of Geothermal Energy: A European Perspective

Philippe Dumas

Abstract The objective of this chapter is to introduce the complex and evolving policy and regulatory framework relevant to geothermal energy in Europe. The analysis covers both shallow and deep geothermal technologies producing electrical power, heat, cold and hot water. It has a focus on the European Union (EU) legislation and its implementation. Indeed, nowadays it results difficult to fully understand the legal system for geothermal energy in a given European country without some acquaintance with the overarching EU framework. To this end, it may be useful to clarify some preliminary principles governing the relations between the EU and its member states. The competences between the two levels are defined in the Treaty on the Functioning of the EU. In areas like energy and the environment, where the competence is shared, the EU can legislate when its action is considered to be more effective than the action taken at national, regional or local level. In the framework of the functioning of the European Economic Area, EU rules can apply to Iceland, Norway and Lichtenstein. Additionally, they can also apply to other countries (e.g. Switzerland, Turkey) through bilateral agreements. National competences can be further devolved to regional and local authorities depending on the degree of self-governance in each country. The chapter is organised as follows: the first section provides an overview of the EU climate and energy framework; Sect. 2 takes a closer look at the key legal issues for the sector and a brief presentation of the most common mechanisms put in place for supporting geothermal energy; finally, Sect. 3 presents the future energy regulatory framework currently under discussion.

Keywords Energy policies · Regulations · Electricity · Heating and cooling

P. Dumas (✉)
EGEC, European Geothermal Energy Council, 2 place du champ de mars,
B-1050 Brussels, Belgium
e-mail: p.dumas@egec.org
URL: http://www.egec.org

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes
in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_2

1 Energy Policies: The European Dimension

The first European and National policies were to secure the energy supply by establishing a coal market managed at European level. Together with an industrial policy on steel, the objective was to relaunch the European economy after the second world war. On top of the need of energy security of supply, the second dimension was to provide affordable prices for the consumers, especially the industry and the agriculture. When the European Coal and Steel Community (ECSC) was launched in 1952, the energy mix was quasi uniquely based on fossil fuels: essentially coal and oil, and operated by national public utilities. Together with biomass, geothermal energy was one of the first renewable energy sources being developed: 120 MWe was already installed in Italy at that time.

Until the seventies, the European and National policies on energy and the energy mix remained nearly similar. But with the oil shocks, the dimension of security of supply took another road with the need to have local production and fuels. The main energy sources picked up for decreasing coal and oil imports were nuclear for electricity and gas for heating. The increase in the electricity consumption led also the European countries to organise better their electricity markets with two consequences: an electrical grid development and its management. It is also during this period that some countries started to develop geothermal district heating systems: Iceland, France, Hungary. Geothermal exploration started to be more supported during this period in particular by national policies in Italy, France and Germany. These activities led to an early geothermal data compilation in the "Terrestrial Heat Flow in Europe" (Cermak and Rybach 1979). Later, a European Commission 'Atlas of Subsurface Temperatures in the EC' was published in 1980 for nine member states (Haenel 1980), completed 2002 by an updated version of the 'Atlas of geothermal resources in Europe' covering all European countries (including Russia) (Hurter and Haenel 2002).

The period 1980–1990 has seen the same development in the energy sector than for the rest of the economy. The achievement of the European internal market established first an internal market for electricity and gas, then its liberalisation by several packages of legislation aiming at opening these markets at national level. It was complemented with an energy research policy, by the launch of the European program for research and development (the FP), and later the Strategic Technology Plan (SET-Plan). The eighties were also the time were the geothermal heat pumps started to be installed in Europe.

The climate policy at International, European and national level started really with the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the adoption of the Kyoto protocol five years later. The objectives of decreasing greenhouse gas emissions in Europe have been mainly transformed in the launch of the Emissions Trading Scheme (ETS) and of regulations for promoting renewable energy sources (RES).

The first piece of European legislation was the directive for promoting RES electricity, then one for promoting RES in the transport sector. But the adoption of the climate and energy package in 2007 with 2020 targets has allowed the real development of RES in all European countries, including in the heating and cooling sector. It was the first one tackling the issues of climate and energy together with objective in terms of greenhouse gas (GHG) emission reduction, energy efficiency improvement and development of RES.

The 2020 package includes several pieces of legislation impacting the geothermal sector: Renewable energy directive, Energy Performance of Buildings Directive, Energy Efficiency Directive.

The development of renewables brought some challenges for the entire energy system and the sector coupling between electricity, heating and cooling and transport. New regulations have been adopted to answer these challenges in terms of building regulations, subsidies and competition rules, standards etc. On the energy efficiency side, the regulations on eco-design and labelling together with the CEN standards complete the legislations. Regarding financial public support to renewable energy sources including geothermal, The European Commission adopt state aid guidelines to ensure compliance with European competition rules.

To sum up, the changes in the energy sector in the last 50 years can be summarised in three elements:

Firstly, the reconnaissance of the non-sustainability of the previous energy mix with three components:

- Power sector fuelled by nuclear (since the 70s) or fossil fuels
- Heating sector supplied by fossil fuels
- Transport based on fossil fuels.

Secondly, a Europeanisation of the energy files through the competences given in the EU Treaties, and the different energy packages of legislations notably on liberalisation of electricity and gas.

Thirdly, a change of paradigm from a centralised system to a local and regional system with a "democratisation" of the energy sector and a security of supply ensured at national level (with less imports).

1.1 The Liberalisation of the Energy Markets

During the 1990s, the European institutions decided several measures to achieve the internal market. In the energy sector, most of the national electricity and gas markets were still monopolised. It was agreed to open these markets to competition gradually. Firstly, the EU decided to distinguish clearly between competitive parts of the industry (e.g. supply to customers) and non-competitive parts (e.g. operation of the gas and electricity networks). It also allowed third parties to have access to the infrastructure. Thirdly, measures to remove market barriers were adopted.

The first liberalisation directives in the energy sector were adopted in 1996 (electricity) and 1998 (gas). The second wave of liberalisation directives on energy markets was adopted in 2003. The third legislative package for an internal EU gas and electricity market was adopted in 2011.

Although significant progress has been made on opening electricity and gas markets, competition between energy market actors is slow to take off. Electricity and gas markets still remain largely national and highly concentrated. Although we notice more and more electricity markets coupling at regional level, the cross-border trade is relatively little.

This liberalisation in the energy sector should even more open the door to new developments in the geothermal power and heat markets.

1.1.1 The Case of State Aid

Financial support granted by Member States may distort competition in the energy sector because it could unfairly strengthen the position of companies that benefit from it vis-à-vis their competitors. This is why the general principle of the EU law foresees a prohibition of State aid. However, exceptions exist in the environmental area. State aid can provide incentives to reach the EU climate targets. This is why they can be eligible when attributed to RES.

1.2 The EU Climate and Energy Policies: The 2020 Package

The choice of the energy mix is done by the member states but energy policy is becoming increasingly a competence of the EU institutions. It is the response to critical supra-national issues such as climate change and security of supply that made the development of a more comprehensive EU energy policy indispensable.

To contribute to the global efforts to mitigate climate change the EU has the objective of reducing greenhouse gas (GHG) emissions by 80–95% by 2050 compared to 1990 (European Council, October 2009). These objectives have been translated in 2007 by an EU agreement on the 2020 targets, the 20-20-20 goals, that are:

(1) Reduction of at least 20% in GHG emissions compared to 1990 levels;
(2) 20% of the final energy consumption to come from renewable sources;
(3) Improvement of energy efficiency by 20% compared to 2007 projections.

A set of legislations have been adopted in the package:

(1) Directive on the promotion of the use of energy from renewable sources (2009/28/EC), setting national binding targets until 2020;

(2) Directive on energy performance of buildings (2010/31/EU), setting minimum requirements for new and refurbished buildings;
(3) Directive on energy efficiency (2012/27/EU) promoting renovation and energy savings through obligations and behavioral changes;
(4) Directives on eco-design requirements (2009/125/EC) and energy labelling (2010/30/EU), promoting efficiency of products.

1.2.1 The First Renewable Energy Directive (2009)

The Directive 2009/28/EC (RES Directive) is designed to ensure the achievement of the 2020 renewable energy targets. It addresses a number of key barriers for the deployment of geothermal such as lack of a widely accepted definition of geothermal energy, removal of administrative barriers, spatial planning, and certification of small-scale shallow geothermal installers. Moreover, it translates the EU target into legally binding national targets. In addition, the directive requires governments to submit national renewable energy action plans (NREAPs)[1] including a qualitative analysis relating to the planned policy measures and quantitative analysis showing sectorial targets and projections for each technology in electricity, heating and cooling, and transport. For the calculation of the RES share in the heating produced by a heat pump, a methodology was adopted. It allows for accounting the contribution of electric heat pumps, including geothermal heat pumps, towards the renewable energy targets.

Looking at the status of the geothermal market today and its trends between 2010 and 2020, Tables 1, 2 and 3 show installed capacity for geothermal electricity and geothermal heat production. The information for the year 2010 and the projections until 2020 are the ones provided by member states in their NREAPs. The latest data available (2015 data for geothermal power and 2014 data for geothermal heat) come from Eurostat and EGEC.

1.2.2 Buildings and Energy Efficiency Legislation

At EU level, a series of measures have been adopted to improve the energy performance of buildings and products and to integrate renewable energy into new buildings and existing buildings subject to major renovation. The most relevant measures having a potential positive impact on geothermal heating and cooling technologies are:

- Directive on energy performance of buildings (2010/31/EU);
- Directive on energy efficiency (2012/27/EU);

[1]https://www.eea.europa.eu/data-and-maps/figures/national-renewable-energy-action-plan.

Table 1 Trends 2010–2020 and status 2015 in geothermal power installed capacity in the EU (MWe)

	2010	2017	2020
Italy	754	915.5	920
Germany	10	38.19	298
Greece	0	0	120
France	26	17.1	80
Portugal	25	33.3	75
Hungary	0	3.35	57
Spain	0	0	50
Ireland	0	0	5
Czech Republic	0	0	4.4
Croatia	N/A	N/A	10
Slovakia	0	0	4
Belgium	0	0	3.5
Romania	0	0.05	
Austria	1	1.2	1
EU	816	1008.29	1627.9

Based on data from: National Renewable Eenergy Action Plans, EGEC (2018)

Table 2 Trends in geothermal heat production in the EU (ktoe)

	2010	2014	2020
Germany	57.1	91	686
France	98.2	125.7	500
Hungary	98.4	124.5	357
Italy	139.3	129.6	300
Netherlands	7.6	35.9	259
Poland	13.4	20.2	178
Slovakia	5	4.2	90
Greece	16	11.7	51
Austria	20.5	19.4	40
Portugal	1	1.3	25
Slovenia	26.3	30.9	20
Czech Rep	0	0	15
Croatia	6.8	10.7	15.7
Spain	16	18.8	9.5
Bulgaria	32.7	33.4	9
Belgium	2.1	1.4	5.7
Lithuania	2.3	0.9	5
Romania	22.1	25.1	80
UK	0.8	0.8	0
Denmark	2.5	2	N.A.
Cyprus	0.8	1.6	N.A.
EU	568.9	689.1	2630.2

Based on data from: EUROSTAT SHARES 2014, National Renewable Energy Action Plans

Table 3 Trends in production of geothermal heat pumps in selected EU member states (ktoe)

	2010	2014	2020
UK	21.7	56.6	953
Sweden	N.A.	803.3	815
France	217.1	261.6	570
Italy	44.2	70.8	522
Germany	246.2	334	521
Netherlands	52.1	81	242
Denmark	56.2	71.8	199
Hungary	N.A.	N.A.	107
Greece	N.A.	N.A.	50
Spain	N.A.	16.4	40,5
Slovenia	N.A.	N.A.	38
Austria	N.A.	N.A.	26
Slovakia	N.A.	N.A.	4
Romania	N.A.	N.A.	8
Finland	N.A.	133.8	N.A.
Czech Republic	26.5	41.8	N.A.
Estonia	N.A.	21.1	N.A.
Poland	3.1	8.4	N.A.
Hungary	N.A.	5	N.A.
Luxembourg	N.A.	0.5	N.A.

Based on data from: EUROSTAT SHARES 2014, National Renewable Energy Action Plans. Countries not reported in the table have not reported the breakdown of heat pumps by source

- Directives on eco-design requirements (2009/125/EC) and energy labelling (2010/30/EU).

The Table 4 below displays the main measures related to geothermal in buildings, taken by these three directives and their respective timetable.

Directive 2010/31/EU (EPBD) requires member states to set primary energy requirements for new and existing buildings undergoing major renovation. These requirements are to be reviewed every 5 years and should be calculated through a cost-optimal methodology taking into account certain elements, including the thermal characteristics of a building. For new buildings, high-efficiency alternative systems, including geothermal heat pumps and district or block heating or cooling, need to be assessed before construction starts. In addition, the EPBD looks to the future and introduces in EU law the ambiguous concept of ‘nearly zero-energy building (NZEB)’, which is ‘a building that has a very high energy performance, whose very low amount of energy required should be covered to a very significant extent from energy from renewable sources produced on-site or nearby’.

These provisions are linked with the RES Directive, according to which member states have, in their building regulations and codes, or by other means of equivalent effect, require the use of minimum levels of RES in new buildings and existing

Table 4 Main measures and timetable related to geothermal in buildings

Date	Provision
Since 2014	Member States to renovate each year an average 3% of the public building stock owned by central governments (Article 5 Energy Efficiency Directive)
Since 2015	Member states to introduce, where appropriate, measures to set minimum levels of RES which should be used in buildings or equivalent supporting measures (RES Directive) and intermediate targets for improving the energy performance of new buildings (Art. 9.3 (b) EPBD)
Since 2015	Energy label for brine-to water heat pumps A++ to G introduced (substituted by a new label ranging from A+++ to D in 2019)
31st December 2018	All new buildings owned or occupied by public authorities shall be nearly zero-energy buildings (Art. 9.1 EPBD)
31st December 2020	All new buildings (including private buildings) shall be nearly zero-energy buildings (Art. 9.1 EPBD)

buildings undertaking major renovation. As a result of the above member states have laid down their own detailed NZEB definition.

This is complemented by the Directive on energy efficiency. It establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. Under the Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain, from production to final consumption. Several measures in this directive allow the development of geothermal energy. In particular, EU countries can opt to achieve their savings through means such as improving the efficiency of heating systems.

Relevant to geothermal heat pump technology only are both the ecodesign and energy labelling regulations. Ecodesign aims to improve the energy and environmental performance of products throughout their life cycle, while energy labelling requirements aim to providing citizens with information about the environmental performance of products. New ecodesign requirements and energy labels for space heaters and combination heaters entered into force in September 2015. An energy label for brine—to water heat pumps is established in two phases: the first entered into force in 2015 ranges from A++ to G, while a second ranging from A+++ to D will be introduced in 2019. As geothermal heat pump is amongst the few technologies to achieve the highest class, this instrument has a significant potential to increase awareness about the technology in Europe.

1.2.3 The Climate Instruments

The EU Emission Trading System (ETS) was set up in 2005. It is the world's first and biggest international emissions trading system, accounting for over three-quarters of international carbon trading. The EU ETS works on the 'cap and trade' principle, with a carbon market. A cap is firstly set on the total amount of selected greenhouse gases that can be emitted by installations covered by the ETS.

The cap is reduced over time to progressively reduce total emissions. Within the cap, companies receive or buy ETS emission allowances which they can then trade with one another. They can also buy limited amounts of international credits from emission-saving projects in third countries.

The EU Emissions Trading Systems covers electricity and industrial installations above 20 MW, and those not covered by the ETS are buildings, services and small industries, and land use, land-use change and forestry (LULUCF). National targets for GHG emissions reduction in non-ETS sectors are then also set to cover emissions from these areas.

1.3 The European Energy Union

In 2015, the European Commission has reorganised all the EU actions in the field in a framework strategy towards the establishment of a 'resilient Energy Union with a forward looking climate policy'. The strategy is being built around the following five dimensions:

(1) security, solidarity and trust: diversifying Europe's sources of energy and ensuring energy security through solidarity and cooperation between EU countries;
(2) a fully integrated internal energy market: enabling the free flow of energy through the EU through adequate infrastructure and without technical or regulatory barriers;
(3) energy efficiency: improved energy efficiency will reduce dependence on energy imports, lower emissions, and drive jobs and growth;
(4) decarbonising the economy: the EU is committed to a quick ratification of the Paris Agreement and to retaining its leadership in the area of renewable energy;
(5) research, innovation and competitiveness: supporting breakthroughs in low-carbon and clean energy technologies by prioritising research and innovation to drive the energy transition and improve competitiveness.

This new dimension for the energy policies should set the frame for having an energy system approach in the climate and energy package 2030 and in the Energy Roadmap 2050.

2 Key Regulatory Issues on Geothermal

A geothermal system is developed in several phases. As illustrated in Fig. 1, a simplified way to classify the different steps of a deep geothermal project is as follows: (a) exploration; (b) resource development; (c) construction; (d) commissioning and operation.

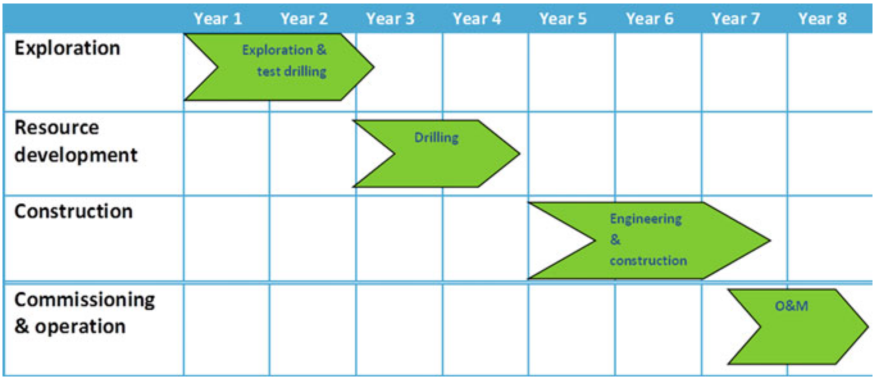


Fig. 1 Phases of a deep geothermal project. Modified from: GEOELEC (2013, p. 41)

Each of these phases requires one or more permits and the compliance with a range of national and local rules. The whole set of rules should be as transparent and balanced as possible in order to ensure, simultaneously, the sustainable use of the resource, confidence in the technology, and investment security. Several studies (GEOELEC 2013; GEODH 2014; REGEOCITIES 2015) have assessed the most relevant regulatory issues affecting the geothermal sector, which can be classified as follows: (a) definition, classification, and resource ownership; (b) licencing and authorisations; (c) sustainability; (d) spatial planning and (e) access to the grid. The following sections provide a brief analysis for each of them.

2.1 *Definition, Classification, and Resource Ownership*

The definition, classification, and ownership of the geothermal resources affect many key aspects of regulation in this field. In Europe, Directive 2009/28/EC (RES Directive) provides a legally binding definition according to which 'geothermal energy' means energy stored in the form of heat beneath the surface of solid earth (Art. 2). Geothermal is therefore to be considered as a renewable energy source of its own kind and any national or local regulation should be in line with the above overarching definition. In practice, however, geothermal resources are still defined in a several ways: as mineral, water or groundwater, heat and, more rarely, as a *sui generis* resource.

Besides that, a classification between different types of resources could be useful for determining the regulatory approach to the various categories of geothermal systems, especially with the objective of simplifying the administrative procedures. A single depth limit may be used at national level to define and differentiate geothermal resources depending on country specific geological conditions, e.g. in France since 2015 simplified procedures for shallow geothermal projects between

10 and 200 m depth have been adopted. Deep geothermal resources could also be defined as occurring below depths of 300–500 m and shallow resources as those located above the chosen threshold. In this regard, the RES Directive refers to 'shallow geothermal' only in relation to training and certification, but does not propose any further distinction. Without an EU-wide approach, member states classify geothermal resources in very different ways.

Another basic but essential legal issue is the resource ownership definition. Three situations can be found in the EU. The first is when the geothermal resource belongs to the state which grants licenses and permits for its use. This is the case in most of the European countries with plants in operation and it seems to be the most desirable option to have security of investments for project developers. A second case, more typical of common law systems, is when the resource belongs to the owner of the surface area; this could lead to competition in the same area, where multiple owners are concerned. The third and the most problematic case is found in some juvenile markets where there are no specifications about ownership. Traditionally, a first come—first served approach is in place, unless priority is given by law to a specific use. The licensing procedures are coming from historical national regulations of the underground in particular the mining code. European standards on resources classification could help geothermal market actors to report their resource to regulators and financial actors but the discussion has just started. An international debate is also taking place to define geothermal resources worldwide.

2.2 *Licensing and Authorisation*

The licencing or authorisation procedure is established by national, and sometime regional, decision-makers. In the geothermal sector a true license provides exclusive rights within a certain area and for a given time period, thereby ensuring investment security. Additionally, a licencing regime tends to clarify issues such as who is eligible to obtain a permit, who are the licencing authorities, how many steps and the time the process involves, the exact time period for which a license can be obtained and extended, if royalties are required, and under what parameters.

The type of permits a project developer must obtain and the respective procedures to follow depend primarily on the definition and classification of geothermal resources (see Sect. 2.1 above). Being an underground resource, the administrative procedures relevant for geothermal stem from a long history in mining and are in many cases part of a wider legal framework intended for coal, hydrocarbons, etc. In the vast majority of European countries, the licencing regime for deep geothermal consists in a two-step process requiring an exploration and a production license. In addition, a number of other permits could be required during these two phases. As we shall see in the next Sect. 2.3, these permits allow the public authorities to ensure that the project is performed in a safely and environmentally sound way and fulfils all public participation and consultation requirements.

While the licensing regime is a key enabler for the geothermal business, it should however be very well regulated. As a matter of fact, in some countries the right to use the geothermal resource is not clearly exclusive, while in other cases complex, long, and sometimes unnecessary procedures represent a significant non-technical barrier for geothermal developers. Delays, for example, can provoke uncertainty and lead to higher risks due to which investors require higher returns. For a capital-intensive technology, a one stop-shop process is desirable for each phase of the project.

In this regard, the RES Directive aims to improve the legal framework for RES projects. To break with the past, Art. 13 requires member states to streamline and rationalise the administrative procedures and to clearly define and coordinate the respective responsibilities of national, regional and local administrative bodies. A good practice in this sense for shallow geothermal systems is found in France.

2.3 Sustainability and Environmental Projects

Negative environmental impacts associated with geothermal energy are minor, especially if compared with conventional fossil fuels and nuclear power plants in a lifecycle analysis. As a matter of fact, a geothermal plant is located right above the resource and does not imply mining, processing, transporting the fuel over great distances, and combustion. Furthermore, the visual and land use impact can be negligible. However, as for every industrial activity, some potential and adverse effects exist such as some forms of gaseous emissions, induced seismicity, ground subsidence, noise during the construction phase, and temperature anomalies in the subsurface and the groundwater. These potential impacts vary depending on the geological settings as well as on the size and type of application. In all circumstances they can be avoided thanks to sound practice, technology developments, and compliance with environmental regulations.

For the geothermal sector, the most relevant EU directives are the following:

- Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment (EIA Directive)[2];
- Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (SEA Directive); and
- Directive 2000/60/EC establishing a framework for Community action in the field of water policy.

[2]As amended by Directive 2014/52/EU.

2.4 Spatial Planning and Grids

The planning of local infrastructure plays an important role for geothermal heating and cooling systems. For example, the very technical feasibility of a geothermal heat pump system may depend on the interaction with underground infrastructure such as parking areas and communication and transport systems. For this reason, it is essential to know the position and the dimensions of this infrastructure to avoid undesirable interference and ensure that the systems can be installed in the planned position for a long period of time. Here, local rules in terms of underground planning play a very important role.

Regarding new geothermal district heating systems, it is the rigidity of local plans for heating and cooling, which once implemented are difficult to alter, that may represent a significant barrier. For this reason, the RES Directive recommends member states to encourage local and regional administrative bodies to include heating and cooling from RES in the planning of city infrastructure (Art. 13). This provision has resulted in some positive changes, for instance in Italy where Legislative Decree 28/2011 imposes on municipalities with more than 50,000 inhabitants the requirement to draft district heating development plans. In this regard, it should be mentioned a requirement from Directive 2012/27/EU (Energy Efficiency Directive or EED) to carry out comprehensive assessments and a cost-benefit analysis of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling as a basis for sound planning (Art. 14). When a potential for the construction of the related infrastructure is identified and its benefits exceed the costs, adequate measures to accommodate its realisation should be put in place. It is still to be seen, however, whether the actual implementation of the above provisions can concretely have an impact on the development of geothermal energy as a renewable and efficient source for district heating.

2.4.1 Grid Access

For geothermal power, grid connection and access is the last key step before remuneration. Given the former monopolistic structure of the electricity market, grid connection and access for new and especially renewable power plants has not always been obvious. This is why there is a need for clear and non-discriminatory rules: the RES Directive addresses this issue by requiring priority or guaranteed access to the grid for renewable electricity (Art. 16). This provision is complemented by a similar guarantee awarded to high efficiency cogeneration in the EED. As a result, member states may set rankings between and within different types of renewable energy and high efficiency cogeneration (Art. 15). The above provisions constitute specific legislation for the connection and dispatching of electricity generating installations and complement Directive 2009/72 (Electricity Directive), which sets the general rules for the electricity sector in the EU.

2.5 State of Play and Evolution of National Incentives

The level and type of support instruments for geothermal energy vary depending on the application, the market maturity as well the geological settings and the accessibility of the resource. For geothermal electricity, the main support is in terms of operating aid.

The instrument of the feed-in tariff, a fixed and guaranteed price paid for each kWh produced, is considered the most attractive financial incentive for a project developer. As a matter of fact, the costs of capital for RES investments observed in countries with established tariff systems have proven to be significantly lower than in countries with other instruments that involve higher risks for future returns on investments. In the EU, however, the new State aid rules for projects in the field of environmental protection and energy (EEAG) for the period 2014–20 are phasing out feed-in tariffs in favour of more market-based incentives such as feed-in premium, i.e. a bonus on top of market price. This mechanism, depending on how it is designed, tends to increasingly expose renewable electricity producers to market and prices signals. For geothermal, it has already been adopted in France, Germany, and the UK.

Policy makers need to set the type and level of support according to the maturity of the technology and of the market. However, only a limited number of European countries support geothermal electricity effectively. In some cases, the level of support appears to be much lower than the one given to other renewable technologies at the same stage of maturity, and many countries do not support geothermal electricity at all.

Substantial support to some renewables, often overcompensating their real cost and bringing about windfall profits, has led to a reduction of costs in these technologies. For this reason, there is more and more support for mechanisms such as feed-in premium schemes that expose renewable electricity producers to market signals, i.e. the price of electricity. Against this background, it should be highlighted that this support was very much focused on some technologies and that most geothermal power plants have been running without support for decades. As only a handful of geothermal projects have received operational aid over the last five years, it seems therefore premature to talk about the need for more market-based mechanisms or even phase-out financial support for geothermal electricity as EGEC described it Fig. 2.

Furthermore, the standard rule of the EEAG foresees that from 2017 this financial support should be allocated via a technology-neutral bidding process open to all technologies regardless of their maturity. Such a development may significantly increase uncertainty for less developed and more capital intensive technologies. This is the reason why the following derogations apply if duly justified by member states:

- Feed in tariff may be possible for demonstration projects;
- Member States may set-up technology-specific bidding to ensure diversification, and take into account different levels of maturity into account;

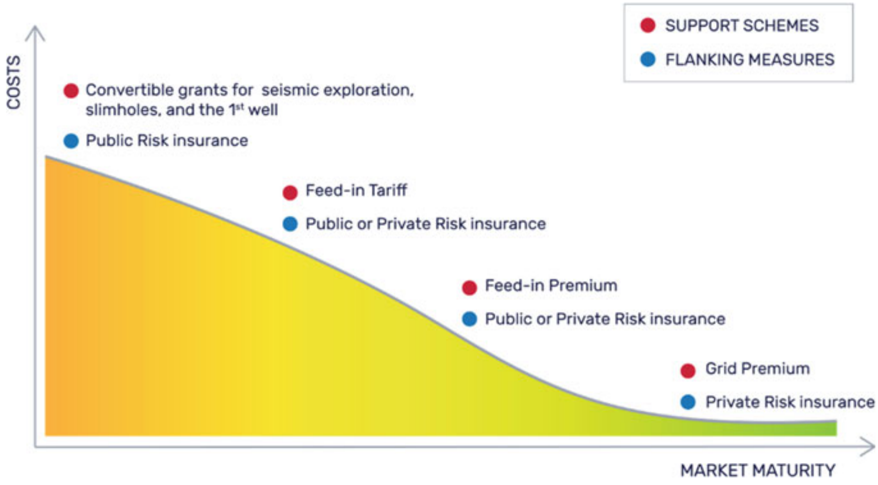


Fig. 2 Support schemes for geothermal adapted to market maturity. *Source* EGEC (2018)

- Support may be granted without bidding if the Member States demonstrates that this would result in underbidding or in low project realisation rates.

An alternative way to provide operating support to renewable electricity is through the instrument of a quota system, which is a legal obligation on energy supply companies to purchase a specified amount of renewable energy. This instrument is used in Flanders (Belgium) and Romania and remains unchanged by the new state aid rules.

As far as geothermal heat projects are concerned, public financial support is more fragmented and is mainly allocated through grants covering part of the higher upfront investment cost compared to conventional technologies. In many member states, especially from Central and Eastern Europe, these funds largely stem from European Structural and Investment Funds in support of the EU energy and climate objectives in the least favoured regions.

Some variations in terms of instruments to support geothermal heat projects is observed, for instance:

- grants combined with tax or VAT incentives (e.g. France and Belgium) or with soft loans (e.g. Germany) with a guaranteed interest rate below market levels and with favourable repayment time;
- tax incentives only;
- alternative instruments offered at the same time, as it is the case in Italy with grants (Conto termico) or tax incentives (Ecobonus) for building renovation.
- operating aid similar to a feed-in tariff system like in the UK and, embedded in a multi-sectorial tendering scheme, in the Netherlands. Operating aid in the heat sector results, however, more complex and less popular compared to the power sector.

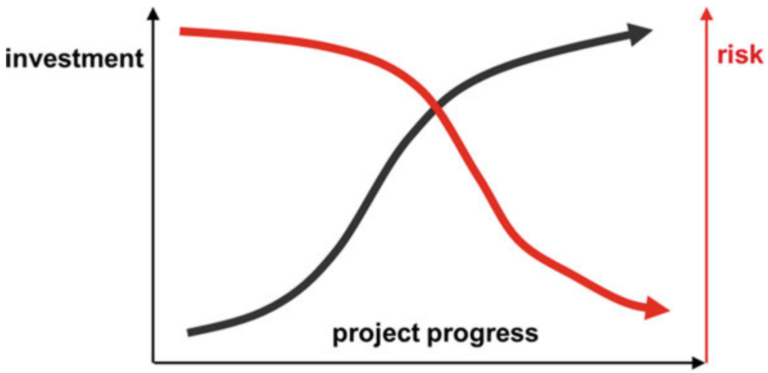


Fig. 3 Risk and cumulative investment during the project progress. Modified from: GEOELEC (2013, p. 50)

While of extreme importance traditional financial incentives may not always be sufficient, especially for deep geothermal projects. Most of the investment falls into the high-risk phase of the geothermal project (Fig. 3). While the project is being developed, the required budget changes successively. And with increasing effort in exploration, more and more knowledge about the resource is acquired and the risk of failure decreases accordingly.

The bottleneck of many geothermal projects is that in most cases 'debt financing by banks is possible only following the completion of the long-term flow tests'. Furthermore, due to the limited practical geological knowledge in some regions, also private insurers consider the operation to be too risky. Under those conditions, a feed-in premium or a soft loan do not guarantee alone the successful financing of a project. This barrier is a common issue and has been successfully overcome in France and The Netherlands where governments have taken action to set a public-private risk mitigation facility. As markets develops and costs decrease, in the medium-term the private sector should be able to manage project risks, thereby enabling a sustainable long-term development.

3 The Future Energy Regulatory Framework 2030 and 2050

In 2012, the European Commission released a long-term energy roadmap for 2050 aiming at presenting different scenarios for decarbonising the sector in view of a full decarbonisation of the economy. The roadmap pursued the objective of reducing greenhouse gas emissions by 80–95% by 2050 compared to 1990, as set by the European Council in October 2009. As regards to the energy sector, this means minimum 85% energy—related CO_2 emission reductions by mid-century.

For the mid-term period, Head of States and Governments decided in 2014 to have a new climate and energy package covering the period 2020–2030.

3.1 The Next 2030 Climate and Energy Package

A new framework was adopted by EU leaders in October 2014, with the following three key targets for the year 2030:

(1) At least 40% cuts in greenhouse gas emissions (from 1990 levels);
(2) At least 27% share for renewable energy binding on the EU level only;
(3) At least 27% improvement in energy efficiency binding on the EU level only.

Beyond the targets, the European Commission introduced in November 2016 a set of directives and regulations to support the ambition of its climate and energy policies. The Clean Energy Package comes to update the current regulatory framework, with a goal of preparing the transformation the European energy system and streamlining EU climate and energy policies. The main pieces relating to the Climate and Energy framework are:

- The Proposal for a recast Renewable Energy Directive (replacing DIRECTIVE 2009/28/EC);
- The Proposal amending the Energy Efficiency Directive (amending DIRECTIVE 2012/27/EU);
- The Proposal for a Governance Regulation (which replaces the whole existing planning and reporting framework);
- The Proposal amending the Energy Performance of Buildings Directive (amending DIRECTIVE 2010/31/EU);
- Proposal for a regulation and a directive on the internal market for electricity (notably replacing DIRECTIVE 2009/72/EC).

The proposal for a Governance Regulation aims at streamlining planning and reporting requirements for EU Member States in order to comply to the Paris Agreement framework at to reduce the administrative burden of Climate and Energy policy. It replaces several legislative texts to define National Energy and Climate Plans for Member States for the period between 2020 and 2030, and to set up the reporting obligations for the period.

The Governance Regulation defines how Member States will plan and develop a vision on their energy systems for the long-term. Currently being discussed, there are many uncertainties regarding the outcome of the text. It has however some potential to contribute to the development of geothermal energy by favouring an integrated planning of the Energy system across the 5 dimensions of the Energy Union (further detailed in Sect. 1.3 above):

(1) security, solidarity and trust;
(2) a fully integrated internal energy market;
(3) energy efficiency;
(4) decarbonising the economy;
(5) research, innovation and competitiveness.

These different pieces of legislation are being discussed between Member States and the European Parliament. An agreement on all these policy dossiers is planned for 2018 in order to be implemented before the end of the 2020 period.

One key point under discussion regards the targets and their ambition:

(1) the reduction in greenhouse gas emissions (from 1990 levels) should be at least 40%;
(2) the share for renewable energy should be binding on the EU level, with a target to be decided of at least 27% or 35%, or between these figures;
(3) improvement in energy efficiency should be binding on the EU level, with a target to be decided of at least 27% or 40%, or between these figures.

4 Conclusions

The EU has set a long-term goal of reducing greenhouse gas emissions by 80–95%, when compared to 1990 levels, by 2050. The Energy Roadmap 2050, published in 2011, explores the transition of the energy system in ways that would be compatible with this greenhouse gas reductions target while also increasing competitiveness and security of supply.

An ideal future energy scenario should envisage a coherent energy mix in the three energy sectors: electricity, heating and cooling, transport. Such a perspective should allow to have a decarbonised energy sector based or nearly fully based on RES. It would provide energy to all at affordable prices to consumers. It would allow to mitigate costs of the energy transition taking into account the full costs for the society. Based on a regional and local energy systems, citizens would decide the energy system and the security of supply would be guaranteed.

The key ways to achieve this ideal scenario are:

(1) continue the decarbonisation of the power sector, still far to be reached, towards more variable and flexible RES and with a mitigation of the system costs;
(2) accelerate the fuel switch in the heating and cooling sector towards more RES, this sector is lagging behind, need to have a new design of the market;
(3) decarbonise the transport sector as far as possible notably with more e-mobility.

Acknowledgements The information provided in this chapter is allowed thanks to the support of the EGEC's members to the work of the association and to the European Commission financial contribution to the European projects coordinated by EGEC: GEOELEC, GEODH and REGEOCITIES.

References

Cermak V, Rybach L (eds) (1979) Terrestrial heat flow in Europe. Springer, Berlin

EGEC (2018) EGEC geothermal market report 2017

European Commission (2012) Energy roadmap 2050. Publications office of the European Union, Luxembourg. Available at https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdfAccessed, 30 Mar 2018

GEOELEC (2013) Towards more geothermal electricity in Europe, final report. Available at: http://www.geoelec.eu/Accessed, 30 Mar 2018

GEODH (2014) Developing geothermal district heating in Europe, final report. Available at: http://geodh.eu/Accessed, 30 Mar 2018

Haenel R (compiler) (1980) Atlas of subsurface temperatures in the European Community. Th. Schafer Druckerei, Hannover

Hurter S, Haenel R (eds) (2002) Atlas of geothermal resources in Europe. Office for Official Publications of the European Communities, Luxemburg

REGEOCITIES (2015) Developing geothermal heat pumps in smart cities and communities, final report. Available at: http://regeocities.eu/results/Accessed, 30 Mar 2018

Philippe Dumas after working in a European engineering company as representative in Brussels for EU affairs (2000–2007), was involved in geothermal energy with EGEC (European Geothermal Energy Council), starting as project manager for European projects. Author and co-author of several publications; frequent contributor to conferences, workshops and seminars; active in a number of EU-funded research and promotion projects from 2000 until today. Since September 2008, he’s the EGEC Secretary general in Brussels managing the association. EGEC is an international association, founded in May 1998 and based in Brussels, Belgium. EGEC unites more than 120 companies and organizations, representing more than 500 entities from 22 European countries, working in the geothermal field in Europe. The main goal of EGEC is to foster market development for geothermal energy and to work for improvement of business conditions in Europe.

Business Strategies in Geothermal Energy Market: A Citizens-Based Perspective

Michele Contini, Eleonora Annunziata, Francesco Rizzi and Marco Frey

Abstract The development of geothermal energy can be hindered by both technical and socio-economic issues. Technical issues are associated with the intrinsic characteristics of geothermal energy and the ways in which is exploited, whereas socio-economic ones arise from the interplay between companies and stakeholders, affected to some extent in the development of geothermal energy. In this contribution, we analysed possible determinants of the relationship between companies and citizens. On the one hand, citizens represent a key stakeholder for energy companies that want to develop a geothermal energy facility. On the other hand, they represent the potential end users of technology providers' products. Accordingly, geothermal energy companies and technology providers are called upon to take action for involving citizens and overcome the related tensions with them. In particular, geothermal energy companies need to face social acceptance issues when developing geothermal energy facilities. In order to achieve a better understanding of these issues, we have analysed suitable strategies and practices from the Corporate Social Responsibility (CSR) perspective, which is becoming a common reference point for geothermal energy companies that need to manage stakeholders' involvement. Technology providers, instead, aim at fostering the adoption of geothermal energy systems at building level. In order to investigate the related dynamics, in this chapter we present an analysis of the most popular promotion and risk sharing strategies and practices that are in place among geothermal players. Among such strategies and practices, two themes emerged as key blocks for citizens' involvement: information and trust. By comparing CSR, promotion and risk sharing strategies and actions, we provide energy companies and technology providers with some suggestions to achieve local acceptance of geothermal facilities.

M. Contini (✉) · E. Annunziata · M. Frey
Sant'Anna School of Advanced Studies, Institute of Management,
Piazza Martiri della Libertà 24, 56127 Pisa, Italy
e-mail: m.contini@santannapisa.it

F. Rizzi
Department of Economics, University of Perugia, Via Alessandro Pascoli,
06123 Perugia, Italy

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes
in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_3

Keywords Citizens' involvement · Corporate social responsibility (CSR)
Information · Trust

1 Current Socio-economic Challenges in the Geothermal Energy Sector

The Paris Agreement, entered into force on 4th November of 2016, represents one of the most important milestone of a process—initiated at the Conference of Rio in 1992—aimed at progressing towards a sustainable model of development. In particular, the Agreement foresees 175 parties—174 countries and the European Union—taking responsibility to reduce greenhouse gas emissions caused by the consumption of fossil fuels, limiting the increase of temperature below 1, 5 °C (UN 2016). Such commitment towards climate change mitigation is necessary because the energy industry is still highly dependent from fossil resources. As an example, the International Energy Agency (IEA) reports that in 2016 around 80% of the total energy produced derived from fossil fuels—i.e. oil, natural gas and coal—with an amount of emissions of 34,000 million tons of CO_2 (IEA 2017). Besides energy efficiency, renewable energies sources (RESs) are expected to play a major role in the pursuit of ambitious greenhouse gas reduction targets of the Paris Agreement.

Past researches confirm the presence of a wide public support for renewable energy technologies (RETs) (Hall et al. 2013). RETs are considered low-emissions sources of energy, able to foster widely diffused energy production as well as local and global greenhouse gas and pollution reduction (Karytsas and Theodoropoulou 2014b). In 2011, a study at European level shows that 84%—or higher—of European citizens support solar, wind and hydroelectricity (Eurobarometer 2011). In a similar study in Canada, such percentage is even higher, with 90% of support for the same types of renewable energies (Insightrix Research Inc 2011; Hall et al. 2013). Despite such support, citizens are still often reluctant to accept renewable energy facilities in their so called "backyard" (Hall et al. 2013), because the adoption of new energy technologies is frequently associated with losses of landscape and lifestyle (Ekins 2004; Hall et al. 2013). Such concerns related to RETs have often been overlooked by policy makers and energy companies, relying on the assumption that RETs adoption is generally driven by economic benefits and on the awareness that taking active part in fighting global-scale issues—e.g. through CO_2 emissions reduction and climate change mitigation—is socially responsible. However, citizens usually are more prone to adopt RETs in order to gain a direct economic benefit and to avoid (perceived) negative impacts at the local scale, favouring an egoistic perspective over the altruistic global-oriented one.

Among RESs, geothermal energy has been characterised by various local issues in the past. While geothermal energy is a programmable source of energy because it is not affected by weather conditions such as solar and wind energy, it raises complex local issues from different perspectives—i.e. technical, financial and socio-economic ones (Kubota et al. 2013). Technical and financial issues are under the direct control of the energy companies, which can design technical solutions and financial instruments to develop and manage geothermal energy facilities. Instead, socio-economic issues are not under direct control of the energy company since they affect and involve external stakeholders. As an example, socio-economic issues are often raised by information asymmetries between citizens and energy companies, which usually withhold information for competitive purposes. In fact, information accumulated during the exploration phase represent an important part of the competitive advantage gained with respect to competitors. The unwillingness to disclose some kind of information can lead to losses of citizens' trust towards geothermal energy companies, creating the perception of danger and sharpening citizens' oppositions. For these reasons, geothermal energy companies need to develop appropriate strategies and actions—information campaigns, trust building activities, etc.—aimed at considering citizens' perspective and their involvement. An important instrument to address challenges associated with stakeholders' management is Corporate Social Responsibility (CSR). The majority of CSR definitions share two basic ideas: companies have responsibilities not limited to the mere seeking of profits or legal compliance, and such responsibilities apply not only to shareholders but also to stakeholders (Swaen and Chumpitaz 2008). Accordingly, corporate actions and strategies leaded by the principles of CSR are able to bring together themes such as labour rights, environmental protection, financial performance and sustainable development, taking into account needs and expectations of a plurality of stakeholders. The adoption of CSR practices is generally considered a suitable approach to create trustworthy relationships and consolidate communication channels for preserving geothermal energy acceptance.

Besides large geothermal energy plans, small-scale renewable energy technologies (S-RETs) represent a sub-category of RETs able to replace fossil fuels in the production of energy, reducing greenhouse gas emissions and pollution (Hyysalo et al. 2017). With no exceptions, S-RETs are affected by market diffusion issues. Among S-RETs, shallow geothermal energy (SGE) systems are a perfect example of a technology that is in the early market stage, despite its high potential. In fact, SGE systems can be installed almost everywhere, to provide heating, cooling and domestic hot water (Karytsas and Theodoropoulou 2014a). However, their development struggles to take off. Technology providers have often used a tailor-made approach to promote SGE systems and induce citizens to purchase these solutions because of their high performance. Such an approach includes the provision of a lot of technical information regarding the system sizing, the best machine to be used according to the results of the underground explorations, etc. All this information has spread among citizens a perceived complexity of these systems, which has resulted into the amplification of citizens' perception of inability to control the installations (Yun and Lee 2015). Thus, only recently technology providers have started developing new marketing approaches aimed at promoting SGE systems as a standardised technology that does not require particular capabilities and knowledge to be run. These solutions aim at reducing the perceived complexity, involving citizens in the purchase and fostering SGE systems development.

While citizens' personal characteristics—such as perception of control over the system functioning, attitude towards the S-RETs, etc.—can influence SGE systems adoption, technology-specific characteristics like the high installation costs if compared to traditional alternatives can represent another discouraging barrier. Thus, promotion strategies and actions alone cannot ensure SGE systems adoption. Technology providers need to build trustworthy relationships with citizens, giving appropriate guarantees on technology reliability while reducing the initial investment cost. Risk sharing mechanisms—in which the technology provider covers the initial costs, while guaranteeing mutually profitable performance standards—can be a suitable solution to create trustworthy relationships with citizens.

These examples support the thesis of Yun and Lee (2015), who affirmed that socio-economic aspects are "more important than technical "ones" in persuading people to adopt" both S-RETs and RETs. This means that there is a need for companies to consider the central role of local stakeholders and potential users in the process of fostering geothermal energy technologies. This poses new questions on how energy companies and technology providers can effectively push deep and shallow geothermal energy development through the adoption of suitable stakeholder-centred strategies and actions.

2 Corporate Social Responsibility (CSR) and Citizen's Involvement: The Role of Trust and Information in Deep Geothermal Energy

Information asymmetries and trust towards the (geothermal) energy company represent two potential issues that can impair the social acceptance of geothermal energy facilities at the local level.

Information asymmetries are often caused by energy companies that want to protect their competitive advantage, since information gathered during the exploration phase are a valuable asset. On the one hand, they represent the informational basis upon which geothermal energy companies evaluate the technical and economic feasibility of the geothermal energy facility. In fact, the information gathered in the exploration phase is used to map the underground, understand opportunities and potential risks, and predict the performances of the geothermal field—in terms of expected MWh extractable from the underground, evaluating its economic profitability in the long-term. On the other hand, the information is very expensive to obtain. Usually, approximately a quarter of the total investment is absorbed by the exploration phase and another quarter is needed for the drilling phase. This means that nearly half of the planned investment needs to be done before knowing with certainty if the expected production outcome can be reached, thus guaranteeing the economic viability of the project. Accordingly, energy companies are reluctant to share the information gathered in the exploration phase, because they want to avoid losing the advantage they have gained with respect to competitors.

Unfortunately, since geothermal exploitation is frequently questioned about environmental impacts, the unwillingness to disclose information can be seen—from the citizens' perspective—as a symptom of geothermal energy companies' lack of interest towards the protection of the natural environment as well as the attention to the local socio-economic dimension. In fact, in name of protecting their competitive advantage, energy companies do not even share information regarding their operational activities, such as information on underground water composition, air pollution, etc. In some citizens' view, by concealing specific information, energy companies can also exploit unsustainably natural resources, focusing just on maximising their profits and minimising their costs. This means that energy companies are expected to hide technical information, trying to concentrate their local strength while remaining the main repository of know-how. By doing this, energy companies can impede the coming of new entrants in their business and prevent the creation of local synergies, which are considered a threat—instead of an opportunity—to the pursue of company's interests. Such opportunistic behaviours are guided by the business-as-usual competitive rules, which means that firms should only seek for their self-interests and obtain short-term competitive advantage through information asymmetries (Rizzi and Frey 2014). By doing this, firms pursue the interests of a part of their shareholders, without considering the other stakeholders affected by companies'—internal and external—activities. Contrarily to this view, there are various management theories that stress the importance of the adoption of a multi-stakeholder perspective, in which cooperative solutions and pro-active approaches create the basis of long-term planning capacity and growth (Rizzi and Frey 2014).

Stakeholder theory is one of the most relevant theories that guide companies—and in this case geothermal energy companies—in taking an active role in their relationships with stakeholders. Stakeholder theory states that "a company has a responsibility toward all those who contribute directly or indirectly to its life close or afar. […]. Concerned parties include suppliers, customers, employees, investors and the local community" (Freeman 1984; Swaen and Chumpitaz 2008). Stakeholder theory reverses the perspective of the business-as-usual, by underlying the importance of including all stakeholders' needs into company's strategies as well as operational practices. Adopting this theory, the company can avoid opportunistic behaviours towards other stakeholders—and simultaneously towards the society and environment at large—, strengthening positive relationships and its reputation. The stakeholder theory is often operationalised through the implementation of Corporate Social Responsibility (CSR) best practices. CSR is a "concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with stakeholders" (European Commission 2001). This definition underlines the effort that companies should make in considering their impacts on society and the environment, while increasing ethics in business practices (Matten and Moon 2008: p. 405; Hur et al. 2014; Moncrieff 2015; Ruggie 2008; Utting 2005; Benites-Lazaro and Mello-Thery 2017). In doing so, companies should “take into account the demands and expectations that emerge from their stakeholders” (Sachs and Ruhli 2011; Scherer and Palazzo 2011; Suchman 1995), seeking “community acceptance” or “social legitimacy” (Benites-Lazaro and Mello-Thery 2017). Following the stakeholder theory perspective, CSR best practices—that range from international standards like SA 8000 and ISO 26000, and voluntary reporting initiatives, like the Global Reporting Initiatives (GRI) and UN Global Compact—allow companies to assume their responsibilities towards society and the environment—by including ethics in their practices—, while simultaneously accounting for the needs of their stakeholders. In past decades, companies have just partially changed their business models, limiting the adoption of CSR to the inclusion of some social and environmental targets in their businesses from a top-down perspective (Du et al. 2011; Sidhoum and Serra 2017). Despite that, today’s companies have more awareness that their approach to CSR should become also “interested in the way they interact with stakeholders” (Sidhoum and Serra 2017), which implies additional efforts for actively involving them. In fact, even though led by ethical principles, companies-focused unilateral CSR practices may not reflect stakeholders’ expectations and concerns, and they can result ineffective. Consequently, the introduction of stakeholders’ needs and expectations within companies’ strategic and operational CSR objectives is today increasingly done, privileging bottom-up approaches.

Among energy companies’ stakeholders, local citizens are of primary importance. In fact, social acceptance issues that impair geothermal energy facility development often derive from information asymmetries and lack of trust between energy companies and local citizens. Citizens’ informational needs could be satisfied by creating ad hoc strategies and actions aimed at aligning energy companies’ behaviours and stakeholders’ needs. In fact, an approach in which energy companies listen to the requests of information from the stakeholders prior to disclose information and give account for their behaviours is desirable, since it would communicate not just that the exploitation of the natural resources is carried out without any harms for local citizens, but could also prevent uncontrolled amplification of fears. This kind of information sharing activities has been proved to be beneficial in terms of citizens’ opinion about geothermal energy. For example, Carr-Cornish and Romanach (2014) reported the positive effect of the provision of information to citizens through focus groups. They found significant changes in citizens’ opinion, becoming more prone to accept and use geothermal energy for their energy consumption. Adopting effective CSR strategies thus require an active involvement of citizens in a two-ways communication channel, in which energy companies and citizens work together to understand each other and develop strategies and actions for mutual benefit. As an example, the multinational energy company ENEL applies instruments such as stakeholders’ map, priorities matrixes with combined priorities of both the company and local citizens, and actions plans to structure its citizens’ involvement strategies and activities in the short, medium and long-term (ENEL 2016). In the ENEL case, the priorities matrixes represent the core instrument, since their fulfilment is the result of a continuous process of mutual understanding of needs and development patterns between the company and local citizens (ENEL 2016). Scientific meetings, public debates, bilateral meetings with parties' spokespersons represent only few examples of possible occasions in which the mutual understanding process can take place. Besides establishing lively communication channels, partnerships could be another effective way to put CSR into practice. In fact, energy companies can engage and empower local actors in the business development process, instead of jealousy retaining their know-how. Energy companies' collaborative strategies and actions have been proved to be beneficial for the geothermal sector's long-term growth (Rizzi and Frey 2014). A typical example is the integration of related business, e.g. district heating networks, greenhouses, food industry dryers, spa and fitness centres. etc. as multipliers of employment opportunities that depend on a sustainable use of geothermal resources. In fact, they can lead to "catalysing positive attitudes towards geothermal development and boosting the search for technology improvements" (Rizzi and Frey 2014). As a consequence, revisiting the business goals from the standpoint of the search for appropriate CSR practices can usefully offer the basis of the «cultivation» of the relationship between energy companies and citizens—and local stakeholders at large—, resulting in an increased technology acceptance as well as an increased energy companies' support.

Such collaborations and partnerships seem to depend more on the organizational culture than on the technical characteristics of the specific project. Not surprisingly, worldwide empirical evidence is drawn from the evolution of explicit and public corporate discourses. Top managers increasingly recognise the importance of involving and cooperating with local communities as a driver for competitive advantage. As an example, Li Huaizhen—President of the worldwide investment group China Minsheng Investment Corp.—affirmed that "*Once you have done your bit—fulfilled your social responsibilities and formed a community with shared interests, with local people—they will welcome your projects and provide huge support. So, a company's own interest and the social value it provides are closely connected. In fact, this is also a kind of investment, and it always brings return*" (PWC 2016: p 16). Even though belonging to a very different sector as compared with the energy sector, Li Huaizhen implicitly introduces one of the most important outcomes of CSR strategies and actions: the definition of trust among parties as a strategic corporate goal. In fact, welcoming and support of projects are dependent from the creation of shared interests with local people, connecting company's own interest and the social value it provides. As stated by Morgan and Hunt (1994), the existence of values that the parties share and think are appropriate and important is the fundament of trust, and drives mutual benefits. To say it with the words of the PWC's report (2016) "*[…] when there is a high level of trust in a company, it drives business performance by attracting new customers and retaining existing ones. A high level of trust also makes employees more committed to staying with the company, partners are more willing to collaborate and investors more prepared to entrust stewardship of their funding. Consequently, those organisations that can build trust seem to garner significant benefits*". In the geothermal energy setting, the removal of information asymmetries—through a mutual understanding process —can allow citizens and energy companies sharing what they both think is important, and establish a trustworthy relationship. Past studies highlighted how citizens' trust—and its various conceptual dimensions—towards energy companies and institutions represent a key factor for the acceptance of geothermal energy facilities. Pellizzone et al. (2017) highlighted the "pivotal role" of trust in cases of technology development. In particular, trust related to competences—towards the energy companies—, and trust related to values—a social trust towards institutions—both emerged as crucial for the acceptance of geothermal energy facilities (Pellizzone et al. 2017). Similarly, Carr-Cornish and Romanach (2014) underlined the importance of trust towards energy companies and institutions in the perception of benefits deriving from the development of geothermal energy facilities: when increasing trust, the perception of benefits becomes stronger. Moreover, trust has been proved to be crucial for energy companies' legitimacy and reputation. In their research, Rizzi and Frey (2014) found that failures in energy companies' legitimation across communities can be attributable to their opportunistic and untrustworthiness behaviours.

In sum, adopting a CSR perspective not only removes information asymmetries—through citizens' involvement—and increases geothermal acceptance, but also increases trust among parties, making energy companies become a privileged industrial partner in the local context. In that, energy companies can benefit from a twofold advantage: they anchor their business model both to tangible (e.g. natural resources) and intangible (e.g. know-how, relations, etc.) assets (Rizzi and Frey 2014), which can be durable and not easy to imitate. Thus, such practices strengthen energy companies' competitive advantage, since it becomes harder for competitors to access or gain similar relational resources (Rizzi and Frey 2014).

3 Promotion Communications, Risk Sharing Mechanisms and Citizen's Involvement: The Role of Trust and Information in Shallow Geothermal Energy

Management of trust and information complements technical issues not only for the exploitation of deep geothermal energy sources, but also for the development of shallow geothermal energy projects.

In the last decade, technological innovation in renewable energy generation has led to the growing awareness among citizens of technologies for decentralised energy generation (Van der Schoor and Scholtens 2015). S-RETs are becoming increasingly affordable for a large part of the population, and their adoption in private buildings—such as houses, commercial buildings, etc.—is rapidly increasing (Yu and Lee 2015).

Among the various S-RETs that citizens can adopt, shallow geothermal energy (SGE) systems represent a valid alternative. Low enthalpy—or shallow—geothermal energy is an "ubiquitous and environmental friendly renewable energy resource" (Bleicher and Gross 2016), that uses the difference of the temperature between the surface and the underground to provide heat, cold and domestic hot water for buildings (Bleicher and Gross 2016). Even if SGE systems can be very efficient and can effectively contribute to the reduction of buildings' energy consumption, their diffusion is still at an early stage. In the attempt to foster the adoption of SGE systems, early technology providers have targeted citizens by using a tailor-made approach, so as to find the best fit between the technical design and the site-specific conditions, such as flows of heat and water underneath the surface. Unfortunately, the adoption of a tailor-made approach, which is reasonable from a technocratic perspective, has not been successful with respect to promotion strategies. In fact, early technology providers' promotion strategies were based on communications assuming that the possession of accurate information is a guarantor of wise judgement and precursor of decisions "taken both in the person's and society's best interest" (Ajzen et al. 2011). Consequently, technology providers overwhelmed the potential users—i.e. citizens—with abundant information, aiming at showing the technical superiority of SGE systems as compared with conventional technologies or other S-RETs. The amount of information provided led citizens perceive SGE systems as highly complicated and difficult to run, discouraging their adoption. Not surprisingly, past studies suggest that S-RETs—and in particular SGE systems—are perceived as complex and difficult to be controlled by citizens (Yu and Lee 2015), and need "ad hoc" promotion strategy (Yu and Lee 2015).

While the perception of technology complexity—i.e. the perception of ease in using a technology—is crucial in the decision to adopt it, economic barriers have also proved to be important in citizens' adoption decisions. First, initial investment costs are usually higher for SGE systems than for all the other S-RETs. In fact, SGE systems often needs multiple bore-holes to allow the exchange of heat with the underground, and the drilling costs represent one of the most relevant costs in the constructions phase. Second, maintenance costs are another factor that can be relevant in the economic balance of the installation. Even though experienced designers can accurately predict maintenance costs, a lack of information about the underground conditions can mislead less experienced designers, resulting in a general perception that maintenance costs of S-RETs are not easily predictable. This aspect represents a factor of risk that citizens need to consider in their adoption decision, since it can impair the technical and economic viability of the entire system. In addition, citizens often associate systems' malfunctioning and related economic problems with the opinion they have about the technology provider. Consequently, positive (negative) experiences with the use of the system can increase (decrease) a citizen' trust towards the technology provider, facilitating (compromising) a solid relationship between the two parties. From the technology provider's perspective, a trustworthy relation with citizens is also helpful to promotion purposes. Citizens with a good experience with the technology provider will be more likely to share with other people their positivity about the technology, increasing others' perceived control over the performance of the system and the trust towards the technology provider itself.

The role of information and, in particular, of promotion strategies, emerged as central for promoting SGE systems adoption. However, early promotion strategies based on a tailor-made and technocratic approach were not able to foster the adoption of SGE systems, since they amplified instead of reducing the perceived complexity of the system. Recently, some technology providers have thus started to present SGE systems as a standardised technology that do not need particular capabilities and knowledge to be installed and run. Standardised products are usually evaluated using the ratio between cost and overall quality of the product: individuals choose the product that, in their opinion, present the best ratio. Accordingly, technology providers should promote SGE systems presenting their favourable cost/quality ratio as compared with other S-RETs. However, presenting such ratio alone is not sufficient to effectively foster SGE systems adoption. In fact, citizens usually have basic information—albeit approximate—about the standardised product they are purchasing while, in the case of SGE systems, such information is often lacking. As an example, technology providers that promote solar panels do not need to explain what is a solar panel: such informational basis is already present for the majority of citizens, even though they have not already been a user of the technology. Therefore, technology providers should make an additional promotion effort, in order to increase citizens' informational basis of SGE systems and make it comparable with other S-RETs.

This approach to promotion could consist of short-term and long-term promotion strategies and actions. On the one hand, short-term promotion strategies should be aimed at influencing potential users' intentions immediately—usually focussing on the cost/quality ratio, pushing them towards the adoption of a new product (or service) in a precise moment in time. An example of short-term promotion action is the use of the appeals for advertising purposes. An appeal is an advertisement tool that present information related the product (or service) to be sold. Examples of appeals can be found in advertisement, in which a photo and product-related information are showed to individuals to foster their purchase. The effectiveness of appeals has also been confirmed by scientific literature in numerous cases, such as promotion of pro-environmental behaviours and, in particular, promotion of behaviours related to the adoption of technologies for energy conservation (Allen 1982; Nolan et al. 2008). Thus, appeals could represent a suitable short-term promotion action for technology providers aimed at fostering SGE systems adoption. On the other hand, long-term promotion strategies should be aimed at increasing the informational basis of potential users with respect to the new product (or service) itself. In this case, technology providers should set-up for their potential buyers a process of prolonged information exposure, in order to repeatedly provide them information about SGE systems. For example, informational campaigns underlying positive characteristics of SGE systems as well as contrasting negative or misleading information can be an effective instrument for increasing citizens' informational basis about SGE systems, as long as they are carried out continuously. In addition, a prolonged process of exposure to information has been proved to indirectly influence individuals' intentions and behaviours (Witzling et al. 2015; Ajzen 2011). As a consequence, informational campaigns addressing, for example, SGE systems' perceived complexity could change not only potential users' informational basis—making SGE systems be perceived as less complex—, but also positively influence potential users' adoption intentions and behaviours. Therefore, long-term promotion strategies and actions should be structured in accord and together with short-term promotion strategies and actions, in order to have a combined effect that could increase the likelihood for citizens to adopt SGE systems.

The increase of citizens' informational basis can also be obtained reporting positive experiences of other people with the technology and the technology provider. This phenomenon is usually called "word-of-mouth" and it is one of the strongest promotion strategies that technology providers can adopt. However, to rely on such strategy, technology providers should provide citizens with solutions that take off the perceived risks—i.e. underground risks and related economic problems—and make people trust they are a good and reliable company. In fact, the judgement on the experience associated with the technology also depends on the quality of the relationship with the technology provider, i.e. whether he is able to guarantee an appropriate support in every critical circumstance. Risk sharing mechanism can be a suitable tool for guaranteeing such support and building a trustworthy relationship between parties. In risk sharing mechanisms, the technology provider is able to simultaneously bear the initial investment cost and guarantee an agreed system performance for a fixed period of time, based on a range of performance assessed beforehand the installation of the system. Through such mechanisms, the technology provider is able to give a tangible support for the appropriate functioning of the SGE system, as well as to show that it is willing to handle, on behalf of the potential user, all the associated risks. Thus, the technology provider is able to reverse the business-as-usual relationship with the potential user —based on a seller-purchaser interaction—, and establish a relationship in which the two parties seek for the well-functioning of the installation. By doing this, the quality of the relation increases, and the potential user's fear of technology provider's opportunistic behaviours is nullified. As a consequence, potential users could be more prone to trust technology providers that use risks sharing mechanisms, since they could rely on a non-adversarial relationship with them.

The combination of information strategies and action with risk sharing mechanisms fostering trustworthy relationships should allow technology providers to push SGE systems adoption, relying on an approach that takes into account citizens' needs and remove the impairing barriers.

4 Conclusions

Energy companies and technology providers need to deal with different aspects to foster deep and shallow geothermal energy. Besides technical issues, the relationship with citizens emerged as one of the key aspect to be addressed. On the one hand, deep geothermal facilities' local acceptance issues emerged from lack of information and trustworthy relationships between citizens and energy companies. On the other hand, limitations in the SGE systems' adoption emerged from lack of appropriate promotion strategies and actions, which are fundamental to establish mechanisms aimed at facilitating the adoption of S-RETs by building trust among parties.

Therefore, the two themes that characterise the *fil rouge* of the future challenges for the development of the geothermal energy sector are information and trust. Information and trust emerged as the necessary key blocks that companies—energy companies and technology providers—need to manage if they want to achieve citizens' involvement. In the past years, companies have started to search for effective ways to involve citizens, since it is "a kind of investment" which "always brings return" (PWC 2016). Despite this effort, it is often difficult for companies—energy companies and technology providers—to identify suitable strategies and actions that can be adopted, due to the high heterogeneity of situations—in terms of citizens with different cultural backgrounds and local needs, as well as different personal characteristics—they need to face. The suggested strategies and actions of CSR, promotion strategies and risks sharing mechanisms represent potential approaches to act on information and trust, fostering citizens' involvement.

Specific relevance should be given to information and trust as mutually reinforcing themes: when information is shared and communicated properly and the perceived risks are reduced, trust among parties increases. This means that, with such premises, energy companies and technology providers can initiate a process of "cultivation" of the relationship with citizens, which can be maintained and strengthen over time. In this way, energy companies and technology providers' place their relationship with citizens at the centre of their strategies and actions, establishing unique relationships with them.

Ultimately, energy companies and technology providers should be prepared to deal with such strategies and actions. In fact, competences and capabilities that are required to design and put into practice CSR, promotion strategies and risks sharing mechanisms are not always present within energy companies and technology providers' human resources. On the one hand, employing internal resources allows energy companies and technology providers to develop personalised solutions to their socio-economic issues, establishing a unique relationship with their stakeholders—in particular, citizens. Despite such advantages, the development of internal competences and capabilities requires conspicuous long-term investments and high levels of commitment within the company. On the other hand, employing external resources represents a short-term and limited investment, but it does not ensure the same level of personalisation and accuracy with respect to the solutions of energy companies and technology providers' socio-economic issues. The decision to use internal resources—i.e. including such competences and capabilities within the company—or external resources—i.e. relying on external partners—represents a strategic decision that need to be accurately evaluated, even though both options can be potentially adopted. Despite the differences among the two alternatives, energy companies and technology providers are encouraged to share, within their organisation, procedures, results and lessons learnt from the implementation of CSR, promotion strategies and risks sharing mechanisms. In fact, this sharing activity is able to foster an organizational culture in which everyone agrees on the importance of stakeholders'—and in particular citizens—involvement, orienting corporate behaviours towards the key blocks of sharing information and building trust. Thus, strategies and practices of stakeholders' involvement become a company diffused patrimony, which allows more reliable investments and improves the ability to tackle accidents in the business environment.

References

Ajzen I (2011) The theory of planned behavior: reactions and reflections. Psychol Health 26: 1113–1127

Ajzen I, Joyce N, Sheikh S, Cote NG (2011) Knowledge and the prediction of behavior: the role of information accuracy in the theory of planned behavior. Basic Appl Soc Psychol 33(2): 101–117

Allen CT (1982) Self-perception based strategies for stimulating energy conservation. J Consum Res 8(4):381–390

Benites-Lazaro LL, Mello-Théry NA (2017) CSR as a legitimatizing tool in carbon market: evidence from Latin America's Clean Development Mechanism. J Clean Prod 149:218–226

Bleicher A, Gross M (2016) Geothermal heat pumps and the vagaries of subterranean geology: energy independence at a household level as a real-world experiment. Renew Sustain Energy Rev 64:279–288

Carr-Cornish S, Romanach L (2014) Differences in public perceptions of geothermal energy technology in Australia. Energies 7(3):1555–1575

Du S, Bhattacharya CB, Sen S (2011) Corporate social responsibility and competitive advantage: overcoming the trust barrier. Manag Sci 57(9):1528–1545

Ekins P (2004) Step changes for decarbonizing the energy system: research needs for renewables, energy efficiency and nuclear power. Energy Policy 32:1891–1904

ENEL (2016) Seeding energies—Bilancio di Sostenibilità. ENEL

Eurobarometer (2011) Special Eurobarometer 372: climate change. European Commission, Brussels. Available at: http://ec.europa.eu/public_opinion/archives/ebs/ebs_372_en.pdf. Accessed 06.08.12.

European Commission (2001) Corporate social responsibility.Available at: http://ec.europa.eu/enterprise/policies/sustainable-business/corporatesocial-responsibility/index_en.htm

Freeman RE (1984) Strategic management: a stakeholder approach. Pitman, Boston

Hall N, Ashworth P, Devine-Wright P (2013) Societal acceptance of wind farms: analysis of four common themes across Australian case studies. Energy Policy 58:200–208

Hur WM, Kim H, Woo J (2014) How CSR leads to corporate brand equity: mediating mechanisms of corporate brand credibility and reputation. J Bus Ethics 125(1):75–86

Hyysalo S, Johnson M, Juntunen JK (2017) The diffusion of consumer innovation in sustainable energy technologies. J Clean Prod 162:S70–S82

IEA (2017) Key World Energy Statistics. IEA, Paris

Insightrix Research Inc. (2011) IPAC CO_2 Research Inc. Public awareness and acceptance of carbon capture and storage in Canada. Saskatchewan, Canada

Karytsas S, Theodoropoulou H (2014a) Public awareness and willingness to adopt ground source heat pumps for domestic heating and cooling. Renew Sustain Energy Rev 34:49–57

Karytsas S, Theodoropoulou H (2014b) Socioeconomic and demographic factors that influence publics' awareness on the different forms of renewable energy sources. Renew Energy 71: 480–485

Kubota H, Hondo H, Hienuki S, Kaieda H (2013) Determining barriers to developing geothermal power generation in Japan: societal acceptance by stakeholders involved in hot springs. Energy Policy 61:1079–1087

Matten D, Moon J (2008) 'Implicit' and 'explicit' CSR: a conceptual framework for a comparative understanding of corporate social responsibility. Acad Manag Rev 33:404–424

Moncrieff L (2015) Karl Polanyi and the problem of corporate social responsibility. J Law Soc 42 (3):434–459

Morgan RM, Hunt SD (1994) The commitment-trust theory of relationship marketing. J Market 58 (3):20–38

Nolan JM, Schultz PW, Cialdini RB, Goldstein NJ, Griskevicius V (2008) Normative social influence is under detected. Pers Soc Psychol Bull 34(7):913–923

Pellizzone A, Allansdottir A, De Franco R, Muttoni G, Manzella A (2017) Geothermal energy and the public: a case study on deliberative citizens' engagement in central Italy. Energy Policy 101:561–570

PWC (2016) Redefining business success in a changing world—CEO survey. PwC

Rizzi F, Frey M (2014) Sustainable co–evolution of environmental regulation and oligopolies: moving towards a managerial theory of meta–organisational approaches. Int J Innov Sustain Dev 8(3):270–289

Ruggie J (2008) Taking embedded liberalism global: the corporate connection. In: Ruggie J (ed) Embedding Global Markets: an Enduring Challenge. Ashgate Publishing Limited, Hampshire, pp 231–254

Sachs S, Rühli E (2011) Stakeholders matter—a new paradigm for strategy in society. Cambridge University Press, Cambridge

Scherer AG, Palazzo G (2011) The new political role of business in a globalized world: a review of a new perspective on CSR and its implications for the firm, governance and democracy. J Manag Stud 48:899–931

Sidhoum AA, Serra T (2017) Corporate social responsibility and dimensions of performance: an application to US electric utilities. Util Policy 48:1–11

Suchman MC (1995) Managing legitimacy: strategic and institutional approaches. Acad Manag Rev 20(3):571–610

Swaen V, Chumpitaz RC (2008) Impact of corporate social responsibility on consumer trust. Recherche Appl Market (Engl Ed) 23(4):7–34

UN (2016) UN Climate Change—Paris Agreement. Retrieved from UN framework convention on climate change. Available at: http://newsroom.unfccc.int/paris-agreement/175-states-sign-paris-agreement/

Utting P (2005) Rethinking business regulation: from self-regulation to social control (No 15). Technology, Business and Society, Geneva

Van Der Schoor T, Scholtens B (2015) Power to the people: local community initiatives and the transition to sustainable energy. Renew Sustain Energy Rev 43:666–675

Witzling L, Shaw B, Amato MS (2015) Incorporating information exposure into a theory of planned behavior model to enrich understanding of pro-environmental behavior. Sci Commun 37(5):551–574

Yun S, Lee J (2015) Advancing societal readiness toward renewable energy system adoption with a socio-technical perspective. Technol Forecast Soc Change 95:170–181

Michele Contini (Ph.D. student, Sant'Anna School of Advanced Studies) is a Ph.D. student at the International Ph.D. in Management, Innovation, Sustainable and Health Care at Sant'Anna School of Advanced Studies, Institute of Management, Pisa, Italy. He is working within the Sustainability curriculum and his research interests focus on marketing and communication, corporate social responsibility, stakeholder engagement and social acceptance, with specific emphasis on the energy sector.

Eleonora Annunziata (Ph.D., Sant'Anna School of Advanced Studies) is a postdoctoral research fellow at Sant'Anna School of Advanced Studies, Institute of Management, Pisa, Italy. Her research interests focus on corporate sustainability, sustainable supply chain, stakeholder

engagement and social acceptance, with particular regard to energy sector. Her studies have been published in such journals as *Business Strategy and the Environment, Organization and Environment, Journal of Cleaner Production, Energy Policy*, and *Energy*.

Francesco Rizzi is associate professor in Management at University of Perugia—Department of Economics, Affiliated Professor at Sant'Anna School of Advanced Studies—Institute of Management and Visiting Researcher at Trinity College Dublin—Trinity Haus. His research interests include sustainable entrepreneurship and the organisational responses to improving the triple bottom line. His articles have appeared, among various journals including *Business Strategy and the Environment, Journal of Cleaner Production, European Management Journal, Futures, Renewable Energy, Energy Policy*.

Marco Frey is full professor of Economics and Business Management and director of the Institute of Management of Sant'Anna School of Advanced Studies. He is research director at IEFE (Centre for Research on Energy and Environmental Economics and Policy—Bocconi University, Milan) and Chairman of Global Compact Network Italy Foundation. His articles have appeared in such journals as *Business Strategy and the Environment, Corporate Social Responsibility and Environmental Management, and European Management Journal, Journal of Cleaner Production*.

Geothermal Energy and Public Engagement

Agnes Allansdottir, Anna Pellizzone and Alessandro Sciullo

Abstract The basic premise of this volume is that the role of society is crucial in shaping the future path of developments in the geothermal sector. This chapter discusses some of the ways in which the science and technology in this field might be aligned with societal values and needs on a path for a sustainable transition towards a low carbon energy future. This is done by briefly presenting potential conceptual frameworks for analysing the societal transition and by discussing some of the tools for public engagement. The chapter is divided into three sections and begins with comparing the concept of Corporate Social Responsibility (CSR), prominent within the literature on business studies and management, with a recent approach termed Responsible Research and Innovation (RRI), of particular relevance for this volume because of the emphasis placed on societal involvement and public engagement in processes of innovation. The second section draws upon literature from social science and socio technical systems to discuss conceptual frameworks for public engagement and citizens' participation as increasingly important element in innovation processes in the energy sector. The third section discusses the diverse tools for public engagement that are currently available for public engagement and citizens' participation processes.

Keywords Responsible innovation · Public engagement · Citizens' participation

A. Allansdottir (✉)
Fondazione Toscana Life Sciences, Via Fiorentina 1, 53100 Siena, Italy
e-mail: a.allansdottir@toscanalifesciences.org

A. Pellizzone
National Research Council, Institute of Geosciences and Earth Resources,
Via Moruzzi 1, 56124 Pisa, Italy

A. Sciullo
Department of Culture, Politics and Society, University of Torino,
Lungo Dora Siena 100/A, 10153 Turin, Italy

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_4

1 Approaches to Responsible Innovation and Society

The aim of this chapter is to briefly outline approaches and social scientific conceptual frameworks as aids to further understanding of the relationship between geothermal energy and societies and to give first steps of guidance for the interpretation of the richness of the material presented in the 11 country profile case studies that follow in the next section of this volume. These are all unique contributions to the emerging field of reflections upon and research on the relationship between geothermal energy and society. Together they make up a new and an innovative corpus of material in this field. Further, the authors come from a wide range of disciplines and approaches, apart from the more notable quality of coming from differing parts of the globe and very diverse cultural and political milieus. As these profiles were solicited from experts ex post, the contributions could not possibly follow a unified conceptual or methodological approach. Rather, these studies represent a patch work vision of what is being done in this field internationally and as such they are a source of learning and inspiration for the future.

As the socio-political pressure towards designing a sustainable future increases, in particular the transition towards a common global low carbon future, it has become evident that the role and the potential contributions of the social sciences have been somewhat neglected in energy studies (Pidgeon et al. 2014; Sovacool 2014; Stirling 2014). The immense societal complexity of the energy transition, in this case geothermal, with shifting constellations of actors and stakeholders necessitates insights and expertise from a broad range of disciplines, from the earth sciences and engineering to economics and social sciences. The social sciences can provide insights on societal questions just as earth sciences and engineering offer on more technical and scientific issues (Minsch et al. 2012).

Oftentimes, the role of the social sciences in energy studies has first and foremost been that of ensuring that techno-economic perspectives prevail by aiding market uptake and ensuring social acceptance (Goldblatt et al. 2012). Indeed much of the social scientific literature on energy and societies originates in studies on management of innovation from the point of view of industry or engineering. In the Chapter "Business Strategies in Geothermal Energy Market: A Citizens-Based Perspective" Michele Contini and colleagues presented the concept of *Corporate Social Responsibility* (CSR) and discussed the different issues such as information and trust that arise in the harnessing both deep and shallow energy resources, from the point of view of energy companies and the ramifications for the business models they apply. By definition, CSR tends to be articulated as corporate strategies driven by industry with the primary mandate of catering to the interests of the *shareholders*, but as Contini and colleagues point out, the concept also includes catering to the interests and perspectives of all *stakeholders*. In recent years, the attention is increasing turning towards business models that aim to foster social legitimacy amongst stakeholders (Sachs and Rühli 2011).

For over a decade now, experts from around the globe have been working on fresh approaches to innovation in order to better align innovation processes with the needs and values of societies or local communities in a rapidly changing world (Ostrom 2010; Jasanoff 2005). This tendency goes hand in hand with growing awareness of environmental concerns and more broadly issues regarding ethics and fairness—in light of "the struggle to govern the commons" (Dietz et al. 2003). This is also exemplified in the growing demand for deliberative democracy that has swept the world in recent years (Fishkin 2011; Thompson 2008). Innovation, science and technology "overflow" and incessantly push back the boundaries of the current scientific and normative institutional frameworks and require "new hybrid forums" for complex, democratic and enriched discussion on innovation (Callon et al. 2009).

Amongst these contemporary approaches, "*Responsible Research and Innovation*" (RRI) as for example clearly articulated by the European Commission and other public authorities has become rather prominent in recent years. It is an attempt to include wider society, beyond shareholders and immediate stakeholders, in technology and innovation processes with the aim of tackling great societal challenges—such as the transition to low carbon society. The most widely used definition of RRI is: "*Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)*" (von Schomberg 2013, p. 19).

The RRI approach is an attempt to forge new and inclusive synergies between science, technology and society, encouraging "upstream" engagement (Jasanoff 2007) of all relevant stakeholders. Upstream engagement implies that efforts should be made to ensure that society becomes a partner in co-constructing the path of innovation from the initial planning stages and throughout developments as opposed to seeking public approval and social acceptance only in the final phases of developments. There are at least four key dimension to RRI, anticipation, inclusion, reflexivity, and responsiveness (Stilgoe et al. 2013). For the purposes of this chapter on geothermal energy and society, those dimensions can be articulated and simplified as: to attempt to anticipate what the future will hold in terms of promises and perils; to include wider society through citizens' participation and public engagement and a range of outreach activities; to be reflexive in the sense of taking all perspectives into account as opposed to merely imposing a predefined agenda in public deliberations and activities; to be responsive in the sense of integrating the outcomes of activities in shaping the direction of innovation (see also Owen et al. 2012).

2 Conceptualising the Relationship Between Geothermal Energy and Society

This section draws upon two diverse streams within the social science literature on energy and society. The first part is tilted towards the sociological side and presents three distinct models from the literature on socio technical systems. The second part tends more towards studies on science and society in general, and the energy sector in particular, from a more social psychological perspective where the emphasis of analysis shifts towards the views of general public and communities.

In any case, there is a certain tendency in studies on innovation and society, the energy transition included, to regard society as an obstacle in the path of smooth innovation, as hurdles that need to be overcome and that is when or why the social science is called upon to come to the rescue. That further rests upon a tacit assumption that only opposition to innovation and development is a worthy object for social scientific research (Pellizzone et al. 2017). Unbridled enthusiasm for new technology is at least an equally important topic for social research as the current upheaval over highly popular social media network and the use of data freely handed over by participants clearly underlines. There is always an ongoing tension between the technology push, where stakeholders that are usually more powerful gather resources to further their agendas and the pull that comes from those who demand the new technology (von Schomberg 2013). Some fields of innovation seem to blend seamlessly into the fabric of society while others become highly contentious and politicised issues and evolve into intractable problems. Millions have handed over very personal and often sensitive information and data about the intimate details of their lives to big commercial companies without a thought, but people have gone out and marched the streets protesting genetically modified organisms (GMOs).

What has that to do with geothermal energy? The short answer is that, in comparison with some other and better known renewable energy technologies such as wind and solar, geothermal energy is much less known and in some cases perceived as shrouded in uncertainty (i.e. Pellizzone et al. 2015) but not rejected as is the case for nuclear energy (Pellizzone et al. 2017). In comparison with other renewables, geothermal energy could possibly fit the description of technologies with controversy potential (Torgersen and Hampel 2012). The future will tell but it is this very uncertainty over geothermal energy resources that makes for an intriguing social scientific study. Further, emerging technologies and major societal transitions, for example towards a low carbon future, tend to have high intrinsic levels of uncertainty and underlines the need for a reasoned public dialogue to avoid the perception of an unfair and technocratic decision making process far removed from the concerns of the citizens.

The term *socio technical systems* (STS) refers to an *ensemble* of technological and social components interacting in an environment in order to fulfill a specific objective (societal functions, Geels 2004) that could not be reached exclusively by the single technological or social component acting (Miller et al. 2015). Based on this definition, geothermal energy systems can be described as STS being a matter of innovation in technology, institutional and regulatory frameworks, market strategies, organizational settings and collective and individual behaviours (Padovan and Arrobbio 2017). Here three different models of STS are briefly discussed.

The *Multi-Level Perspective* model (Geels 2004, 2010) regard STS transitions as the result of the linkage of developments at three levels: *micro-level* (or niches-of-innovation), *meso-level* (the socio-technical regime intended as the *assemblage* of actors, networks and rules), *macro-level* (the socio-technical landscape intended as exogenous environment of cultural, economic and political patterns).

A second model (Walker and Cass 2007) is based on the continuous interaction and mutual shaping between technical and social component and on the vision of technologies as "…configurations of the social and technical which have emerged contingently in particular contexts and which mirror wider social, economic and technical relations and processes". In the model, the *hardware* is intended to be socially constructed in the sense that it is not mere technical stuff, but a material and organizational technology aimed at providing a function/service. The *software* is the "…social and infrastructural organization through which hardwares are utilized and given purpose and meanings". Alternative organizations and different STS resulting from different assemblages of *hardware* and *software* components are always possible.

The *reflexive governance* model (Smith and Stirling 2007) conceptualises the combination of two mutually constituting processes. On the one hand, the 'epistemic' process of *social appraisal,* or the definition of actors' 'ways of knowing' the STS itself that may result in more or less differentiated or shared perspective on the techno-scientific objects; the 'ontological' process of *social commitment,* or the definition of actors' 'ways of being' in relation to the STS that is their position and relationships on the other hand. The coevolving relationship between appraisal/commitment processes defines a model of governance that result from the wrestling between two ideal-types: the *governance on the outside* aimed at acting upon STS by instrumental and managerial tasks and the *governance on the inside* intended as a process of conditioning and being conditioned by the techno-scientific object itself (i.e. reflexive).

The models described above differ in their conceptualization of the STSs' components and dynamics but have in common the relevance assigned to the alignment and co-evolution among different parts of the systems. Although these models are valuable conceptual tools and shine a light on the complexities of co-evolving systems, for example the societal transition towards a low carbon future, they do not give priority to citizens' participation and public engagement processes.

In a recent article, Patrick Devine-Right and colleagues proposed a novel conceptual framework for understanding the social acceptance of energy infrastructure (Devine-Wright et al. 2017). The authors aim to build upon and further refine the by now classic model of social acceptance of renewable energy (Wüstenhagen et al. 2007; Wüstenhagen and Menichetti 2012) by adding a more social psychological perspective that "focuses upon the role of belief systems held by diverse social actors (e.g. policy makers, journalists, community leaders)" and "cannot be understood without also taking existing political, economic, socio-cultural and geographical factors into account". Although this framework is being developed in the emerging issues surrounding the future of energy storage it appears to be rather fitting for the issue of geothermal energy as well.

Their interdisciplinary approach draws upon on the theory of social representations that are conceptualised as systems of beliefs and processes of communication in society. The theory of social representations has been highly influential in contemporary social psychology where it originated in studies on how science, technology and innovation become a part of society or not, as the case might be. Thus the theory is particularly well suited as a framework for the analysis of technological change and the role of society in innovation processes and has been applied in studies on a range of techno scientific issues (Gaskell et al. 2015).

In this context it is worth raising two important points, or insights, that stem from years of social psychological research. On the one hand the balance between perceptions of risks and benefits and on the other hand the issue of trust. Research from a social psychological perspective, across diverse domains and situations of high level of uncertainty, indicates that the old adage "better the devil you know" tends to hold true. Although a gross simplification, that is the essence of the elegant Prospect Theory that perception of risk carry a greater weight than equally likely benefits (Tversky and Kahnemann 1992; Kahnemann 2011). In other words, when the potential benefits of innovation are less salient than the potential risk perceived the developments in question are less likely to be supported. Further, trust is a potent force in the relationship between society and innovation. Trust is conceptualised as being constituted by two different elements: *confidence* that is related to perceived competence, for example directed at actors in the energy transition, and *social trust* that relates to values share with those actors (Greenberg 2014).

3 Tools for Public Engagement

Almost 15 years ago, Alan I. Leshner the CEO of the American Association for the Advancement of Science (AAAS) and editor of the journal Science wrote "*We need to engage the public in a more open and honest bidirectional dialogue about science and technology and their products, including not only their benefits but also their limits, perils, and pitfalls. We need to respect the public's perspective and concerns even when we do not fully share them, and we need to develop a partnership that can respond to them*" (Leshner 2003, p. 977). These words were both prophetic and emblematic for the zeitgeist at the beginning of a new millennium when a new consensual societal pact on research, innovation and technological progress was firmly on the horizon. Such a clear framing of the science–society relation in terms of a bi-directional dialogue inevitable brought with it new sets of concerns and perplexities as further efforts were needed to clarify what the mechanisms of public engagement were actually meant to achieve (Hagendijk and Irwin 2006; Wilsdon and Willis 2004).

Research on the relationship between society and science, technology and innovation has gone through successive stages over the last decades (Bauer et al. 2007). Each stage has been characterised by a preferred conceptual and methodological approach. The research agenda has moved from the early days of science literacy, with emphasis on public education, grounded in the assumption that if unruly publics would just be given accurate information as decided and defined by expert authorities technological progress would run smoothly in the right direction. That stage gave way to the growing interest in what public understanding of science and innovation might entail with the emphasis shifting from literacy to research on sets of attitudes. Finally, in recent years public participation and deliberative exercises have come to be considered the privileged approach (Owen et al. 2012; Stilgoe et al. 2013).

A concise, clear and highly influential overview of the tools and mechanisms of public engagement with controversial issues of innovation differentiated between three distinct types of activities and initiatives (Rowe and Frewer 2005). Initiatives were differentiated in terms of the flow of information between participants and sponsors organising the initiatives or activities. First, *public communication* where the sponsor is the sources of information that is then given to the participating public. Second, *public consultation*, where information is gathered from the public and conveyed to the sponsors, although no real dialogue takes place between the parties. Third, *public participation*, where exchange of information takes place between the sponsors and the participating public. This typology only applies to the flow of information between previously defined actors, sponsors versus participating public, within the setting of the engagement activities and does really cover what happens once the initiatives are concluded. In other words, how the eventual outcomes might impact decision making processes in the field under consideration. However, the normative framework that later grew out of this work was validated and put to the test in the context of the "GM nation initiative" commissioned by the UK government with the aim of gauging public opinion on genetically modified crops ahead of major policy decision making (Rowe et al. 2008).

The literature on public engagement is rapidly growing as recent years have seen a proliferation of initiatives and activities. However, consensus has not yet been reached on which approach is the most appropriate, or effective for that matter, and researchers have to make informed and reasoned choices about the approach to be applied in particular research setting on how a given public and stakeholders engage with innovation and development.

Public engagement and deliberation exercises differ widely on a number of dimensions, for example in their geographical scope. Most initiative that concern the energy transition and the environment have taken place in somewhat restricted areas dealing with localised issues and concerns of local communities (Dietz 2013) and that holds true for many of the case studies presented in the national country profile in the next section of this volume. In contrast, a recent research project designed and carried out a national citizens' engagement exercises on the future energy policy of the UK (Pidgeon et al. 2014).

All forms of public engagement activities and deliberation exercises can draw up on the rich toolkit of social science research (Bickman and Rog 2009; Denzin and Lincoln 2011). Such tools range from large scale cross national surveys (conducted face to face, by telephone or online panels) that are particularly useful when the research interest is on mapping the prevalence of given sets of views and beliefs across social groups and countries. The data obtained in this way easily lend themselves to quantification and statistical analysis. On the other end of the spectrum of social scientific tools are those that give a much more nuanced picture of the views and perspective of different actors, such as in depth interviews with members of the public, local groups and stakeholders. Interviews can be conducted individually or discussions can be carried out in groups, using the "focus group" methodology. In any case, the analysis can be both quantitative or qualitative, depending on the aims and scope of the analysis. Other tools include systematic media analysis and analysis of documents produced by diverse actors and stakeholder, in all cases the researcher has a choice to make between quantitative and qualitative approaches to the analysis.

4 Conclusions

This chapter has given a short overview of some of the main approaches to the issues surrounding geothermal energy and society. It has briefly outlined influential approaches to innovation in the field of energy and society by comparing and contrasting Corporate Social Responsibility (CSR) with Responsible Innovation or Responsible Research and Innovation. This was done by contextualising these approaches to innovation in wider socio political change such as the emerging concerns over environment, justice and ethics and the move towards experimenting with deliberative democracy in political decision making processes more in general. The second section of the chapter presented conceptual frameworks to social scientific research on energy and society by moving from a sociological take on socio technical systems to more social psychology approaches and some key concept embedded within them. The third section presented some selected tools to be used and efforts that have been made to design and conduct public engagement exercises.

Public engagement in the energy transition is very much work in progress as the conceptual frameworks and actual methodological guidelines are still under construction. That said, public engagement and citizens' participation has gained a new momentum in mainstream political discourse across the globe in recent years and will therefore play an increasingly important part in decision making processes in the transition towards renewable energy, such as the responsible harnessing of geothermal resources. A recent book by an influential scholar carried an unusual title: "Are we all scientific experts now?" (Collins 2014). Of course not, but including a variety of views in determining a sustainable path for the future can only strengthen policy making processes surrounding innovation.

Acknowledgements The corresponding author acknowledges the NERRI project funded by the European Commission (GA No. 321464) on Responsible Research and Innovation, public engagement and mobilisation and mutual learning activities.

References

Bauer MW, Allum N, Miller S (2007) What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda. Public Underst. Sci. 16:79–95

Bickman L, Rog DJ (eds) (2009) The SAGE handbook of applied social research methods. SAGE Publications, Thousand Oaks

Callon M, Lascoumes P, Barthe Y (2009) Acting in an uncertain World: an essay on technical democracy. MIT Press, Cambridge

Collins H (2014) Are we all scientific experts now? Polity Press, Cambridge

Denzin NK, Lincoln YS (eds) (2011) The SAGE hand book of qualitative research, 4th edn. SAGE Publications, Thousand Oaks

Devine-Wright P, Batel S, Aas O, Sovacool B, LaBelle MC, Ruud A (2017) A conceptual framework for understanding the social acceptance of energy infrastructure: insight from energy storage. Energy Policy 107:27–31

Dietz T (2013) Bringing values and deliberation to science communication. Proc Natl Acad Sci U S A 110:14081–14087

Dietz T, Ostrom E, Stern PC (2003) The struggle to govern the commons. Science 302:1907–1912

Fishkin JS (2011) When the people speak: deliberative democracy and public consultation. Oxford University Press, Oxford

Gaskell G, Valsiner J, Sammut G, Andreouli E (eds) (2015) Handbook on social representations. Cambridge University Press, Cambridge

Geels FW (2004) From sectoral systems of innovation to socio-technical systems. Insights about dynamics and change from sociology and institutional theory. Res Policy 33:897–920

Geels F (2010) Ontologies, socio-technical transition (to sustainability) and the multi-level perspective. Res Policy 39:495–510

Goldblatt DL, Minsch J, Flüeler T, Spreng D (2012) Introduction. In: Spreng D, Flüeler T, Goldblatt D, Minsch J (eds) Tackling long-term global energy problems. Environment & Policy, 52. Springer, Dordrecht

Greenberg M (2014) Energy policy and research: the under appreciation of trust. Energy Res Soc Sci 1:152–160

Hagendijk R, Irwin A (2006) Public deliberation and governance: engaging with science and technology in contemporary Europe. Minerva 44:167–184

Jasanoff S (2005) Designs on nature: Science and democracy in Europe and the United States. Princeton University Press, Princeton

Jasanoff S (2007) Technologies of humility. Nature 450:33

Kahnemann D (2011) Thinking, fast and slow. Macmillan, UK

Leshner AI (2003) Public engagement with science. Science 299(5609):977

Miller CA, Clark A, Richter J, O'Leary J (2015) Socio-energy systems design: a policy framework for energy transitions. Energy Res Soc Sci 6:29–40

Minsch J, Goldblatt DL, Flüeler T, Spreng D (2012) The indispensable role of social Science in energy research. In: Spreng D, Flüeler T, Goldblatt D, Minsch J (eds) Tackling long-term global energy problems. Environment & Policy. Springer, Dordrecht

Ostrom E (2010) Polycentric systems for coping with collective action and global environmental change. Glob Environ Change 20:550–557

Owen R, Macnaghten P, Stilgoe J (2012) Responsible research and innovation: from science in society to science for society, with society. Scie Public Policy 39:751–760

Padovan D, Arrobbio O (2017) Making energy grids smart. The transition of sociotechnical apparatuses towards a new Ontology. In: Labanca N (ed) Complex systems and social practices in energy transitions. Green Energy and Technology. Springer, Cham

Pellizzone A, Allansdottir A, De Franco R, Muttoni G, Manzella A (2015) Exploring public engagement with geothermal energy in southern Italy: a case study. Energy Policy 85:1–11

Pellizzone A, Allansdottir A, De Franco R, Muttoni G, Manzella A (2017) Geothermal energy and the public: a case study on deliberative citizens' engagement in central Italy. Energy Policy 101:561–570

Pidgeon N, Demski C, Butler C, Parkhill K, Spence A (2014) Creating a national citizen engagement process for energy policy. Proc Natl Acad Sci U S A 111:13606–13613

Rowe G, Frewer LJ (2005) Atypology of public engagement mechanisms. Sci Technol Human Values 30:251–290

Rowe G, Horlick-Jones T, Walls J, Poortinga W, Pidgeon NF (2008) Analysis of a normative framework for evaluating public engagement exercises: reliability, validity and limitations. Public Understand Sci 17:419–441

Sachs S, Rühli E (2011) Stakeholders matter—a new paradigm for strategy in society. Cambridge University Press, Cambridge

Smith A, Stirling A (2007) Moving outside or inside? Objectification and reflexivity in the governance of socio-technical systems. J Environ Planning Policy Manage 9:351–753

Sovacool BJ (2014) Energy studies need social science. Nature 511:529–530

Stilgoe J, Owen R, Macnaghten P (2013) Developing a framework for responsible innovation. Res Policy 42:1568–1580

Stirling A (2014) Transforming power: social science and the politics of energy choices. Energy Res Soc Sci 1:83–95

Thompson DF (2008) Deliberative democratic theory and empirical political Science. Annu Rev Polit Sci 11:497–520

Torgersen H, Hampel J (2012) Calling controversy: assessing synthetic biology's conflict potential. Public Underst Sci 21:134–148

Tversky A, Kahneman DJ (1992) Advances in prospect theory: cumulative representation of uncertainty. J Risk Uncertainty 5:297

von Schomberg R (2013) A vision of responsible research and innovation. In: Owen R, Bessant R, Heintz M (eds) Responsible innovation. Managing the responsible emergence of science and innovation in society. Wiley, Chichester, pp 51–74

Walker G, Cass N (2007) Carbon reduction, 'the public' and renewable energy: engaging with socio-technical configurations. Area 39:458–469

Wilsdon J, Willis R (2004) See-through science: why public engagement needs to move upstream. Demos, London, pp 1–69

Wüstenhagen R, Menichetti E (2012) Strategic choices for renewable energy investment: conceptual framework and opportunities for further research. Energy Policy 40:1–10

Wüstenhagen R, Wolsink M, Bürer MJ (2007) Social acceptance of renewable energy innovation: an introduction to the concept. Energy Policy 35:2683–2691

Agnes Allansdottir is a social psychologist researcher who studied at the London School of Economics and Political Science. She has extensive experience of empirical research on societal dialogues on science and technology. From 1996 she lectured on psychology of communication, science communication, bioethics and science in society at the University of Siena. She has been a principal investigator on a series of EC funded international research projects on life sciences and society, climate change, public engagement, ethically sensitive technologies and public ethics. She has repeatedly given advice to international and national policy making bodies and has presented and published widely in high-level international journals, including Nature, Nature Biotechnology, Plos One, PNAS and Energy Policy.

Anna Pellizzone is a science writer and researcher. In 2017 she got a scholarship at the Italian National Research Council, Institute of Geosciences and Earth Resources. Natural scientist, she holds a master in Science Communication and a PhD in Earth Sciences, obtained with a thesis on the social aspects of geothermal technologies in collaboration with the Italian National Research Council. Since 2012 she has been conducting research activities for the CNR and has participated in several projects (VIGOR, ATLANTE, GEOELEC, ETIP-DG) on geothermal energy, with contributions aimed at deepening the relationship between innovation, research and society. Her research interests are focused on Responsible Research and Innovation (RRI) and she is author of several academic papers related to public engagement with geothermal energy. Since 2010 she has been writing also for generalist newspapers, magazines and websites and since 2016 Anna has been collaborating with Fondazione Bassetti on the SMART-map project (projectsmartmap.eu) and with Fondazione Eni Enrico Mattei.

Alessandro Sciullo post doc research fellow, University of Torino, Department of Culture, Politics andSociety. Alessandro graduated in political science at University of Torino. He received a master in Public Policy Analysis and completed his PhD in Sociology at the same institution. After a decade spent in providing consultingfor organizational improvement in public administration, Alessandro joined in 2009 the Institute of Socio-economic Research of Piemonte regione (Ires Piemonte) where he mainly focused his research on diffusionof ICTs innovation and their impact on local development. From 2011 Alessandro have been doing researchon topics related with sustainable development and energy transition at department of Culture, Politics andSociety of University of Torino.

Drawing the Picture: Public Engagement Experiences as Tools Towards an Emerging Framework

Anna Pellizzone and Agnes Allansdottir

Abstract This chapter is a bridge between the two first sections of the book and it introduces the readers to the core of this volume, that is the collection of eleven case studies on public engagement with geothermal energy around the globe (i.e. Australia, Canada, Greece, France, Japan, Iceland, Italy, New Zealand, Philippines, Switzerland and Turkey). These studies are excellent examples of activities and research carried out across the world but the collection is not to be considered exhaustive. Evidently there are other participatory experiences in the field of geothermal energy that have been conducted and an overview of references is included in the chapter. The studies on the societal aspects of geothermal energy have significantly increased in the last years, however the development of a comprehensive framework is becoming urgent. We consider this collection of case studies as a first step towards the construction of a novel and comprehensive framework on public engagement with geothermal energy in both local and international contexts.

Keywords Comparative case studies · Public engagement · Participation

When Gustav Klimt in 1887 was asked by the Wien Municipality to represent the Burgtheater, a very important theatre at the heart of the Austria, the artist decided to draw its attention to the public. Instead of portraying the stage, or the prestigious structure of the building, he opted to represent the people and "The Old Burgtheater" (1888–1889) became one of the most famous paintings of his career. The story might look off-topic, but it helps us introduce the next part of the book, which is composed by a collection of case studies on citizen engagement with geothermal energy in different countries from all around the globe. The section

A. Pellizzone (✉)
National Research Council, Institute of Geosciences and Earth Resources, Via Moruzzi 1, 56124 Pisa, Italy
e-mail: anna.pellizzone@igg.cnr.it

A. Allansdottir
Fondazione Toscana Life Sciences, Via Fiorentina 1, 53100 Siena, Italy

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_5

describes the geothermal landscape and the legal framework with particular attention being devoted to the involvement of the public and civil society.

The case studies gathered in the next unit regard different regions of the globe: Oceania (Australia and New Zealand), East and South East Asia (Japan and Philippines), Europe (Greece, France, Iceland, Italy and Switzerland), Middle East (Turkey) and North America (Canada). Of course many other experiences could have been included in the book, as the studies focusing on geothermal energy and society are rapidly growing worldwide. Stakeholders' engagement exercises and research projects including societal issues are flourishing in many other countries: in Germany (Meller et al. 2017), in Mexico (Martínez-Gomez et al. 2017), in Colombia, Peru and Ecuador (Prieto et al. 2016), in Chile (Vargas Payera 2018), in Kenya (Mwanghi-Gachau 2011), in Papua Nuova Guinea (Chrisp 2015), in Vanuatu (Daysh et al. 2015), just to mention a few, however it is important to note that social studies and humanities are still rather marginalized in energy research. Although social studies are considered a pillar for energy research and innovation by an increasing number of scholars, all too often the energy debate is limited to the domains of technology development and economics (Sovacool et al. 2016) and citizens' role in the discussion needs to be further discussed and consolidated. Issues such as social justice, ethical concerns and democratic participation are rarely included in the energy policy and technology discussion and a systematic public consultation in the field of renewables development is still work in progress even if some innovative initiatives are emerging (Chilvers et al. 2017).

On the one hand, the goal of our collection of case studies from a very broad geographical area is to provide the reader with current research in the field of geothermal energy and society in diverse countries. The assessment of public expectations and concerns is even more interesting from a comparative perspective, since past experiences, key values and questions concerning energy development—such as accessibility, affordability, transparency, sustainability, inter-generational and intra-generational equity, social justice—can be play out differently across locations and cultures. Furthermore, comparative information on local regulatory frameworks or local engagement exercises provide us with very useful examples for the development of effective tools for improving socially sustainable innovation process of geothermal energy technology. In this respect, we hope that the following compendium can be a source of inspiration for researchers and students from difference disciplines as well as for policy makers working in the energy and innovation field. We consider the field of geothermal energy a very interesting case study for the investigation of current policies and approaches to public engagement on account of the dual nature of geothermal resources. On one extreme of the continuum we have a centralized production of electricity, where citizens mainly have the role of consumers—also known as *hard energy path*—that in the case of geothermal at times raises societal controversies regarding land management and risks, e.g. water contamination, induced seismicity and air pollution. On the other extreme, we have a distributed system of geothermal heat pump—a *soft energy path*—where citizens play the emerging role of *prosumers*, i.e. agents that both produce and consume, opening up new opportunities, but also bringing unknowns roles and ethical issues that still need to be understood. Between these two ideal paths, there is a large span of technologies for heating and cooling applications that are opening to a series of new potential social scenarios. As Adele Manzella described in the first chapter of this book, different applications require extremely different technologies, and different technologies—as you will see in the next section—provoke very different public reactions and require completely different approach to governance as outline in the chapter on regulation by Philippe Dumas in Chapter "Policy and Regulatory Aspects of Geothermal Energy: A European Perspective". Further, the two different fields of application bring with them diverse business models as outlined in the Chapter "Business Strategies in Geothermal Energy Market: A Citizens-Based Perspective" by Michele Contini and his colleagues. Future challenges in the field of geothermal energy will increasingly depend upon social sustainability, meaning that development need to be aligned with the views, values and needs of society and local communities and various forms of stakeholder and societal engagement exercises and practices discussed in Chapter "Geothermal Energy and Public Engagement" on citizens' engagement by Agnes Allansdottir and colleagues. In short, the following chapters make up a series of national case studies on geothermal developments and society that necessarily stimulates a reflection on a broad range of issues related to innovation processes. The energy resource is the same, as it comes from the natural heat of the Earth, but the implications for the society are complex and diverse.

On the other hand, our tentative purpose is to go one step further than collecting different experiences. Drawing upon the following case studies, we aim to identifying a series of emerging issues, and to contribute to the development of a comprehensive approach to the study of geothermal energy and society with a focus on public engagement. Major evidence emerging from the following chapters is the fragmentation of energy and society research considering both the conceptual and the methodological frameworks. Socio-Technical Systems, Social Innovation, Technology Assessment, Responsible Research and Innovation, Corporate Social Responsibility are just few examples of difference conceptual approach that are currently applied to geothermal energy and society studies. The same goes for the wide extent of different methods of public engagement applied within this energy sector. Focus groups, media analyses, surveys, workshops, just to mention a few, are used in the following case studies.

In order to contribute to the development of a comprehensive approach to research and innovation in the field of geothermal energy and society and in order to build a common ground for developing a set of best practices towards the energy transition, we propose to start our reflection from the following case studies, all of them quite recent, and give voice to citizen expectations, needs and concerns by adopting different approaches. If Klimt was a geothermal expert of our time, he might have been very interested in the next chapters.

Acknowledgements The authors would like to express a particular thanks to Francesco Samorè, Angela Simone and the Giannino Bassetti Foundation team for their precious suggestions and the many opportunities to reflect upon public engagement with science and innovation.

References

Chilvers J, Pallett H, Hargreaves T (2017) Public engagement with energy: broadening evidence, policy and practice. UK Energy Research Centre, London

Chrisp M (2015) Development of a geothermal resource policy for Papua Nuova Guinea. In: Proceedings of the 37th New Zealand Geothermal Workshop, Taupo, 18–20 Nov 2015. https://www.geothermal-energy.org/pdf/IGAstandard/NZGW/2015/43_Chrisp.pdf. Accessed 30 March 2018

Daysh S, White B, Tari T, McPherson K (2015) Effective environmental decision making in the Pacific—Takara geothermal project, Efate, Vanuatu. In: Proceedings 37th New Zealand Geothermal Workshop, Taupo, 18–20 Nov 2015. https://www.geothermal-energy.org/pdf/IGAstandard/NZGW/2015/68_Daysh.pdf. Accessed 30 Mar 2018

Martínez-Gomez J, Peña-Lamas J, Martín M, Ponce-Ortega JM (2017) A multi-objective optimization approach for the selection of working fluids of geothermal facilities: economic, environmental and social aspects. J Environ Manage 203(3):962–972

Meller C, Schillb E, Bremer J, Kolditz O, Bleicher A, Benighaus C, Chavot P, Gross M, Pellizzone A, Renn O, Schilling F, Kohl T (2017) Acceptability of geothermal installations: a geoethical concept for GeoLaB. Geothermics 128(2):165–172

Mwanghi-Gachau E (2011) Social aspects of geothermal development—a case of Olkaria geothermal project in Kenya. Paper presented at short course VI on exploration for geothermal resources, UNU-GTP, GDC and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, 27 Oct–18 Nov. https://orkustofnun.is/gogn/unu-gtp-sc/UNU-GTP-SC-13-0806.pdf. Accessed 30 March 2018

Prieto A, van Campen B, Carvajal P, Moya Pinta D, Akamine (2016) Opening new frontiers for geothermal generation in Colombia, Peru and Ecuador: resource regulation & capacity building. In: Proceedings 38th New Zealand Geothermal Workshop, Auckland, New Zealand 23–25 Nov 2016. https://www.geothermal-energy.org/pdf/IGAstandard/NZGW/2016/068_VanCampen_Final.pdf. Accessed 30 Mar 2018

Sovacool BK, Heffron RJ, McCauley D, Goldthau A (2016) Energy decisions reframed as justice and ethical concerns. Nature Energy. https://doi.org/10.1038/nenergy.2016.24

Vargas Payera S (2018) Understanding social acceptance of geothermal energy: case study for Araucanía region, Chile. Geothermics 72:138–144

Anna Pellizzone is a science writer and researcher. In 2017 she got a scholarship at the Italian National Research Council, Institute of Geosciences and Earth Resources. Natural scientist, she holds a master in Science Communication and a PhD in Earth Sciences, obtained with a thesis on the social aspects of geothermal technologies in collaboration with the Italian National Research Council. Since 2012 she has been conducting research activities for the CNR and has participated in several projects (VIGOR, ATLANTE, GEOELEC, ETIP-DG) on geothermal energy, with contributions aimed at deepening the relationship between innovation, research and society. Her research interests are focused on Responsible Research and Innovation (RRI) and she is author of several academic papers related to public engagement with geothermal energy. Since 2010 she has been writing also for generalist newspapers, magazines and websites and since 2016 Anna has been collaborating with Fondazione Bassetti on the SMART-map project (projectsmartmap.eu) and with Fondazione Eni Enrico Mattei.

Agnes Allansdottir is a social psychologist researcher who studied at the London School of Economics and Political Science. She has extensive experience of empirical research on societal dialogues on science and technology. From 1996 she lectured on psychology of communication, science communication, bioethics and science in society at the University of Siena. She has been a principal investigator on a series of EC funded international research projects on life sciences and society, climate change, public engagement, ethically sensitive technologies and public ethics. She has repeatedly given advice to international and national policy making bodies and has presented and published widely in high-level international journals, including Nature, Nature Biotechnology, Plos One, PNAS and Energy Policy.

An Application of Social Science to Inform the Stakeholder Engagement of an Emerging Geothermal Industry in Australia

Simone Carr-Cornish, Lygia Romanach and Cameron Huddlestone-Holmes

Abstract At the peak of geothermal energy development in Australia, government policy suggested geothermal energy would be a greater part of Australia's energy supply. As the geothermal industry emerged, social scientists at Australia's national science agency conducted a series of studies to explore perceptions of this industry. This chapter outlines the history and potential of the geothermal resource in Australia, the rationale and main findings of three social science studies conducted and their implications for building the industry's capacity for stakeholder engagement. Specifically, the three studies identified: (1) the industry's perspective of its social licence; (2) the representation of the technology in the news media; and (3) community perceptions. While the Australian geothermal industry has stalled due to economic and technical challenges, the social science studies presented in this chapter offer relevant insights for other emerging geothermal or energy industries, globally.

Keywords Australia · Social science · Stakeholder engagement
Emerging industry · Stakeholder perception

1 The Geothermal Resource in Australia and Its Potential to Meet Energy Demand

The Australian continent is entirely within the Indo-Australian tectonic plate and as a result, does not have the convective heat flow regimes that typify the majority of geothermal provinces worldwide (Beardsmore et al. 2015). Rather, geothermal resources in Australia are generally considered to be conductive heat flow.

S. Carr-Cornish (✉) · L. Romanach
CSIRO, Ecosciences Precinct, 41 Boggo Road, Dutton Park 4102, Australia
e-mail: Simone.Carr-Cornish@csiro.au

C. Huddlestone-Holmes
CSIRO, Queensland Centre for Advanced Technology, 1 Technology Court, Pullenvale 4069, Australia

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_6

Three types of these resources have been targeted: (1) shallow, heat resources, typically, aquifers from 500 to 1500 m deep with high permeability at low to moderate temperatures; (2) deep, natural reservoirs of depths greater than 1500 m in highly permeable sedimentary or fractured aquifers; and (3) enhanced geothermal systems (EGS) which require stimulation to increase permeability (Huddlestone-Holmes 2014).

The actual size of the Australian geothermal resource is uncertain, as there is a lack of data about temperature and permeability at depth. Geoscience Australia estimates that the amount of heat in rocks less than 5 km deep but over 150 °C in temperature exceeds 1.9×10^{10} PJ (Budd et al. 2008). Total energy consumption in Australia in 2015–16 was 6066 PJ (Department of the Environment and Energy 2017). Coal and gas resources are Australia's primary sources of electricity generation, coal supplied 63% of electricity demand and gas supplied 20%. Coal and gas are also export commodities, exported at approximately 10 times that of domestic consumption. Renewables only supplied approximately 15% of electricity generation, comprising of hydro, wind, solar photovoltaic and bioenergy. Electricity supply (29%) and transport (27%) sectors, respectively accounted for just over a quarter of the energy consumption in Australia, followed by manufacturing (18%), mining (10%), the residential (8%) and commercial (6%) sectors. Despite the estimated geothermal resource well exceeding Australia's domestic energy demand, attempts to develop the resource beyond small scale initiatives have been unsuccessful, partly because of challenges to the economic feasibility and the available technical capacity (Grafton et al. 2014).

1.1 The Emergence of a Geothermal Energy Industry in Australia

Prior to the mid-90s, commercial geothermal energy systems in Australia were primarily heat-use applications that accessed warm water from sedimentary aquifers (Cull 1985). For over 100 years, the Great Artesian Basin that extends from Queensland to north-west New South Wales and northern South Australia, has been utilised for both household and agricultural consumption. In doing so, thousands of bores have accessed the basin, many beyond 1000 m deep with water temperatures up to 110 °C (Cull 1985). Other examples of heat-use applications include a district heating system in Portland, Victoria, which operated from 1983 to 2006 (Beardsmore and Hill 2010; Chopra 2005) and a system in Traralgon, Victoria, that supplied 68 °C process water for paper manufacturing (Burns et al. 2000).

The hot water of the Great Artesian Basin has also been used for therapeutic baths and provided heat for Australia's first two geothermal power plants. The Birdsville geothermal power plant in south-west Queensland is Australia's only operating geothermal power plant (Burns et al. 2000). The plant started operations in 1965 using hot water from the town bore. While operations were discontinued several times, the power plant has been recommissioned into operation in December 2005 and has a current output of 80 kW, supplying around 30% of the town energy. In 2017, the Queensland Government announced $7.4 million for capital works on the plant. These works are expected to double the capacity to between 150 kW and 200 kW, which will generate approximately 70% of the remote town's electricity needs (Queensland Government 2017). The other Australian operating plant, the Mulka geothermal power plant, was developed in 1986 in northern South Australia, but operated as a trial plant for only three years with a rating of 20 kWe (Popovsky 2013).

In the mid 1990s, interest in geothermal energy increased, following a study of the potential of Australia's geothermal resource to make large scale contributions to the supply of electricity (Somerville et al. 1994). In 1998 and 2000, respectively, the New South Wales and South Australian Governments enacted legislation to allow for the exploration of the geothermal energy resources (Burns et al. 2000). In 2003, Geodynamics Limited drilled Australia's first well and EGS system, Habanero 1, with a well depth of 4421 m. Following, private sector interest in geothermal energy increased in Australia. By 2004, there were 24 geothermal exploration leases in South Australia and two in New South Wales (Chopra 2005). At the peak in 2010, there were 414 exploration licences or applications, spanning approximately 472,000 km^2 across all Australian states and the Northern Territory (Goldstein and Bendall 2013).

During the 2000s, the industry focused on developing resources for electricity generation. At the peak, government policy suggested renewable energy would have an increased role in Australia's energy mix, with geothermal contributing up to 8% by 2050 (Bureau of Resources and Energy Economics 2013). This would have exposed Australians to more geothermal energy technology, including EGS, which utilises hydraulic fracturing, a technology that has attracted opposition when used in Australia's coal seam gas industry (Cham and Stone 2013).

During this peak in interest, the geothermal industry primarily targeted reservoir temperatures over 150 °C. There were four projects that drilled to reservoir depths in Australia: Geodynamics Limited's Innamincka Deeps Project; Petratherm's Paralana Project; Origin Energy Limited's Innamincka Shallows Project; and Panax Limited's Penola Project (Huddlestone-Holmes 2014). The first two projects targeted EGS resources, the others targeted deep natural reservoirs. The only project to progress beyond a single well was the Innamincka Deeps Project with six wells.

At the Innamincka Deeps Project, Geodynamics Limited ran a 1 MWe pilot plant from April to October 2013. The system ran in standalone mode from June 2013, with availability exceeding 75%. The maximum well head temperature achieved was 215 °C with a flow rate of 19 kg/s (Mills and Humphreys 2013). The flow rate was limited by the capacity of the injection well. However, the plant was able to generate approximately 650 kWe gross which supplied all auxiliary loads (Beardsmore et al. 2015). Despite this significant achievement, after more than a decade of activity at Innamincka, all of the six wells have now been abandoned and the project closed as it could not demonstrate financial viability.

1.2 The Current State of Geothermal Energy Development in Australia

Interest in utilising geothermal resources for large scale electricity generation has stalled. This halt in interest and activity, particularly from the perspective of investors and government is due to the economic and technical challenges evidenced by projects (Grafton et al. 2014). The activities that continue, primarily involve using the heat of geothermal resources for tourism and swimming pool heating, including many examples of the hot artesian waters in the Great Artesian Basin being used for therapeutic baths. There are also two fish farms that use warm groundwater for aquaculture in Victoria and South Australia, and a meat processing plant in Victoria using warm groundwater for sterilization and hand washing purposes (Beardsmore et al. 2015). There are more than 10 geothermal commercial heat-use projects in Perth, utilising the Yarragadee Aquifer to heat swimming pools (Pujol et al. 2015). The application of ground source heat-pumps for heating and cooling of buildings has also grown, from what was a very small base (Beardsmore et al. 2015). There are also plans for small scale electricity generation from geothermal systems to service small communities in rural Queensland (Department of State Development 2017).

2 The Drivers to Use Social Science Studies to Inform Industry's Stakeholder Engagement Practices

Prior to the peak of interest in large scale geothermal energy, Australia's national science agency, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) had undertaken studies to assess the likely acceptance of a range of energy technologies in Australia, including geothermal technology (e.g. Ashworth and Gardner 2006; Ashworth et al. 2006; Hobman et al. 2012). Through this research, it was established that, in general, Australians' supported renewable energy technologies. However, it was also known through other research that the acceptance of specific technologies and projects was informed by a range of factors (Devine-Wright 2005; Wustenhagen et al. 2007). Similarly, workshops with the public at Australian capital cities during 2008 to 2009 identified that although there was support for geothermal energy technology, partly due to geothermal being considered a renewable energy resource, knowledge of the technology was low and there were concerns about water usage and seismic activity (Dowd et al. 2011). In 2011, a representative sample of 1907 Australians completed an online survey, which again showed low levels of knowledge of geothermal technology in Australia (Hobman et al. 2012). Also, similar to earlier observations, despite limited knowledge being reported, over half of participants (57%) agreed with the use of geothermal technology in Australia. At this time, there were indications that large scale geothermal projects would mature in Australia and in doing so, have more presence within communities. Therefore, the CSIRO sought to contribute to the emerging industry's capacity for stakeholder engagement by understanding stakeholders' perspectives through a series of social science studies.

2.1 The Studies

In total, three studies were conducted with the aim of representing multiple stakeholder perspectives. These published studies were: (1) the industry's perspectives of its social licence (Hall et al. 2015), (2) perspectives reflected in and generated through media (Romanach et al. 2015), and (3) perspectives from the public of the likely acceptance of the technology (Carr-Cornish and Romanach 2014). The research designs for each are summarised in Table 1.

2.1.1 The Industry's Perspectives of Its Social Licence

With its origin in the mining industry, a social licence to operate has been defined as the level of ongoing approval or societal acceptance of a resource development (Joyce and Thomson 2000). The key engagement processes underpinning the social licence of a resource development identified by research within the mining context include fair treatment, quality engagement and the mitigation of impacts (Moffat and Zhang 2014). To identify the then emerging Australian geothermal industry's perspective of its acceptability and engagement processes, this study assessed how the concept of a social licence was being translated by the industry (Hall et al. 2015). The focus was on identifying how industry stakeholders assigned meaning to the social licence to operate concept, how it was applied in engagement practices and how this approach compared with other energy industries (Hall et al. 2015). The geothermal industry's perspectives of its social licence were collected through semi-structured telephone interviews with industry and company representatives. Participants were asked of the meaning of the term, what it involved in practice, its relationship with other concepts and likely future. The themes were coded using descriptive analysis informed by grounded theory, which guided the generation of insights from the data (Corbin and Strauss 2008). This chapter presents the findings that were relevant to the geothermal energy industry, from a comparison of industries published in Hall et al. (2015).

2.1.2 Perspectives Reflected in and Generated Through Media

It has been established that media has a role in the public's process of making sense of science and technology (Scheufele and Lewenstein 2005). This role can be one of transferring knowledge and influencing the public's perspective, though also, reflecting the opinions held by a range of stakeholders, including the wider public.

Table 1 The studies, research aims, samples, data collection, data analysis and citations

Study	Research aims	Sample	Data collection	Data analysis	Citation
Industry's perspectives of its social licence	Identify industry's perspectives of its social licence: - Meaning and practice of social licence to operate - Relationship to other concepts and likely changes in the future - Comparison to other energy industries	- 3 company and 2 industry representatives	- Semi-structured telephone interviews - During May and June 2013	- NVivo qualitative data analysis software was used to descriptively code themes - Coding was based on grounded theory	Hall et al. (2015)
Perspectives reflected in and generated through media	Identify the perspectives reflected in and generated through media: - Perceived risks - Perceived benefits - Cited social actors	- 451 news media items - Included newspaper reports, transcripts from radio and TV programs - Sourced through the ProQuest Australia New Zealand Newsstand database	- News media - From July 1 2011 to June 30 2012	- NVivo was used to code themes according to schema - The reliability of coding was assessed by comparing the coding of two researchers - Stata MP12 statistical software was used for descriptive statistics and cross-tabulations with the Pearson Chi-Squared test	Romanach et al. (2015)
Perspectives from the public of the likely acceptance of the technology	Identify perspectives from the public: - Extent of agreement with technology's use - Changes with media information about the technology - Characteristics of different levels of agreement	- 101 members of the public - Represented Australian population in age, gender and location	- 9 online focus groups, involving exposure to media - Collected both typed dialogue and questionnaires - During May 2013	- Statistical Package for the Social Sciences (SPSS) 20 was used for descriptive statistics and group comparison tests such as paired sample t-tests, analysis of variance, and cross-tabulations with Pearson's chi-squared tests - NVivo was used to code typed dialogue	Carr-Cornish and Romanach (2014)

Therefore, a media analysis was undertaken to identify the perspectives reflected in and generated by media reporting of the emerging geothermal industry (Romanach et al. 2015). Given the industry was in its infancy, the analysis focused on how risks and benefits were reported, which are common subjects in media coverage of emerging technologies and industries (Druckman and Bolsen 2011; Lee et al. 2005). The analysis also considered the social actors cited, to identify whose perspectives were being represented (Bocking 2012). The media analysis assessed how geothermal energy technology was presented in the Australian media, from July 1st, 2011 until June 30th, 2012, which included the peak of published articles on geothermal due to the announcement of the Australian Government′s Clean Energy Plan on July 10, 2011 (Commonwealth of Australia 2011). The news items were primarily newspaper articles, though, radio or TV programs represented 3% of transcripts. The coding focused on the technology's benefits and/or risks and social actors cited, identifying whether geothermal was the primary focus of the news article, the secondary focus or mentioned as part of the Clean Energy Plan. The results include descriptive statistics and cross-tabulations with Pearson Chi-Squared tests. This chapter reports on the leading findings published in Romanach et al. (2015).

2.1.3 Perspectives from the Public of the Likely Acceptance of the Technology

While energy technologies may present benefits, their acceptance by the public cannot be assumed, as opposition has manifested across the range of energy technologies (Batel et al. 2013; Huijts et al. 2012). For example, opposition has been reported in response to technologies more known for controversy, such as nuclear power plants (Pickett 2002) and also technologies perceived to be more environmentally friendly, such as wind farms (Hall et al. 2013) and geothermal energy projects (Popovski 2013). Therefore, to identify the public's likely levels of acceptance of the technology, several variables were considered that are known to characterise public perceptions of energy technologies (Carr-Cornish and Romanach 2014). These variables included people's knowledge of the technology (Huijts et al. 2012), perceptions of the benefits and risks of the technology (McComas et al. 2008), the location of projects applying the technology (Devine-Wright 2005) and socio-economic characteristics (Polyzou and Stamataki 2010).

Online focus groups were used to identify perspectives from the public of the likely acceptance of the technology, before and after consideration of internet based media reports on the technology. Online focus groups were conducted using an online qualitative research (OQR) platform where participants could be invited to complete a range of activities, including watching videos, reading news articles, responding to survey questions and/or joining an online discussion at a determined day and time. The online environment aided easy access to a sample that was representative of the age and sex distribution within the Australian population, and the distribution of Australians across its states and territories. Due to the range of activities OQR allowed, a mixed method approach with the collection of both qualitative and quantitative data was taken.

This mixed method involved the collection of open text from participants through typed dialogue, as well as responses to questionnaires completed by participants at the start and end of the focus groups. Two-tailed paired sample t-tests were used to compare quantitative questionnaire responses at the start and end of the focus groups. The analysis explored whether participants that disagreed, were unsure or agreed with geothermal technology being used in Australia, rated the technology benefits and risks differently. Analysis of variance tests were used when such comparisons involved continuous variables and cross-tabulations while Pearson's chi-squared tests were used when analysis involved categorical variables. This chapter reports on the leading findings published in Carr-Cornish and Romanach (2014).

3 Results

The three studies combined, informed us as to the industry's perspective of its social licence, the reporting of and profile of the technology in the media, and the extent to which communities would be willing to accept nearby application of the technology. The leading results from each study are presented in the following sections.

3.1 The Industry's Perspective of Its Social Licence: An Implicit Practice Positioned to Evolve

The insights presented here are drawn from research which informed a cross-industry examination of the meaning and application of the social licence to operate (Hall et al. 2015). Interviews with representatives from the geothermal industry revealed that although the term social licence was not common within the industry, it was common to consider stakeholders' perceptions. The infancy of the industry was often the rationale for limited use of the term, as was the perceived ambiguity of the definition of the term. For example, 'Well, I'm not sure. I was going to ask you that question, how you define it' (Interviewee 1).

Interviewees suggested the term reflected a broad range of stakeholder engagement themes, such as people and the environment, industry impacts, community and other social groups, and the political climate. Sustainability and corporate social responsibility were cited as more commonly used terms and were considered interrelated with the social licence concept. For example: 'It's an overarching term that takes on the corporate social responsibility, which takes on your sustainable business practices' (Interviewee 3).

The industry representatives also reflected that to date their social licence had not been challenged. The industry's perception that amongst the public there were mainly positive perceptions of the industry was in part attributed to the environmental benefits of the technology (i.e. renewable, low emissions energy technology) and operations being located away from populated areas. For example, 'we are lucky in a sense that there's been no negative connotations…we are perceived as clean renewables and also being very rural' (Interviewee 3). It was also acknowledged that there was no standard for evaluating their social licence.

Rather, the activities related to a social licence were described as implicit in everyday practices: 'those responsibilities or those concerns are just a part of everyday thinking about what you're doing and how you're doing it' (Interviewee 2) and '…you've got to make sure that as you go you take people with you and they understand why some of the impacts that we might have on a given area might only be temporary and we understand what the long-term impacts are…' (Interviewee 5). The themes that characterised these everyday practices were communication processes, engaging community and gaining a form of consent.

When asked of the future of the term, industry representatives were critical. However, the relevance of the meaning of the term and related practices into the future were emphasised: 'definitely something that needs to keep going … for the industry and our company to continue we definitely need buy-in from the community, engagement and support from the government' (Interviewee 3). Also emphasised was that the meaning and practice was 'bound to evolve' (Interviewee 2), which included becoming more formalised, '…objective-based framework rather than a belief-based framework…[to] test are we meeting the objectives with our current methods and technologies to deliver the outcome that communities accept' (Interviewee 4). When compared to other energy industries in Australia, these interviews reflected the stakeholder engagement practices of an industry in its infancy and although these practices were largely implicit, they were described as part of everyday practice and positioned to evolve with the industry (Hall et al. 2015).

3.2 *Perspectives Reflected in and Generated Through Media: A Limited Profile Focused on Economic Feasibility*

Media reporting influences public sentiment but is also shaped by it (Nisbet et al. 2003; Scheufele and Lewenstein 2005). To explore how public sentiment of geothermal energy was portrayed in the Australian media, an analysis of Australian news items on geothermal energy technology was conducted (Romanach et al. 2015). News items were analysed from a period of major change in Australia's energy policy and a peak in interest in developing geothermal resources for large scale energy use. The analysis afforded insight into the most cited social actors, and the perceived benefits and risks of the technology reported at that time. Consistent with the infancy of the industry, social actors mostly cited were industry, government and scientists. Also, given limited application of the technology in Australia, the benefits and risks reported were mainly of an economic and scientific nature (Lee et al. 2005). The percentage of articles that reported on the benefits and risks are in Fig. 1.

Economic feasibility and uncertainty about the technology were the most frequently reported risks. Industry was more likely to be cited in articles reporting on the economic feasibility and uncertainty about the technology. For example:

> The answer - if it exists - is partly a function of carbon price mathematics, and partly a leap of faith about the ability of a handful of listed companies led by Geodynamics in partnership with Origin Energy to prove up new, deep drilling technology and tap beds of hot rock that begin about 3 km below the surface. (The Age, September 3, 2011, p. 2)

As shown in Fig. 1, there was limited mention of other potential risks such as electricity costs, seismicity, water and noise pollution. The most frequently cited benefits were that the technology enabled renewable and low-emission energy. These benefits were frequently reported in articles, which were dominated by the release of the Australian Government *Clean Energy Plan. For example:*

> Redirecting our efforts in Australia to providing solar, wind and geothermal energy would clean our atmosphere, reduce greenhouse emissions and create thousands of jobs around the country. (The Hills Shire Times, March 27, 2012, p. 15)

Different applications of geothermal technology were reported on: electricity generation, heat-use in non-residential applications and heat-use in residential applications. Presented in Fig. 2 is the trend that, depending on the application,

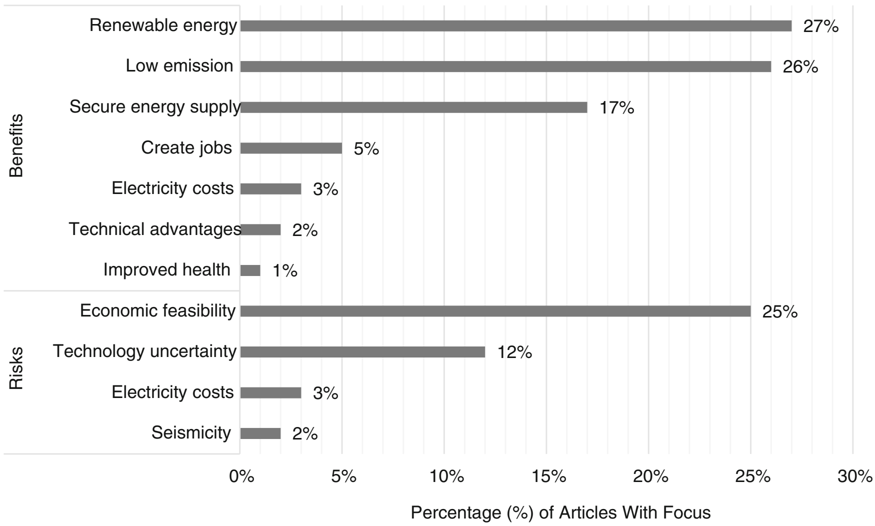


Fig. 1 Percentage (%) of articles with a focus on benefits and risks

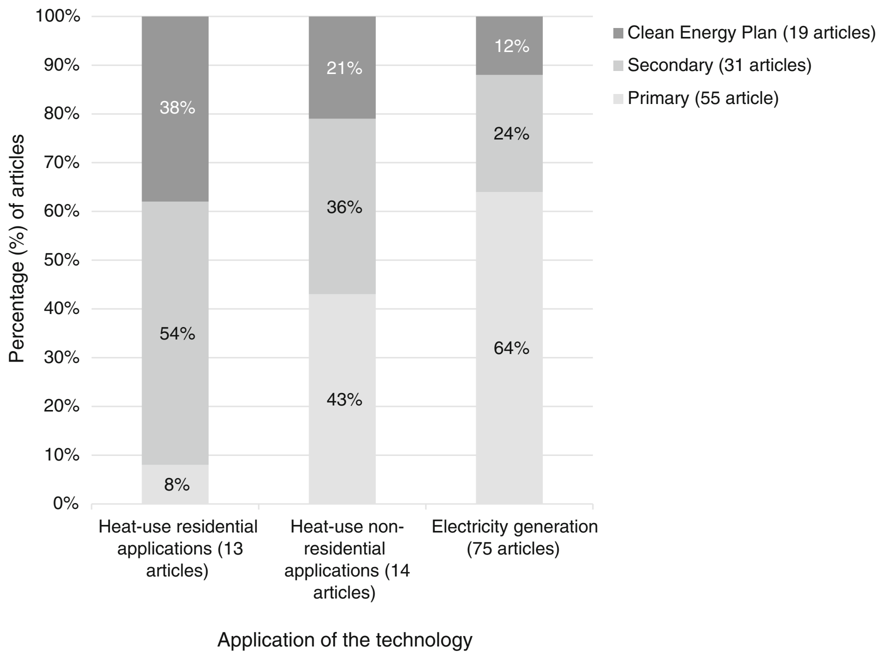


Fig. 2 The percentage (%) distribution of articles by focus and application of the technology

geothermal technology was featured differently in the article; either as the primary focus of the article, the secondary focus or as part of reporting on the Australian Government's Clean Energy Plan. Geothermal technology was more likely to be the primary focus in articles that reported on electricity generation and non-residential heat-use applications. Whereas, geothermal technology was likely to be a secondary focus in articles that reported on residential heat-use applications.

3.3 Perspectives from the Public: Acceptance but with Concern for the Risks and Proximity of Projects

Online focus groups were conducted to directly assess the level of acceptance of the Australian general public towards geothermal projects and their perspective about the proximity of projects to communities (Carr-Cornish and Romanach 2014). The insights that follow were gained from 101 participants, with demographic characteristics similar to the Australian population. Acceptance of geothermal energy technology was explored along with other characteristics that could influence acceptance, including the impact of internet based media reports (e.g. Huijts et al. 2012).

Prior to the focus group discussions, participants were asked in an initial survey, their level of agreement towards the use of geothermal energy technology in Australia. Because of previously observed limited awareness of the technology, participants were then asked to consider two media articles about the technology. Combined, the articles presented both the benefits and risks of the technology, with one article more focused on the technology's benefits and the other on the technology's risks. After exposure to media reporting, participants were asked to complete another survey.

Figure 3 shows the percentage of participants that agreed with the use of the technology at the start and end of the focus groups, including the percentage of those who agreed, were unsure and disagreed. After information was provided, the responses were more varied with less participants unsure and more participants agreeing with the use of the technology, although these differences were not statistically significant.

The focus group setting also afforded the opportunity to gain insight into the narratives that characterised different levels of acceptance. For example strong agreement was reflected in comments such as:

> I'm pleased that Australia is making some effort to explore and develop its geothermal resources, but I'd like to see more action given our enormous potential for energy derived through geothermal technology. I sense we are somewhat lagging other parts of the world in this respect, which is disappointing. (Participant 80)

Whereas, the following demonstrate some of the conditions of agreement:

> I think that Australia can play a significant role in the development of geothermal energy and should continue to do so if it can be proven to be 'safe'. To me, I am very happy to see geothermal projects in Australia, but importantly for me, we must not implement fracking or anything similar. (Participant 19)

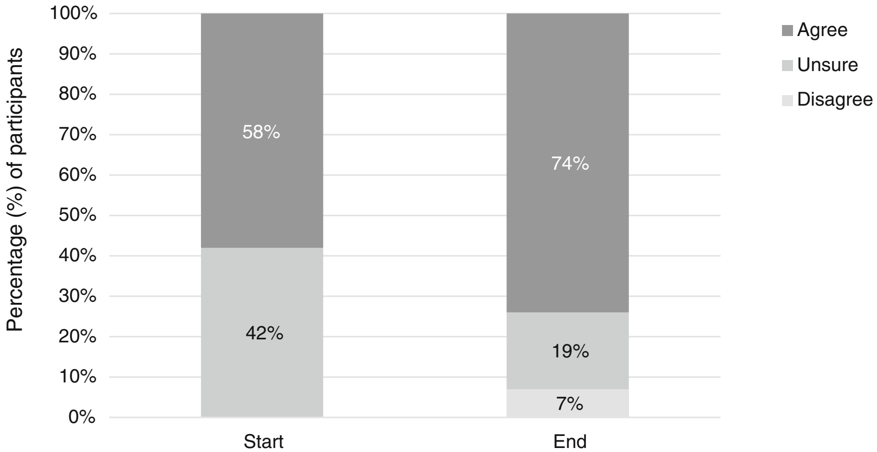


Fig. 3 Percentage (%) of participants agreeing with the use of geothermal energy technology in Australia at the start and end of the online focus groups

> It should be slowly funded as it is until we know we are not throwing money down a hole. (Participant 10)

There were also some participants that indicated they did not have enough information to express agreement or disagreement:

> I struggle with this right now, simply because we have incomplete information. If this were to be implemented here in Australia, I would want to know that there was going to be no disastrous or potentially disastrous results. In theory it's a great idea, and one that appears to be a long term supply, but none of that will matter if we end up with earthquakes and poisoned water! (Participant 6)

Similarly, participants that expressed disagreement, emphasised the need for more research and consideration of alternatives:

> I think a lot more testing, scientific discussion and research is required before Australia can step into this kind of technology. I feel there are several easier, sustainable and less dangerous alternatives to geothermal energy systems available to us at the moment. Let's utilise these options first. (Participant 29)

Participants that agreed with the use of the technology had characteristics that distinguished them from those that were unsure or disagreed. Females were less supportive than males. More specifically, females were more likely to be unsure or disagree with the technology and males were more likely to agree, both at the start and at the end of the focus group. Self-rated knowledge of the technology was higher for participants that agreed with the use of the technology, compared to those that were either unsure or disagreed. Finally, participants that agreed with the use of the technology rated benefits of the technology higher and the risks lower. The mean of responses to these benefits and risks are shown in Fig. 4.

Belief about the opportunity to participate in decision making about geothermal projects and preference for the location of geothermal projects also varied depending on whether participants agreed or otherwise with use of the technology. Participants could rate from 1-not at all to 5-very much, the extent to which they believed people in their community would have the opportunity to participate in decisions about geothermal energy projects. Participants that agreed with the use of the technology in Australia (mean 3.2) reported significantly more agreement with the opportunity to participate in decisions, than participants that disagreed with the use of the technology (mean 2.0) or that were unsure (mean 2.6).

Participants were also asked what distance they preferred geothermal projects to be from built-up areas in their community. As shown in Fig. 5, greater distances from built-up areas of the community where preferred; with 74% of participants at the start and 72% at the end of the focus group preferring a distance of 'at least 50 km' or greater. There were no statistically significant differences between the responses given by the participants at the start and end of the focus groups. Overall, responses suggest that geothermal energy technology was likely to be accepted by the majority of Australians, however, such acceptance would be subject to community perceptions of its potential risks and its distance from communities.

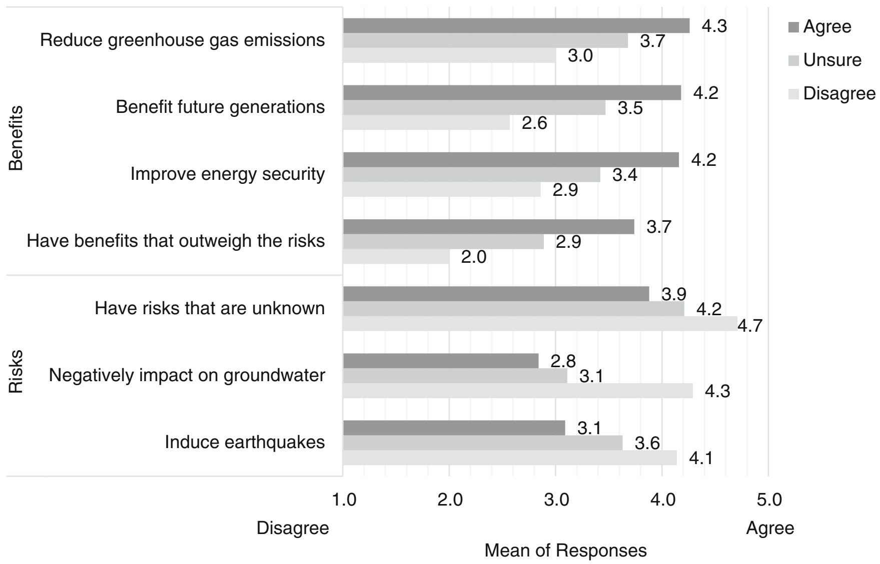


Fig. 4 Mean ratings of benefit and risks statements by attitude group at the end of the focus groups

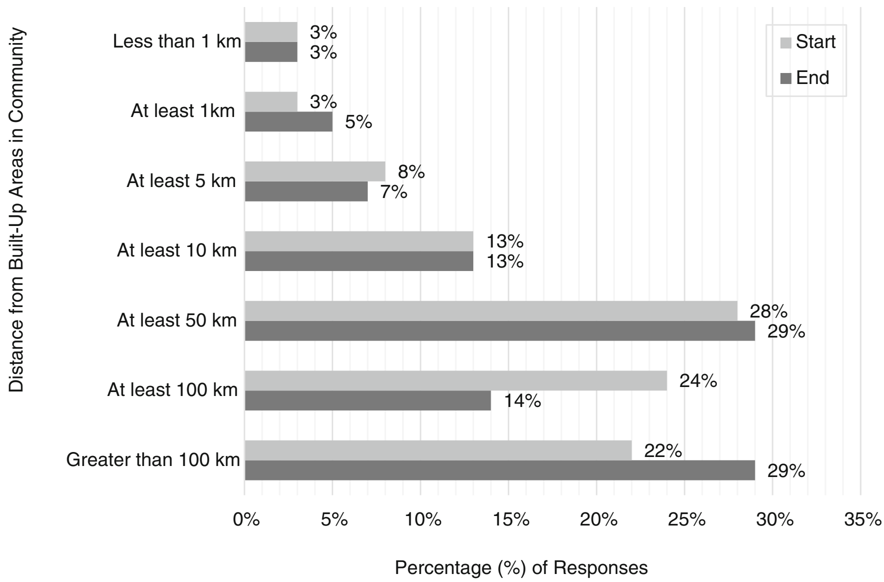


Fig. 5 Percentage (%) of agreement with distance of geothermal projects from built-up areas in the community

4 Implications, Future Research and Conclusion

When new energy projects are considered, it is critical that the industry's bodies, first-mover companies and regulators carefully consider the potential benefits and risks that such projects offer to communities near and far. The Australian geothermal industry was still in the early stages of development when the three social studies presented in this chapter were conducted. Therefore, it is not surprising that these studies found that the industry's stakeholder engagement practices were largely implicit (Hall et al. 2015), that the industry had a limited media profile (Romanach et al. 2015) and that the general population had low levels of awareness yet a positive response to the technology (Carr-Cornish and Romanach 2014). These findings also suggest, that if the industry had proceeded, it's likely that more formalised engagement would have been required, a more diverse profile may have emerged in the media and a more diverse perception of the technology would have emerged among the general population. Once the technology moved from its early stages of development, it is likely that concerns about the risks of the technology would have manifested, and the industry would have encountered more controversial perspectives to navigate. It is likely that a more formalised approach to community engagement would have aided in constructively acknowledging such concerns, as demonstrated in more established industries (Hall et al. 2015). In sum, challenges to the stakeholder engagement practices of the industry were likely, though, consistent with an industry that would have been in the process of establishing a presence with a wider range of stakeholders.

4.1 Implications

4.1.1 Implicit to Formalised Stakeholder Engagement

The perspectives shared by industry about their stakeholder engagement practices, reflected a commitment to engagement. Though, given the limited scale of the industry, the engagement practices were primarily described as an implicit part of everyday operating. If the industry had continued to develop, it's likely that more formalised stakeholder engagement would be needed for new projects, especially if close to communities. Such formalisation may have been concerned with the definition of a social licence, the metrics for its monitoring and the characteristics of stakeholder engagement that support a social licence (Hall et al. 2015). Such considerations may have challenged the geothermal industry to have greater presence in the community, with increased interactions, as well as responding to concerns. Developing the engagement practices of an industry and increasing its capacity for managing complex relationships, is an important but challenging part of establishing and maintaining a social licence within and across energy industries (Hall et al. 2015).

4.1.2 Increased Media Profile

The analysis of media reporting identified that the Australian geothermal energy industry's limited media profile was consistent with that of an emerging technology (Romanach et al. 2015). Reporting of the technology had been mostly free of controversy and attempts to politicise the technology, even though the focus of the reporting was on economic and technical challenges—the challenges which ultimately stalled the industry (Grafton et al. 2014). However, if the industry had progressed, it is likely the increase in projects would have triggered a more complex discourse about the technology with a wider range of stakeholders and perceptions present in the media (Romanach et al. 2015). For example, an increase in projects within close distance of communities, would most likely broaden the range of stakeholders involved, to include a greater presence of local residents and businesses, potentially bringing concerns of other local issues. Such an increased profile, could have also been a prompt for a more formalised stakeholder engagement strategy.

4.1.3 Shift in Technology Perceptions

Consistent with earlier studies (e.g. Hobman et al. 2012), the online focus groups found that attitudes towards the use of geothermal energy technology in Australia were mostly positive (Carr-Cornish and Romanach 2014). However, it also showed that there are concerns with potential risks, especially if developed close to communities. Such concerns suggest that if the industry had progressed, it was likely that the industry and its potential projects would need to engage in dialogue with community, in conversations beyond the technology's benefits, to include the technology's potential risks and uncertainty. As the online focus group results showed, it is likely communities would prefer for the technology to be utilised away from built-up areas (at least 50 km away). A preference for energy projects to be located away from communities is not uncommon (Devine-Wright 2005). However, such preferences would need to be closely investigated as they might vary depending on the type and use of geothermal application. This is particularly important, given that in Australia, heat-use applications need to be proximal to their end-use.

Focus groups results also showed that participants who were less likely to agree with the notion that they have the opportunity to participate in decisions about projects, were more likely to disagree or be unsure of the use of the technology. As demonstrated by social licence research within the mining industry, it is critical that dialogue with communities be inclusive and constructive (Moffat et al. 2015). In addition, it is the onus of resource companies for developing and maintaining such dialogue and establishing a formalised approach to community engagement (Hall et al. 2015; Moffat et al. 2015).

4.2 Future Studies

Given large scale development within the geothermal industry has stalled in Australia, social studies pertaining to the Australian industry have also ceased. While the studies presented in this chapter offer a baseline of the industry's acceptance within its early stages of development, such studies should be revisited, should investment in the industry restart. The benefit of revisiting the studies, if the Australian industry was to restart, would be an ongoing benchmarking of acceptance and an evidence-base for identifying the engagement approaches that would support the industry having a social licence (Moffat et al. 2015). Ongoing benchmarking in other countries could have similar benefits. The studies presented in this chapter could also provide insights to emerging geothermal industries of other countries or other industries in their infancy.

4.3 Conclusion

This chapter presented reflections on the role of three social science studies in understanding Australia's emerging geothermal industry's engagement with stakeholders. Specifically, these studies reflected on the industry's perspective of the meaning of a social licence, how technology is portrayed by the media reflects its stage of development and the key factors that are likely to influence community acceptance of potential future applications of geothermal energy. Although the Australian geothermal energy industry is currently stalled, these studies demonstrate the range of social science research that can assist with determining an industry engagement profile, as well as the key factors for developing an effective stakeholder engagement strategy when implementing geothermal projects in Australia. These studies also offer insights to other emerging geothermal or energy industries worldwide.

Acknowledgements This chapter presents research published in Carr-Cornish and Romanach (2014) and Romanach et al. (2015), which received strategic funding from the CSIRO's Petroleum and Geothermal Resources Portfolio. This chapter also presents research published in Hall et al. (2015) which also received funding from the CSIRO and the Global Carbon Capture and Storage Institute. We would also like to acknowledge the contributions of our co-authors to these publications, Grace Muriuki, Nina Hall, Justine Lacey and Anne-Maree Dowd.

References

Ashworth P, Gardner J (2006) Final report: understanding and incorporating stakeholder perspectives to low emission technologies in New South Wales. CSIRO, Pullenvale

Ashworth P, Pisarski A, Littleboy A (2006) Final report: understanding and incorporating stakeholder perspectives to low emission technologies in Queensland. CSIRO, Pullenvale

Batel S, Devine-Wright P, Tangeland T (2013) Social acceptance of low carbon energy and associated infrastructure: a critical discussion. Energy Policy 58:1–5. https://doi.org/10.1016/j.enpol.2013.03.018

Beardsmore G, Hill A (2010) Australia—country update. In: Proceedings of the World Geothermal Congress 2010, Bali, Indonesia, 25–30 Apr 2010

Beardsmore G, Budd A, Huddlestone-Holmes CR et al. (2015) Country update—Australia. In: Proceedings of the World Geothermal Congress 2015, Melbourne, Australia, 9 Nov 2016

Bocking S (2012) Mobile knowledge and the media: the movement of scientific information in the context of environmental controversy. Public Underst Sci 21:705–723. https://doi.org/10.1177/0963662510389977

Budd AR, Holgate FL, Gerner E et al. (2008) Pre-competitive geoscience for geothermal exploration and development in Australia: geoscience Australia's onshore energy security program and the geothermal energy project. In: Gurgenci H, Budd AR (eds) Proceedings of the Sir Mark Oliphant international frontiers of science and technology Australian Geothermal Energy Conference, Melbourne, August 2008, pp 1–8

Bureau of Resources and Energy Economics (2013) Energy in Australia 2013. Commonwealth of Australia, Canberra

Burns K, Weber C, Perry J, Harrington, H (2000) Status of the geothermal industry in Australia. In: Proceedings of the World Geothermal Congress 2000, Beppu-Morioka, Japan, 28 May–10 June, 2000

Carr-Cornish S, Romanach L (2014) Differences in public perception of geothermal energy technology in Australia. Energies 7:1555–1575. https://doi.org/10.3390/en7031555

Cham ST, Stone P (2013) How can understanding community concerns about hydraulic fracturing help to address them? In: Bunger AP, McLennan J, Jeffrey R (eds) Effective and sustainable hydraulic fracturing. InTech, Rijeka (Chapter 12)

Chopra P (2005) Status of the geothermal industry in Australia, 2000–2005. In: Proceedings of the World Geothermal Congress 2005, Antalya, Turkey, 24–29 Apr 2005

Commonwealth of Australia (2011) Securing a clean energy future: the Australian government's climate change plan. Commonwealth of Australia, Canberra

Corbin J, Strauss A (2008) Basics of qualitative research: grounded theory procedures and techniques, 3rd edn. SAGE, Thousand Oaks

Cull J (1985) Geothermal energy in Australia. In: Proceedings of the World Geothermal Congress 1985, Kailua-Kona, Hawaii, USA, 26–30 Aug 1985

Department of State Development (2017) Winton Shire geothermal power generation. https://www.statedevelopment.qld.gov.au/index.php/regional-development/regional-economic-development/building-our-regions/remote-communitiesinfrastructure-fund/1248-winton-shire-geothermal-power-generation. Accessed 28 June 2016

Department of the Environment and Energy (2017) Australian energy update, 2017. Commonwealth of Australia, Canberra. https://www.environment.gov.au/system/files/resources/f02a388d-74eb-4200-96fb-fe2a9d0caf5b/files/energy-update-report-2017.pdf. Accessed 23 Jan 2018

Devine-Wright P (2005) Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. Wind Energy 8(2):125–139. https://doi.org/10.1002/We.124

Dowd A-M, Boughen N, Ashworth P et al. (2011) Geothermal technology in Australia: investigating social acceptance. Energy Policy 39(10):6301–6307. https://doi.org/10.1016/j.enpol.2011.07.029

Druckman JN, Bolsen T (2011) Framing, motivated reasoning and opinions about emergent technologies. J Commun 61:659–688. https://doi.org/10.1111/j.1460-2466.2011.01562.x

Goldstein B, Bendall B (2013) Australian geothermal implementing agreement annual report 2011. In: International Energy Agency Geothermal Implementing Agreement Annual Report 2011. http://iea-gia.org/wp-content/uploads/2013/10/2011-GIA-Annual-Report-Final-4Oct13.pdf. Accessed 23 Jan 2018

Grafton Q, Horne R, Moore M, Petty S, Livesay B (2014) Looking forward: barriers, risks and rewards of the Australian geothermal sector to 2020 and 2030. https://arena.gov.au/assets/2017/02/ARENA-IGEG-main-report.pdf. Accessed 14 Feb 2016

Hall N, Ashworth P, Devine-Wright P (2013) Societal acceptance of wind farms: analysis of four common themes across Australian case studies. Energy Policy 58:200–208. https://doi.org/10.1016/j.enpol.2013.03.009

Hall N, Lacey J, Carr-Cornish S et al. (2015) Social licence to operate: understanding how a concept has been translated into practice in energy industries. J Clean Prod 86(1):301–310. https://doi.org/10.1016/j.jclepro.2014.08.020

Hobman EV, Ashworth P, Graham P et al. (2012) The Australian public's preferences for energy sources and related technologies. CSIRO, Brisbane

Huddlestone-Holmes C (2014) Geothermal energy in Australia. Prepared for the Australian Renewable Energy Agency International Geothermal Expert Group. Available at: http://arena.gov.au/about/what-is-renewable-energy/geothermal/arena-international-geothermal-expert-group/. Accessed 14 Feb 2018

Huijts NMA, Molin EJE, Steg L (2012) Psychological factors influencing sustainable energy technology acceptance: a review-based comprehensive framework. Renew Sustain Energy Rev 16:525–531. https://doi.org/10.1016/j.rser.2011.08.018

Joyce S, Thomson I (2000) Earning a social licence to operate: social acceptability and resource development in Latin America. Can Min Metall Bull 93:49–53. https://doi.org/10.1016/j.resourpol.2013.11.003

Lee CJ, Scheufele DA, Lewenstein BV (2005) Public attitudes toward emerging technologies examining the interactive effects of cognitions and affect on public attitudes toward nanotechnology. Sci Commun 27:240–267. https://doi.org/10.1177/1075547005281474

McComas KA, Besley JC, Yang Z (2008) Risky business: perceived behavior of local scientists and community support for their research. Risk Anal 28:1539–1552. https://doi.org/10.1111/j.1539-6924.2008.01129

Mills T, Humphreys B (2013) Habanero pilot project—Australia's first EGS power plant. In: Proceedings of the Australian geothermal energy conference, Brisbane, Australia, 14–15 Nov 2013

Moffat K, Zhang A (2014) The paths to social licence to operate: an integrative model explaining community acceptance of mining. Resour Policy 39:61–70. https://doi.org/10.1016/j.resourpol.2013.11.003

Moffat K, Lacey J, Carr-Cornish S et al. (2015) Stakeholder research toolkit. International Council for Mining and Metals (ICMM), London. http://www.icmm.com/website/publications/pdfs/8516.pdf. Accessed 28 June 2016

Nisbet MC, Brossard D, Kroepsch A (2003) The stem cell controversy in an age of press/politics. Framing Sci 8:36–70. https://doi.org/10.1177/1081180X02251047

Pickett SE (2002) Japan's nuclear energy policy: from firm commitment to difficult dilemma addressing growing stocks of plutonium, program delays, domestic opposition and international pressure. Energy Policy 30:1337–1355. https://doi.org/10.1016/S0301-4215(02)00028-9

Popovski K (2013) Political and public acceptance of geothermal energy. In: Proceedings of the intergovernmental conference short course geothermal training programme, The United Nations University, Reykjavík, Iceland, 14–17 Sept 2013

Popovsky J (2013) First Australian geothermal plant—Mulka case study. In: proceedings of the Australian geothermal energy conference, Brisbane, Australia, 14–15 Nov 2013

Polyzou O, Stamataki S (2010) Geothermal energy and local societies—a NIMBY syndrome contradiction? In: Proceedings of World Geothermal Congress, Bali, Indonesia, 25–29 Apr 2010

Pujol M, Ricard LP, Bolton G (2015) 20 years of exploitation of the Yarragadee Aquifer in the Perth Basin of Western Australia for direct use of geothermal heat. Geothermics 57(April):19–25. https://doi.org/10.1016/j.geothermics.2015.05.004

Queensland Government (2017) Queensland budget 2017–2018: regional action plan. http://www.budget.qld.gov.au. Accessed 31 July 2017

Romanach L, Carr-Cornish S et al. (2015) Societal acceptance of an emerging energy technology: how is geothermal energy portrayed in Australian media? Renew Sustain Energy Rev 42:1143–1150. https://doi.org/10.1016/j.rser.2014.10.088

Scheufele DA, Lewenstein BV (2005) The public and nanotechnology: how citizens make sense of emerging technologies. J Nanopart Res 7:659–667. https://doi.org/10.1007/s11051-005-7526-2

Somerville M, Wyborn D, Chopra P et al. (1994) Hot dry rock feasibility study. Energy Research and Development Corporation, Canberra

Wustenhagen R, Wolsink M, Burer MJ (2007) Social acceptance of renewable energy innovation: an introduction to the concept. Energy Policy 35(5):2683–2691. https://doi.org/10.1016/j.enpol.2006.12.001

Simone Carr-Cornish is a social researcher at Australia's national science agency, CSIRO. Simone applies sophisticated research designs and methods of analysis to define the social impacts of industries, innovations and pathways for their management. She has collaborated with industry, policy-makers and communities to generate best practice stakeholder-led solutions.

Lygia Romanach conducts applied social research at the CSIRO, Australia's national science agency. Her research focuses on the relationships between scientific and technological innovations and society within the energy and resource sector.

Cameron Huddlestone-Holmes is a Senior Research Scientist in CSIRO Energy. Cameron works on environmental, geological and geotechnical problems in the earth resources industry, primarily in the unconventional gas, coal and geothermal sectors. His speciality is in integrating multi-disciplinary capabilities in geoscience and resource engineering and applying them to solving problems in industry.

Public Perception Regarding Deep Geothermal Energy and Social Acceptability in the Province of Québec, Canada

Michel Malo, Frédéric Malo, Karine Bédard and Jasmin Raymond

Abstract Deep geothermal energy is unknown to a large proportion of Canadians and even less well known in the province of Québec. Public outreach and acceptance associated with this "new" energy is a key factor for its development. In the fall of 2013, an Internet-based public awareness and opinion survey of Québec province residents was conducted to investigate their opinion about energy with a focus on their knowledge and opinion about deep geothermal energy. Québec's population recognized the challenge of developing renewable energies. However, geothermal energy was more or less known. Only 17% knew the difference between shallow and deep geothermal energy. After reading a text describing deep geothermal energy exploitation, 67% of the respondents supported its use to produce electricity in the province, and 64% would be in favour of a pilot project in their region. When hydraulic fracturing was introduced as a technique sometimes used in deep geothermal energy, the level of support decrease to 56% for the use of deep geothermal energy to produce electricity in the province and to 52% for a pilot project in their region. The main concerns of Québec's population on deep geothermal energy are related to groundwater pollution and soil contamination.

Keywords Province of Québec · Geothermal energy · Public perception
Social acceptability

M. Malo (✉) · K. Bédard · J. Raymond
Institut national de la recherche scientifique, Centre Eau Terre Environnement,
490 de la Couronne, Quebec City, QC G1K 9A9, Canada
e-mail: michel.malo@ete.inrs.ca

F. Malo
Université Laval, Hautes Études Internationales, 1030 avenue
des Sciences-Humaines, Quebec City, QC G1V 0A6, Canada

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes
in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_7

1 Introduction

Canada is the second largest country in the world with a population of around 35 M people in 2016. It comprises ten provinces in the south and three territories in the north. Most of the population live in the southern parts of the ten provinces. Québec is the largest province, located in eastern Canada, with a total area of 1,667,712 km^2 and a population of 8,326,089 people (ISQ 2017). In 2016, the gross domestic product (GDP) of Canada was 2036 G$, whereas Québec GDP was 395 G$ (Statistics Canada 2017). The total domestic energy production in Canada in 2014 was 17,402 PJ (National Energy Board 2017). Petroleum and natural gas are by far the two most important energy sources with 9283 and 5807 PJ, respectively (National Energy Board 2017). Hydroelectricity is the third energy source (1350 PJ) followed by nuclear energy (363 PJ), whereas wind, tidal and solar electricity, altogether, produced 22 PJ, and 566 PJ are produced by a mix other energy sources, such as geothermal energy.

Geothermal energy is mostly used for two applications in Canada: heating and cooling buildings with ground source heat pumps and hot spring fed bathing pools (Raymond et al. 2015). There is no production of electricity by geothermal energy in Canada, but a demonstration project at Meager Mountain in British Columbia successfully produced electricity for two years in the 1980s (Grasby et al. 2012). Geothermal heat pumps are spread through urban centres, with highest concentration in the Québec City-Windsor corridor enclosing Toronto and Montréal, while commercial hot spring bathing facilities are found in or near the Western Cordillera. Private companies are carrying exploration projects with the hope of developing geothermal power from deep resources in Western Canada. There are also different research initiatives across the country to evaluate deep geothermal resources potential, including enhance geothermal systems outside high heat flow regions.

1.1 General Context in the Province of Québec

As for the rest of Canada, there is no utilization of deep geothermal energy in Québec province for power or even for direct use of heat. However, shallow geothermal energy using ground source heat pump systems is well developed in the province, particularly between Québec City and Montréal (Raymond et al. 2015; Fig. 1). Geothermal heat pump systems are used for both residential and commercial sectors for heating and cooling. The total energy produced by these systems does not represent a large part of the total energy production in Québec which is dominated by petroleum, electricity and natural gas (ISQ 2017). The electricity itself is mainly produced by hydroelectricity (97%, ISQ 2017) and is entirely supplied by Hydro-Québec, a crown corporation. The small amount of electricity produced by wind (2%, ISQ 2017) is supplied by private companies and bought by Hydro-Québec to be distributed on its grid.

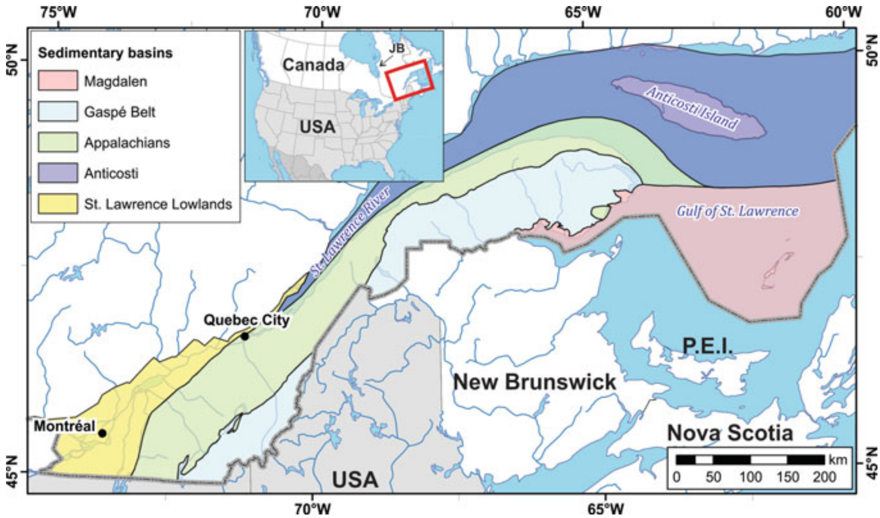


Fig. 1 Sedimentary basins in southern Québec. JB: James Bay. P.E.I.: Prince Edward Island. Modified from Malo et al. (2015)

The use of deep geothermal energy for electricity generation purpose could be useful in the province of Québec for remote regions that are not connected to the main grid. Electricity supplies distributed through Québec main grid are almost exclusively generated by hydroelectric sources (ISQ 2017), whereas autonomous grids, mainly located in the far north of the province and on islands, rely on power plants that burn fossil fuels and, consequently, emit greenhouse gases (GHG) into the atmosphere. Deep geothermal energy could also be used to produce heat for space heating, as the residential, commercial and institutional sector accounts for about 10% of GHG emitted in Québec. Hydro-Québec, through its research institute IREQ, developed a collaborative project with universities in Québec to assess the deep geothermal energy potential for electricity generation (Richard et al. 2017). The project was oriented on sedimentary basins located in the south of the province (Fig. 1). These basins are of particular interest as past oil and gas exploration provided useful data for geothermal potential evaluation. Previous studies on the basins showed thermal anomalies that could lead to temperature sufficiently high to produce electricity from 4 to 6 km deep geothermal resources (Bédard et al. 2017; Majorowicz and Minea 2012, 2015).

As deep geothermal energy is currently not widely known, particularly in the province of Québec, public outreach and acceptance associated with this energy will be a key factor for its deployment. One of the many conditions for this energy to be used is support from local populations, which could be gained by informing the public in order for them to understand this "new" energy. A research component on social acceptability was included on the collaborative project between IREQ and INRS (Malo et al. 2015, 2016). A public awareness and opinion survey of Québec residents was conducted in the fall of 2013 to get information about public awareness and acceptance of deep geothermal energy in the province.

1.2 Methodology

The main objectives of the survey were to understand: (1) the most important energy-related issues in the province as perceived by the Québec residents, (2) their opinion regarding the production of different energy sources in Québec, (3) their level of knowledge concerning various energies, including deep geothermal energy, (4) their opinion regarding the use of deep geothermal energy in the province as well as the establishment of a pilot project in their region and (5) their concerns about the use of this energy.

A bilingual (French/English) Internet-based survey was created by the INRS team in coordination with survey experts from Leger, a major Canadian survey institute (http://leger360.com/en-ca/home). The survey was inspired by other surveys on geothermal or renewable energy conducted around the world (ex. Hobman and Ashworth 2013; Tampakis et al. 2013). Some questions were open-ended, but most of them were multiple-choice questions with an "I don't know/I prefer not to answer" option available. In this paper, only the open-ended questions are specified, when needed. The survey was composed of 15 questions and a series of demographic questions necessary for statistical interpretations. Leger conducted the survey, using its online survey panel, a representative sample of Québec's population (French and English-speaking adults, male and female, 18 years old and more) with 1353 respondents (220 English-speaking adults and 1133 French-speaking adults) from November 25 to December 1st, 2013. A probability sample of the same size would yield a margin of error of ±2.7%, 19 times out of 20. The average interview length was 11 min.

Since it was presumed that few people would have heard about deep geothermal energy, parts of the survey were designed to inform the respondents (Carr-Cornish and Romanach 2012). Thus, a text with a diagram provided to the respondents explained deep geothermal energy and, most specifically, the difference between shallow and deep geothermal energy (Fig. 2).

2 Social Acceptance of Energy Sources in the Province of Québec

Even if Quebecers are proud and very supportive of hydroelectricity (Malo et al. 2017), its more recent development was not always straightforward (Malo et al. 2016). The public began to perceive environmental impacts associated to the flooding of large areas for big dams located in the north after the development of a

Geothermal energy consists of extracting the heat stored in the earth. There are two main types of geothermal energy: shallow and deep geothermal energy.

Shallow Geothermal Energy

Shallow geothermal energy consists of using wells that are approximately 100 metres deep to recover low-temperature heat used, among other things, to heat individual homes or businesses.

Deep Geothermal Energy

Deep geothermal energy refers to facilities that require much deeper wells, between 1,000 and 5,000 metres under the earth's surface. Deep geothermal energy allows for the recovery of high-temperature heat used, among other things, to heat a network of buildings or to generate electricity. An electric power plant using deep geothermal energy consists of:

1. Drilling, in general, between 2 and 4 wells up to depths than can reach 5,000 metres;
2. Circulating water between the injection wells (cold water) and the production wells (hot water);
3. Using the heat extracted to generate electricity.

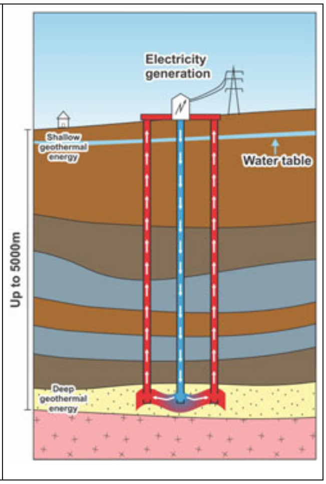


Fig. 2 Text and diagram explaining the difference between shallow and deep geothermal energy. Modified from Malo et al. (2015)

major project in the James Bay area in the 1970s (Fig. 1). Public debates occurred when Hydro-Québec wanted to build new large dams to increase its electricity production in the 1990s and, as a result, some projects were abandoned (Lasserre 2009). After consultation, small-scale hydraulic power plant projects in the south were also abandoned in the 2000s because the social acceptability was not at the *rendezvous* (Filiatrault 2007).

The wind energy development began with a population highly favourable to this new energy source because it was renewable electricity with no emission of GHG. However, very soon, local communities expressed environmental concerns about noise and visual impacts (Jegen and Audet 2011). The development of oil and gas in the province of Québec is another example of how public's opinion can have an impact on the development on energy sources. During the 1980s and 1990s, oil and gas companies conducted exploration in the province free of any public concern. In 2010, exploration was focused on shale gas in southern Québec while there was a worldwide debate on the use of hydraulic fracturing to extract gas from these shale reservoirs. This lead to a strong public protest and debate and shale gas exploration activities have almost been stopped since 2011 in the province (Malo et al. 2015). Following this shale gas crisis, the Québec Ministry of energy and natural resources (MERN 2014) developed a strategic plan for taking into account of the social acceptability for the development of energetic and mineral resources. These examples demonstrate that the public wants to be part of the decision-making process and that public acceptance is important in order to obtain a licence to operate in any new energy-related development.

3 Results and Discussion

3.1 Results Concerning Questions on Energy

Respondents were asked what energy-related issues would be the most important in Québec and what would be the second among a list of seven choices (Fig. 3a). Three issues related to energy stood out from the others: (1) cost of energy in general (electricity, gas, etc.) for 61% of the respondents, (2) renewable energy development for 43% of them, and (3) environmental impacts related to energy production and use for 40% of them (percentage given for the first and second choices together; Fig. 3a).

The survey also sought to understand respondents' opinion on Québec's objectives relating to renewable and fossil energies. 52% of the respondents chose the answer stating: "In my opinion, when it comes to renewable energy (wind power, biofuels, etc.), Québec's objectives should be to locally produce the maximum amount of renewable energy to export as much of this energy as possible." At the same time, 47% of the respondents chose the answer stating: "In my opinion, when it comes to fossil fuel (oil, gas, etc.), Québec's objectives should be to locally produce only the amount of fossil fuel necessary to meet the province's needs." Thus, respondents were not against production of fossil energy but only to meet local needs. Only 2% of the respondents believed that Québec's objectives should be to locally produce no renewable energy whatsoever compared to 22% who believed Québec's objectives should be to locally produce no fossil fuel whatsoever.

For the next question, respondents were asked to choose the two more important benefits in their opinion among a list of six benefits associated with renewable energies. The reduction of GHG emissions was the first benefit chosen by the respondents (53%, first and second choices together). The second most important benefit arising from the use of renewable energies is job creation in the province for 40% of the respondents (percentage given for the first and second choices together). The other chosen benefits are assurance of supply (39%), energy independence (35%), revenue coming from know-how exportation, particularly for hydroelectricity in Québec (17%), and reduction of energy loss due to local production and consumption. Only 2% of respondents chose "I don't know/I prefer not to answer".

The respondents were then asked on a scale of 0–10, where 0 meant they had never heard of a source of energy and 10 meant they knew it very well, to indicate their level of knowledge of several renewable energy sources. It should be specified that it was considered everyone knew hydroelectricity in Québec and its level of knowledge was not evaluated. Wind and solar energies are the two best-known renewable energy sources (scores of 7.6 and 7.5 on 10), followed by tidal energy (5.2) and biofuels (5.1), which are better known than geothermal (4.7) whereas hydrogen fuels is the less known source of energy (3.9). 56% admitted they had a poor knowledge on geothermal energy (score between 0 and 5), whereas only 14%

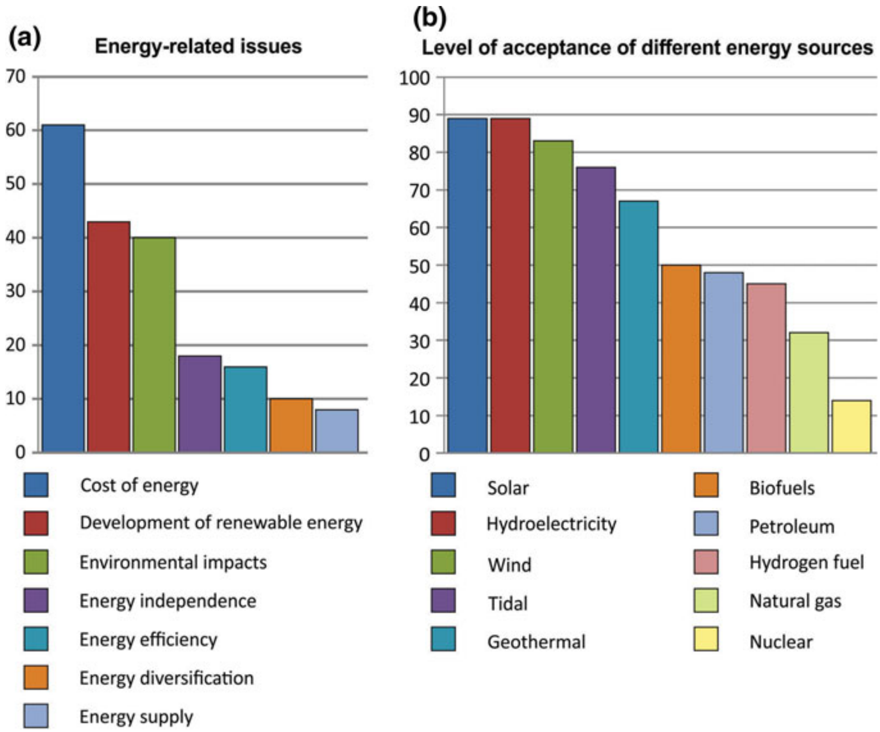


Fig. 3 **a** Most important energy-related issues. Respondents had to select two choices among a list of seven. Each bar thus shows the percentage of respondents that have chosen these issues (percentage given for the first and second choices together). **b** Level of acceptance of different energy sources (self-declared level of agreement between 6 and 10)

said they know it very well (score of 9 and 10). These results underscored the fact that geothermal energy was not very well known.

Subsequently, the respondents were asked on a scale of 0–10, where 0 meant they strongly disagreed and 10 meant they strongly agreed, to indicate their level of agreement with Québec producing several energy sources on its territory. Hydroelectricity, oil, natural gas and nuclear energy, which were not listed in the previous question, were included in this question. Globally (Fig. 3b), 67% of the respondents were favourable to geothermal energy production in the province (self-declared level of agreement between 6 and 10). Respondents were favourable to solar (89%), hydroelectricity (89%) and wind (83%) energy production in the province (self-declared level of agreement between 6 and 10). Concerning other energy sources, for example, 48, 32 and 14% of the respondents were favourable to oil production, natural gas production (including shale gas) and nuclear energy production, respectively (self-declared level of agreement between 6 and 10).

3.2 Results Concerning Questions on Deep Geothermal Energy

The level of knowledge of respondents on geothermal energy was not very high (4.7 on 10) and only 17% of them knew the difference between shallow and deep geothermal energy. The majority of the respondents who said they knew the difference were able to roughly explain it (open-ended question). For example, 39% of them said that the difference lies in the depth at which the energy is tapped in the ground and 10% of them said that the difference lies in the fact that shallow geothermal produces less heat than deep geothermal. However, 16% of the respondents who said that they knew the difference could not explain that difference in a few words.

After those questions, the survey gave to all the respondents a simplified description of deep geothermal energy that included a diagram (Fig. 2). Following the explanatory text, 67% of the respondents said they were favourable toward the use of deep geothermal energy to produce electricity in the province. In addition, 64% of the respondents said they would also support the implementation of a pilot project on deep geothermal energy to generate electricity in their region.

37% of the respondents considered that deep geothermal energy was already used around the world to generate electricity. 6% thought it was not the case and 57% said that they didn't know. Among the 37%, less than half could name a country where they believed deep geothermal energy was being used to generate electricity (open-ended question).

Among a list of eight conditions for the acceptance of such a pilot project in their region, they ranked "respect and protection of the environment" as being the most important condition (chosen by 65% of respondents, Fig. 4a). The following most important conditions are safety for the employees and nearby communities (47%), and information and consultation of local residents (46%, Fig. 4a). It should be noted that only 8% of the respondents would not support a pilot project, no matter the conditions.

After those questions on the necessary conditions to support a pilot project, respondents were informed that hydraulic fracturing is sometimes used in deep geothermal projects and their level of acceptance of deep geothermal energy was evaluated again with this new information. The percentage of respondents favourable in the province significantly dropped from 67 to 56% (−11%), whereas the percentage of respondents favourable toward the implementation of a deep geothermal energy pilot project to produce electricity in their region significantly decreased from 64 to 52% (−12%).

The survey ended by asking the respondents what would be their most and second most important concerns, if this project would take place in their region, among a list of eight potential impacts associated with a deep geothermal energy project (Fig. 4b). Groundwater pollution was the first concern of the respondents (58%, first and second choices together). The second concern was soil contamination (43%, first and second choices together). The other impacts concerning the

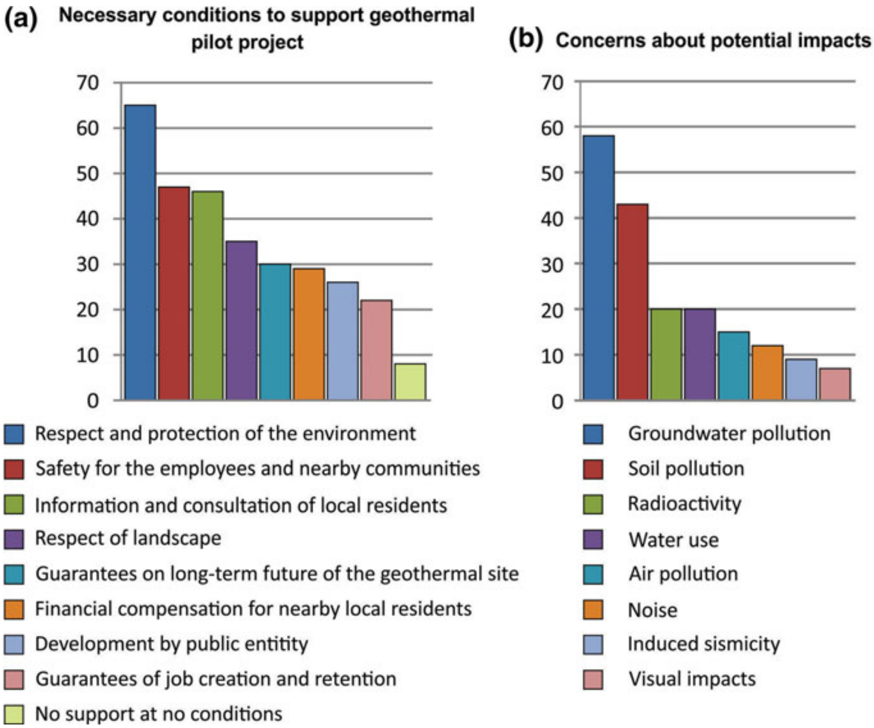


Fig. 4 **a** Necessary conditions to support a pilot project of deep geothermal energy in respondents' region. Each bar of this graph shows the percentage of respondents that have chosen this condition. **b** Potential impacts of a deep geothermal power plant. Respondents had to select two choices among a list of eight. Each bar of this graph thus shows the percentage of respondents that have chosen these potential impacts as their first and second choices together

respondents were radioactivity (20%), water use (20%), air pollution (15%), noise (12%), induced seismicity (9%) and visual impacts (7%). Only 5% of respondents were not worried by listed impacts and 10% choose "I don't know/I prefer not to answer".

3.3 Discussion

Respondents supported maximum provincial production of renewable energy for provincial needs and to export as much of this energy as possible. Besides, renewable energy development was, for the respondents, the second most important issue related to energy (Fig. 3a). Wind and solar energy sources were very well known (level of knowledge of 7.6 and 7.5, respectively), whereas the level of knowledge for other renewable energy sources is not high, below 5.2. The level of knowledge for the geothermal energy is only 4.7 and 56% admitted their poor knowledge (score between 0 and 5). The level of acceptance is the highest for hydroelectricity, wind and solar energy sources, whereas a majority of respondents (67%) is favourable to geothermal energy in the province. The gap in acceptance, as well as in knowledge, between wind, solar and hydroelectricity, on one hand, and geothermal, on the other hand, is similar to what was found in other surveys conducted in other jurisdictions such as Italy and Australia (Hobman and Ashworth 2013; Lagache et al. 2013; Pellizzone et al. 2015; Carr-Cornish and Romanach 2012; Carr-Cornish et al. 2011; Dowd et al. 2011). Acceptance of geothermal energy appears to be behind other renewable options, which can be partly due to a poor public knowledge of the technology.

Even if fewer Québec respondents were favourable toward geothermal energy production compared to solar or wind energy production, they were more favourable than toward oil or gas production. Furthermore, a priori, the use of deep geothermal energy to produce electricity received widespread support. Respondents did not generally reject the use of deep geothermal energy or a potential pilot project in their region. In fact, they were, for most of them, quite favourable to a pilot project. The eventuality of a pilot project located in the region of the respondents didn't really impact their acceptance toward the use of deep geothermal energy (decrease of only 3%). However, the potential use of hydraulic fracturing had a major influence on respondents' acceptance of deep geothermal energy (decrease of 11%) and the implementation of a potential pilot project with hydraulic fracturing in their region (decrease of 12%). Therefore, even in the case of a pilot project in their region, knowing that hydraulic fracturing could be used, the majority of Québec's population was still favourable to such a project. Hydraulic fracturing appears to be a sensitive subject, which should be investigated in other regions of the world as similar surveys consulting the population on this topic are expected to reveal important concerns.

Potential obstacles toward social acceptability of a deep geothermal energy project are of environmental nature. The main concerns of Québec's population linked to a deep geothermal energy project are groundwater and soil contamination.

4 Conclusions

Lessons must be learned from recent public debates on shale gas and uranium in the province of Québec, suggesting that social acceptability is a key factor for the development of energy and natural resources. Public hearings on the development of a uranium mine in the James Bay area (Fig. 1) influenced the government of Québec in refusing to issue the authorization certificate for developing a mineral deposit that was proven to be concentrated enough to become an economic mine as the Cri First Nation did not accept the project. Deep geothermal energy is not exploited yet, so that there is an opportunity for promoters to lean toward a proactive approach raising awareness among Canadians. The level of knowledge on this "new" energy source is fairly low and promoters must inform the population on all aspects (benefits and potential impacts) related to the exploitation of geothermal energy. For example, the comments of those opposed to a pilot project in their region showed through an open question that they needed more information about deep geothermal energy to develop an informed opinion on this energy source. Deep geothermal energy could be better accepted by the public if information and consultation campaigns would be conducted, among others, to clearly take people's concerns into consideration and provide answers to their questions. In addition, the survey indicates that, depending on the information provided, Québec respondents' opinions may change rapidly.

Québec's population overwhelmingly supported local production of renewable energy and recognized that the most important advantage arising from the development of renewable energy is the decrease of GHG emissions. This is an interesting result from the survey conducted in Québec because geothermal energy could be used in the province to replace fossil fuel for power plants in remote regions that are not connected to the main grid and for heating in buildings. This also shows that the basis for legitimating a deep geothermal energy pilot project in the province is already in place. However, experiences from deep geothermal energy projects in other countries can also be used to increase the probability of a future pilot project to be accepted from communities in the province. Lagache et al. (2013) explained that the Soultz-sous-Forêts project in France would have gained a better acceptance if the community had felt benefits in their day-to-day life. Creating benefits for the host community and informing its citizen about them is a key to increase the social acceptance of a deep geothermal power plant. This approach of community benefits creation was confirmed by Kubota's et al. work (2013) on local stakeholders in host communities in Japan, as well as, in Germany (Leucht 2012). The heat from the Unterhaching geothermal power plant in Germany plant is used as an energy supply for a residential heating system benefiting 5000 households. Leucht (2012) supports that this project was deemed a success at the social level since it combines community benefits and a good level of public awareness on the technology. Public awareness and information on geothermal technology itself and not only on the benefits is also a key determinant for high level of social acceptance. Dowd et al. (2011) showed that information can play a role in increasing social acceptance of new renewable energies through focus group activities. For a deep geothermal pilot project to obtain a high level of social acceptability in Québec, these findings should be taken into consideration. The application of these findings during the development of a project in Québec would be a good opportunity to confirm their efficiency to create high level of social acceptability. However, potential promoters must have, like for all energy and natural resources development projects involving public perception, to actively consult and listen to the population living near the project to obtain social acceptability. A priori, geothermal energy technologies should be well accepted in the province.

Acknowledgements Some parts of this work were presented at the World Geothermal Congress in Melbourne in 2015. This work was funded by the *Fonds de Recherche Nature et Technologies du Québec* and Hydro-Québec as well as a Banting scholarship given to the last author.

References

Bédard K, Comeau FA, Raymond J, Malo M, Nasr M (2017) Geothermal characterization of the St. Lawrence Lowlands sedimentary basins. Nat Resour Res. https://doi.org/10.1007/s11053-017-9363-2

Carr-Cornish S, Romanach L (2012) Exploring community toward geothermal technology in Australia. CSIRO, EP129117. https://doi.org/10.4225/08/584af4356be3f

Carr-Cornish S, Huddlestone-Holmes C, Ashworth P (2011) The ARRC/Pawsey geothermal demonstration project: an example of how to engage the community. In: Proceedings of the Australian geothermal energy conference, Melbourne, Australia, 16–18 Nov 2011

Dowd AM, Boughen N, Ashworth P, Carr-Cornish P (2011) Geothermal technology in Australia: investigating social acceptance. Energy Policy 39:6301–6307. https://doi.org/10.1016/j.enpol.2011.07.029

Filiatrault K (2007) Hydro-Québec, autochtones et régions: Gouvernance environnementale et acceptabilité sociale: Le cas de SM-3. M.Sc. thesis, Université du Québec à Montréal, Canada

Grasby SE, Allen DM, Chen Z, Ferguson G, Jessop AM, Kelman M, Ko M, Majorowicz J, Moore M, Raymond J, Therrien R (2012) Geothermal energy resource potential of Canada. Geological Survey of Canada, OF 6914. https://doi.org/10.4095/291488

Hobman V, Ashworth P (2013) Public support for energy sources and related technologies: the impact of simple information provision. Energy Policy 63:862–869. https://doi.org/10.1016/j.enpol.2013.09.011t

ISQ (Institut de la statistique du Québec) (2017) Le Québec chiffres en main, Édition 2017. http://www.stat.gouv.qc.ca/quebec-chiffre-main/pdf/qcm2017_fr.pdf. Accessed 15 Dec 2017

Jegen M, Audet G (2011) Advocacy coalitions and wind power development: insights from Quebec. Energy Policy 39:7439–7447. https://doi.org/10.1016/j.enpol.2011.09.012t

Kubota H, Hondo H, Hienuki S, Kaieda H (2013) Determining barriers to developing geothermal power generation in Japan: societal acceptance by stakeholders involved in hot springs. Energy Policy 61:1079–1087. https://doi.org/10.1016/j.enpol.2013.05.084t

Lagache L, Genter A, Baumgaerther J, Cuenot N, Koelbel T, Texier P, Villadangos G (2013) How is evaluated acceptability of an EGS project in Europe: the Soultz-Kutzenhausen geothermal project? In: Proceedings of the European geothermal congress, Pisa, Italy, 3–7 June 2013

Lasserre F (2009) Les aménagements hydroélectriques du Québec: le renouveau des grands projets. Géocarrefour 84(1–2):11–18. https://doi.org/10.4000/geocarrefour.7186

Leucht M (2012) Medienresonanzanalyse – zu Projekten der tiefen Geothermie in Landau, Bruschal, Brühl und Unterhaching. Research report, Karlsruhe, Freiburg, EIFER, enerchange 2012

Majorowicz J, Minea V (2012) Geothermal energy potential in the St. Lawrence River area, Québec. Geothermics 43:25–36. https://doi.org/10.1016/j.geothermics.2012.03.002t

Majorowicz J, Minea V (2015) Geothermal energy potential in low enthalpy areas as future energy resource: identifying feasible targets, Québec, Canada, study case. Resources 4(3):524. https://doi.org/10.3390/resources4030524

Malo M, Moutenet JP, Bédard K, Raymond J (2015) Public awareness and opinion on deep geothermal energy in the context of shale gas in the province of Québec, Canada. In: Proceedings of the world geothermal congress 2015, Melbourne, Australia, 19–25 Apr 2015

Malo F, Raymond J, Malo M (2016) L'acceptabilité sociale des projets d'énergie géothermique au Québec. INRS, report R1662. http://espace.inrs.ca/4030/1/R1662.pdf. Accessed 15 Dec 2017

Malo F, Bédard K, Malo M, Rivard C, Lavoie R (2017) Perception regarding mineral resources development in the province of Québec, Canada. In: Proceedings of the 14th Biennial SGA meeting, Québec, Canada, 20–23 Aug 2017, pp 1445–1448

MERN (Ministère de l'Énergie et des Ressources naturelles du Québec) (2014) Orientations du Ministère de l'Énergie et des Ressources Naturelles en Matière d'Acceptabilité Sociale. http://mern.gouv.qc.ca/wp-content/uploads/orientations-complet-acceptabilite-sociale.pdf. Accessed 15 Dec 2017

National Energy Board (2017) Canadian energy overview 2014—energy briefing note. https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/vrvw/2014/index-eng.html. Accessed 15 Dec 2017

Pellizzone A, Allansdottir A, De Franco R, Muttoni G, Manzella A (2015) Social acceptance of geothermal energy in southern Italy. In: Proceedings of the world geothermal congress 2015, Melbourne, Australia, 19–25 Apr 2015

Raymond J, Malo M, Tanguay D, Grasby S, Bakhteyar F (2015) Direct utilization of geothermal energy from coast to coast: a review of current applications and research in Canada. In: Proceedings of the world geothermal congress 2015, Melbourne, Australia, 19–25 Apr 2015

Richard MA, Giroux B, Gosselin L, Kendall J, Malo M, Mathieu-Potvin F, Minea V, Raymond J (2017) Intégration de la géothermie profonde dans le portefeuille énergétique canadien. IREQ-Hydro-Québec, report IREQ-2017-0032, Laboratoire des technologies de l'énergie (LTE)

Statistics Canada (2017) Gross domestic product, expenditure-based, by province and territory. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ15-eng.htlm. Accessed 15 Dec 2017

Tampakis S, Tsantopoulos G, Arabatzis G, Rerras I (2013) Citizen's views on various forms of energy and their contribution to the environment. Renew Sustain Energy Rev 20:473–482. https://doi.org/10.1016/j.rser.2012.12.027

Michel Malo is a professor at INRS. He specializes in structural geology and Appalachian geology. He is also interested in natural resources contained in sedimentary rocks (hydrocarbon reservoirs and ore deposits) and, more recently, the geological storage of CO_2 and geothermal energy. With his team, he conducted research on social acceptability of new energy sources in the province of Québec. He holds a Ph.D. in Geology from *Université de Montréal*.

Frédéric Malo is a master student in International Development at the *Institut des Hautes Études Internationales* at *Université Laval* in Quebec City. He completed his B.Sc. in geography in 2015 at the same university. He worked at INRS during summers 2015, 2016 and 2017 on the social acceptability of deep geothermal energy and mining development

Karine Bédard joined INRS in 2008. In the last years, her work particularly focused on rock properties and 3D geological modelling of sedimentary basins and reservoirs in the context of CO_2 geological storage and geothermal energy. She holds a B.Sc. in Geology from University of Ottawa and an M.Sc. in Geomatics from Université Laval.

Jasmin Raymond is a hydrogeologist and teaches geothermal energy basics at INRS. He conducts research on low to medium temperature resources, including heat pump systems. Professor Raymond currently holds a research chair from l'*Institut nordique du Québec* to investigate the geothermal potential of northern communities and mines in addition to be the coleader of an international research group on geothermal energy supported by UNESCO. He coauthored a report from the Geological Survey of Canada on the geothermal potential of the country.

Geothermal Energy in France. A Resource Fairly Accepted for Heating but Controversial for High-Energy Power Plants

Philippe Chavot, Anne Masseran, Cyrille Bodin, Yeny Serrano and Jean Zoungrana

Abstract In this chapter, we will see that geothermal energy is guided by dynamics of development that are uneven depending on the region and the nature of the projects. Use of geothermal resources for heating had a major boom following the energy crises of the 1970s, particularly in the Parisian region. High-energy geothermal projects were first developed in the volcanic islands of French overseas territories in the 1980s. Its developments in mainland France are then linked to the energy transition policy implemented in the early 2010s. However, in several regions, opponents point out the risks arising from drilling techniques used to facilitate water circulation in rocks. But criticism is also focused on economic and political aspects. The first part of this chapter reports on the first developments of geothermal energy in France and its links with energy policies. The second part deals with social aspects, evoking the controversies that arose in France from 2014 onwards and the role of consultation mechanisms in these controversial situations.

Keywords France · Citizen participation · Energy transition
Public controversy

P. Chavot (✉) · C. Bodin · Y. Serrano
LISEC, University of Strasbourg, 7 rue de l'Université,
67100 Strasbourg, France
e-mail: philippe.chavot@unistra.fr

A. Masseran
CREM, University of Lorraine, île du Saulcy, BP 60228,
57045 Metz Cedex 01, France

J. Zoungrana
SAGE, University of Strasbourg, 5 allée du Général Rouvillois,
CS 50008, 67083 Strasbourg, Cedex, France

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes
in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_8

1 Geothermal Framework

Located at the western end of Europe, the mainland part of France benefits from a temperate climate with strong oceanic influence. It has some ancient massifs (including the Massif Central, which is volcanic) and recent mountain ranges created by several tectonic episodes. These massifs are bordered by very fertile sedimentary basins that have enabled France to become the 8th largest agricultural power in the world. As witnesses of an important colonial past, overseas territories remain attached to the country: the islands of Guadeloupe, Martinique and St. Martin in the French West Indies, Reunion Island in the Indian Ocean, Guyana in South America. The first power plants based on geothermal drilling have been tested in the volcanic island of Guadeloupe.

Since the COP21 climate agreements of 2015, France wants a leading role in the energy transition, a role it confirmed in 2017 by organizing the One Planet Summit. In this chapter, focusing on the developments of geothermal energy in France, we will first present the framework in which this new energy resource was explored by proposing a brief review of France's energy policy. What role are renewable energies playing in this policy, and what about geothermal energy? Secondly, we will address the pioneering work carried out in France on deep geothermal energy and then discuss its contemporary developments. What societal and political evolutions have enabled geothermal energy to establish itself in France? How are its developments managed? And finally, how are the risks associated with drilling and the running of geothermal plants assessed by the public?

1.1 *A Late Commitment in the Development of Renewable Energies in France*

During its recent history, France has benefited from several energy resources. Important coal deposits were the spearhead of its industrial revolution in the 19th century. However, the First World War raised awareness of the dangers of dependency on a single energy source. This is when the first major hydroelectric dams were built. Similar projects followed one another until the 1970s. Despite the exploitation of a few deposits, France depends on imports for almost all of its oil and gas consumption. The two oil crises of the 1970s led to the major development of the nuclear industry. France then became one of the world leaders in this sector, as much for fuel extraction (carried out in France for a time, then in Niger) as for the manufacture of power plants, and more recently for nuclear waste management (Hecht 1998; Topçu 2013). France is currently the world's second largest nuclear power producer. In 2016, 72.3% of the electricity produced in France came from nuclear power, making it one of the few countries that can export electricity.

This all-nuclear policy has led France to neglect renewable energy sources (RES) for a long time, the hydroelectric sector being the only one to have had a steady development since 1914 and until the 1970s. It currently produces around 11% of the electricity consumed in mainland France.

Other RES sectors were more recently developed due to the policies implemented in France since the early 2000s. Initial measures included the development of national climate plans (2000 and 2004): lined up with the Kyoto Protocol (1997), they aim to reduce greenhouse gas emissions. However, they do not directly encourage the use of RES. The Grenelle Environment Forum[1] (2007) and the subsequent two laws (2009, 2010[2]) propose more concrete targets for the development of RES: they are expected to account for 23% of the final energy consumption by 2020. An incentive policy towards regional districts have led these to define their own territorial climate plans and promote green energy (heat and electricity). Finally, the Energy transition law adopted on August 15, 2015 includes the Grenelle targets and sets a 32% share of RES in final energy consumption by 2030. The main innovation of this law concerns nuclear power, whose share of electricity production will have to decrease from 78 to 50% by 2025.[3] Emphasis is again placed on local territorial actions.

These recent policies are giving results. Between 2005 and 2015, a downward trend in the import of energy resources, electricity consumption and CO_2 emissions was recorded. Demand for primary energy decreased by 9.3% and final consumption by 13%.[4] Since 2004, the decline in consumption has been most notable in the residential heating and cooling (−15.4%) and trade (−11.7%) sectors.

At the same time, the share of renewable energy has increased from 9 to 14.9% of the energy consumed. However, this increase is, for the time being, insufficient to reach the 23% target by 2020. Among RES, the wood sector (74.9%) is preferred for heat production, far ahead of heat pumps (16.1%). For green electricity production, hydropower accounts for the largest share (61.1%), followed by wind power (23.8%) and photovoltaics (8.1%).[5] Deep geothermal energy occupies a rather modest position in this panorama, less than 1% of the renewable energy production, but projects are still in the process of being implemented.

---

[1]The term "Grenelle" refers to the multi-party debates that took place on Rue de Grenelle in Paris in May 1968, at the end of one of the largest workers and students revolts that France has seen in the 20th century. It now refers, by analogy, to any structured, multi-party debate which includes government representatives, representatives of different political sensitivities, various associations and NGOs.

[2]Act no 2009-967 of 3 August 2009 programming the implementation of the Grenelle for the Environment, and Act no 2010-788 of 12 July 2010 establishing a National Commitment regarding the Environment.

[3]However, the current Minister of the Environment has repeatedly pointed out in 2017 that this objective is not sustainable.

[4]The Total primary energy supply (TPES) amounted to 245.7 MTOE in 2015 and Total Energy Consumption (TFC) was 147.7 MTOE in 2014.

[5]Ministère de l'environnement, Chiffres clés des énergies renouvelables Édition 2016, http://reseaux-chaleur.cerema.fr/wp-content/uploads/CC-des-energies-renouvelables-edition-2016.pdf (accessed on 02/26/2018).

1.2 Pilot Projects for High-Temperature Geothermal Energy (Power Generation)

Despite its small footprint, geothermal energy in France already has a long history. In the 1960s, at the instigation of Jean Goguel, sometimes referred to as the “father of French geothermal energy”, the French geological survey organization (the *Bureau de recherches géologiques et minières*, BRGM), started several exploratory works on volcanic geothermal energy in Guadeloupe on behalf of the Electricity production and distribution company of Guadeloupe. Several wells, from 450 to 2000 m deep, were drilled between 1967 and 1971 by the French oil drilling company Eurafrep (Guillou-Frottier 2003). Exploitation of the resource, whose temperature exceeds 200 °C, began in 1984 with the installation of the first electricity production unit, the Bouillante 1 plant, commissioned in 1985 by the National French electricity company (*Electricité de France*, EDF) and BRGM. New drillings in the early 2000s led up to the commissioning of Bouillante 2 in 2005.[6] Bouillante 1 (which was refurbished in 2013) and 2, with a total production capacity of 15.5 MWe, cover 6% of the electricity demand of Guadeloupe (Demarcq et al. 2014).[7]

Over the same period, a more ambitious project for the West Indies aimed to exploit the geothermal resources of the Dominica island. The aim was to develop a large geothermal power plant capable of supplying electricity to the island of Dominica but also to the two neighbouring French islands of Guadeloupe and Martinique *via* a network of submarine cables. Exploratory studies were carried out as early as 1977 and the project, entitled *Géothermie Caraïbes*, took concrete form in 2003, involving several partners.[8] The production capacity is estimated at 150 Mw. *Géothermie Caraïbes* together with a third power plant in Martinique should allow the three islands to benefit from less expensive energy and be a step closer to energy self-sufficiency (Laplaige et al. 2013). The implementation of this project was, however, slowed down in 2013 by EDF’s withdrawal from *Géothermie Caraïbes* and from the Bouillante power plant. While the American operator Ormat took over the activities of the Guadeloupe power plants in February 2016 (by purchasing 80% of the shares), the *Géothermie Caraïbes* project is still pending.

Exploratory work was also carried out in the Indian Ocean during the 1970s and 1980s, on the volcanic island of Réunion to produce electricity. The project was considered economically unviable in 1986 but became relevant again in the 2000s. A first project was aborted in 2008 due to a strong mobilization of the population

---

[6] http://www.geothermie-perspectives.fr/article/historique-lexploitation-champs-bouillante (accessed on 02/26/2018).

[7] http://www.guadeloupe-energie.gp/geothermie/2180-2 (accessed on 02/26/2018).

[8] The project involves the government of Dominica, the French regions of Guadeloupe and Martinique, the French Development Agency (AFD), the French Environment and Energy Management Agency (ADEME) and the BRGM.

against drilling, which was to be carried out within a protected natural area. A new project led by Volcanergie (a subsidiary of the Electerre group) is being implemented.

1.3 The Development of Geothermal Energy in Mainland France

In the 1980s, following the oil crisis, low-temperature geothermal energy emerged as one of the lower-cost solutions promising to supply heat to homes and industries. In Mainland France, the "heat" potential of geothermal energy was therefore the primary driving force towards its development. Between 1980 and 1985, some thirty low-energy geothermal plants were built in the Paris Basin and in Aquitaine. In the Paris Basin, the plants exploited the Dogger aquifer, which has a temperature between 55 and 80 °C and is located in fractured limestone at 1600–1800 m depth. These installations did not prove very cost-effective and maintenance was complicated due to corrosion. The more favourable political conjecture of the 2000s made it possible to rehabilitate old wells and build new ones. With 44 installations in operation, the Paris Basin has become an area in the world where the density of geothermal plants is among the highest, supplying nearly 200,000 homes (Boissavy et al. 2016). The objective is to keep these plants in operation for about 50 years, which will only be possible if they are able to manage the cooling associated with the re-injection into groundwater of water after heat extraction.

High temperature geothermal energy is emerging in France thanks to the creation of the pilot project of Soultz-Sous-Forêts in 1985 and of the EEIG (European Economic Interest Grouping), which manages the project since the late 1990s.[9] A truly genuine laboratory for deep geothermal energy, it was intended to exploit the thermal anomaly of the Rhine basin by first developing a Hot Dry Rock type geothermal project. After several exploratory phases, and two boreholes more than 5000 m deep, the group discovered a very saline aquifer located 3500 m deep, in a naturally fractured granitic bedrock and a temperature of 200 °C. The EEIG's activity provided the basis for the Enhanced Geothermal System (EGS) technique. The aim has been to experiment the different types of stimulation (hydraulic or chemical) that allow better water circulation in micro-cracks. The EEIG was converted into an industrial site in June 2016 following the acquisition by Electricité de Strasbourg (a subsidiary of EDF), which invested 8 million euros in the site. With a capacity of 1.7 MW, the site can now produce 12,000 MWh of electricity per year, supplying electricity to the equivalent of 2400 homes.

[9]This project is supported by the European Commission, the French Ministry of Research through the AFME (now ADEME), and the German Ministry of Environment.

Inspired by the Soultz-Sous-Forêts model, many projects have been launched since the 2000s in the German, Swiss and French regions of the Rhine basin. Thus, on the French side, in Alsace, the 24 MW Rittershoffen geothermal power plant was inaugurated in 2016. It supplies heat to the Roquette starch factory located about 30 km away. In Alsace, three cogeneration power plant projects are currently being carried out within the Eurometropolis of Strasbourg and three projects are being defined in Northern Alsace and in the near outskirts of Strasbourg. The Rhine basin is not the only area where deep geothermal energy is being developed. The Ministry of Mines has issued a dozen or so research permits regarding high-temperature geothermal energy, to be carried out in Alsace and in areas of the Massif Central and of south-western France (Fig. 1). Thus, 23 projects could be completed by 2030, which would generate 211.5 MWe and 245 MWth for an investment of 1500 million euros.

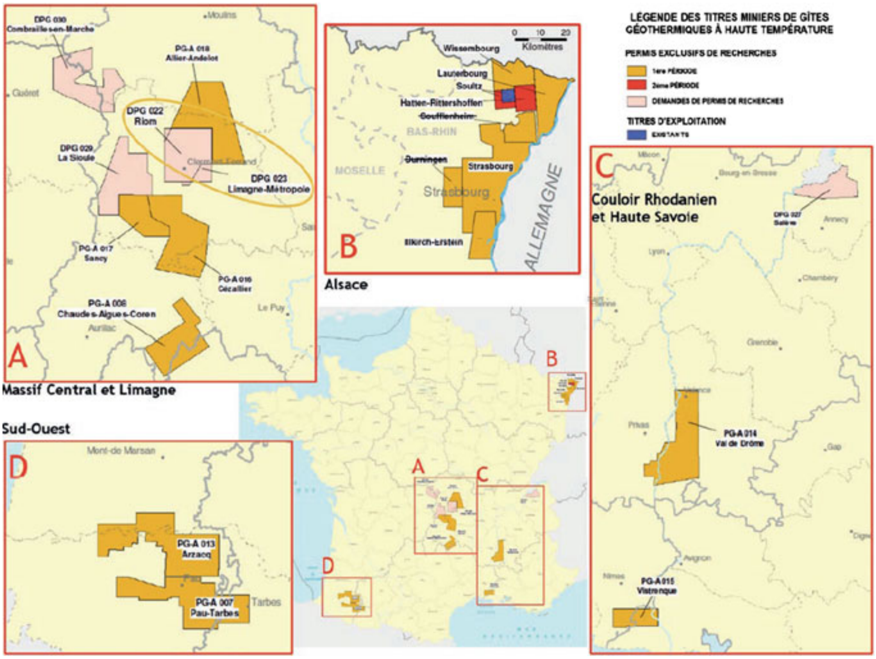


Fig. 1 Map related to permit areas for high temperature resources. Rose color: pending applications. Brown and red colors: permits issued. Blue color: concessions. Modified from: Ministry of Environment, January 2016, presented in AFPG 2016

1.4 Geothermal Policy and Stakeholders

The development of low and high-temperature geothermal energy is backed by various provisions taken within the framework of the national climate plan (2004) and the Grenelle 1 and 2 laws (2009/10). First, the Renewable Heat Fund was created in 2009, which includes a total allocation of 1.12 billion euros and target renewable energy and energy recovery (EnRR) heat projects. It allows operators to produce heat at a competitive price compared to the use of fossil fuels. The revival of low-temperature geothermal energy in the Paris Basin has been partly achieved thanks to this Fund. It has also encouraged provincial cities to integrate the development of geothermal energy into their territorial climate plan.[10] This is the case, for example, with the climate plan of the Eurometropolis of Strasbourg, which sets a target of 20–30% of renewable energy usage for private and public needs.[11] Secondly, EDF's electricity purchase tariffs were revalued in 2010, setting the price of kWh from geothermal energy at 20 cents, which also benefited from an 8 cents premium. This measure made it possible to ensure the economic viability of cogeneration projects and led several companies to favour this option rather than heat production alone, despite the low efficiency of converting heat into electricity. Finally, the establishment of a guarantee fund set up by companies with the support of the Ministry of Ecology allowed companies to obtain financial compensation in the event of unsuccessful drillings.

The development of geothermal energy depends on the mining code, since it is linked to the exploitation of underground resources. Likewise, the granting of research and concession licenses is controlled by the state and by local prefectures. For low-temperature geothermal energy (<150 °C), all procedures are managed locally. The exclusive licence to prospect (*Permis exclusive de recherche*, PER) is granted by the prefecture for a period of three years. For high-temperature resource projects (>150 °C) with or without electricity generation, applications for the PER are processed by the Ministry of Mines. In this case, the state or prefecture solicits several evaluations or consultations:

- The analysis of licence applications, their compliance with the legal framework and the monitoring of drilling operations is carried out by the Regional Directorate for Environment, Development and Housing (DREAL) linked to each prefectures.
- Additional expertise can be provided by the French national institute for industrial environment and risks (Ineris), with regard to subjects relating to risk management. The Departmental Council of Environment and Sanitary and Technological Risks (CODERST) can also be sought regarding environmental and sanitary issues.

[10]http://www.energivie.info/PCET (accessed on 02/26/2018).

[11]http://blog.bio-ressources.com/non-classe/alsace-geothermie-profonde (accessed on 02/26/2018).

- In addition, the public and the local residents are consulted at various stages of the procedure. We will come back to that later.

Outside this regulatory framework, multiple actors are involved in the definition and implementation of projects. The French Geological Survey, BRGM, which, as we have seen, has played a decisive role in the implementation of overseas projects, also intervenes more or less directly in mainland France. It provides its expertise, makes available and coordinates information intended for professionals, whether it concerns subsoils geology or the preparation of applications.[12] It can also become financially involved in projects.

Low temperature projects generally depend on local dynamics, involving cities or service providers in charge of water management or heat networks. Therefore, in the Paris Basin, projects are set up by local authorities, which are already involved in the management of heat networks. Only a few projects in the outskirts of Paris are carried out by new operators in the RES sector. For example, Engie, the historical operator of natural gas distribution in France, recently became involved in the creation of several heat networks powered by geothermal energy through its subsidiary, Engie Réseau.

High-temperature geothermal energy projects don't have as many local connections, their main objective being the production of electricity. New players have emerged and competition is conducted under the Ministry of Mines' arbitration. 18 high temperature PER have been issued during the last five years, including two overseas. The project leaders are subsidiaries of large groups specialized in the energy sector (*Electricité de Strasbourg Géothermie*, 5 licences), newly formed groups in the field of renewable energies (Fonroche, 7 licences) or in the geothermal energy sector (TLS, 1 licence), and local companies created to exploit geothermal resources (Electerre, Volcanergie, Géothermie de la Guadeloupe).[13]

These companies work closely with the research sectors, national agencies and offices as well as professional drilling businesses. Electricité de Strasbourg Géothermie (ESG) draws on the experience gained during its involvement in the Soultz-sous-Forêts EEIG consortium (see above). The Rittershoffen power station is the result of a collaboration between ESG, BRGM, the French Environment and Energy Management Agency (ADEME) and the *Caisse des dépôts et consignations*. Finally, ESG is involved, together with the CNRS and the *Ecole et Observatoire des Sciences de la Terre* (EOST) in the creation of the *Laboratoire d'excellence* (Labex[14]) *G-EAU-THERMIE profonde* located in Strasbourg, Alsace. This Labex is itself involved in collaborations with the Karlsruhe Institute of Technology (KIT) in Karlsruhe with whom it organises an annual European

[12]The main BRGM reports are available at http://infoterre.brgm.fr (accessed on 02/26/2018).

[13]These companies generally request a low-temperature permit in conjunction with a high-temperature permit, in order to be able to exploit the resource even if the temperature is less than 150 °C. A draft decree aims to lower the low-high temperature threshold to 110 °C.

[14]Labex are high quality research laboratories created in the early 2000. They are part of a €45 billion investment program aiming at favoring French innovation.

Geothermal Workshops (EGW) since 2012.[15] These collaborations aim to better understand and exploit the geothermal resources of the Rhine basin.

Other forms of collaboration exist in the field of geothermal energy. A co-investment partnership in the drilling rig was initiated by Fonroche together with two more experienced German companies[16]: Herrenknecht Vertical GmbH and Angers&Soehne Gmbh. These groups notably co-founded Foragelec. Lastly, international connections are also being set up as part of shareholdings. Hence, the Bouillante plant, which was partially acquired by the American company Ormat Technlogy with 59.3% of the capital, has these other shareholders: BRGM (for 20.36% of the capital) and the *Caisse des Dépôts et Consignations* (19.91%).[17]

The companies and agencies involved in the development of geothermal energy find themselves within the *Association française des professionnels de la géothermie* (AFPG), created in 2010. In addition, a group of companies from the French energy industry gathered around the GEODEEP Cluster in relation with a consulting agency, the AFPG, and various service companies. The cluster's objective is to propose turn-key solutions for all low and high energy projects. It created a guarantee fund to compensate the company in the event of an unsuccessful drilling (see above).

2 Studying Social Aspects of Geothermal Energy Development in France

The French energy transition policy, implemented since the early 2000s, has led to a major reconfiguration of the energy field. The former centralized and state managed power production (typical of nuclear policy) has given way to decentralized management involving a multitude of actors. Local and regional authorities are becoming increasingly responsible and, as we have seen, the evaluation and control of projects is carried out by a plurality of actors. Finally, a consultation of citizens is required by the environmental legislation alongside the mining code because such geothermal projects are considered to have a possible impact on the environment or on the quality of life of local residents.

This reconfiguration is a privileged field of study for the humanities and social sciences (HSS). Energy sociology tends to become an area of research in itself, which the Ministry of Research coordinates through the National Thematic Alliance

[15]The last EGW workshops was held in Karlsruhe on 12–13 October 2017: https://indico.scc.kit.edu/indico/event/343/ (accessed on 02/26/2018).

[16]According to the document below, these German companies have achieved 8 deep boreholes in Germany and have 150 years of existence in the field of geothermal energy. http://www.fonroche.fr/sites/default/files/GEO_STRAS_Brochure_A6_FAQ_32pages%20WEB.pdf (accessed on 02/26/2018).

[17]http://www.brgm.fr/brgm/le-groupe-brgm/geothermie-bouillante (accessed on 02/26/2018).

of Humanities and Social Sciences (Athena) (Labussière and Nadaï 2015).[18] The involvement of HSS in the energy field is also facilitated by the fact that social analyses are increasingly required within the calls for scientific projects launched by the European Community or the French National Research Agency (ANR). It is within this framework that initial work has been carried out on the social aspects of geothermal developments.

2.1 Legal Public Consultations

Geothermal projects over 200 m deep are subject to a variety of assessments and controls, and approval procedures can take a very long time. For example, the procedures that opened up geothermal drillings within the Eurometropolis of Strasbourg in 2017 began in 2010. In this context, the public is consulted several times (see Table 1). First, when considering applications for exclusive licence to prospect,[19] two different procedures are put in place depending on the nature of the licence: for low temperature licence administrated by local prefecture, citizens' opinions are collected through a local public enquiry; for high temperature licence controlled by the State, the Ministry of Environment has set up a web platform to collect citizens' comments.[20] Once the licence has been granted, a second consultation is carried out for the exploration authorization request administered by the prefecture, which takes the form of a public inquiry. Finally, the public is consulted again before the plant is put into operation and during the application for a concession.

In addition to these consultations, monitoring committees or acceptability surveys may be set up from time to time by prefectures or companies when drilling is carried out or during the first years of the power plant' operations.

2.2 The Public Inquiry, a Platform for Protest

The public inquiry mechanism is an old system (1810) whose scope was extended to environmental issues in 1983. Organized by the prefecture, these public

[18]The Athena Alliance presents itself as a forum for strategic cooperation and consultation between universities and research organizations. It takes a reflective look at HSS research orientations and contributes to the construction of a research policy: http://www.allianceathena.fr/ (accessed on 01/10/2018).

[19]The exclusive research license gives the company an exclusive right to carry out exploration work on geothermal deposits within a defined perimeter and to apply for a concession if the resource is proven.

[20]This collection of citizens' points of view is done *via* the online system "Consultations publiques":http://www.consultations-publiques.developpement-durable.gouv.fr/ (accessed on 01/10/2018).

Table 1 Mandatory public consultations for low and high temperature geothermal projects

	Low temperature project Drilling depth over 200 m Temperature <150 °C	High temperature project Drilling depth over 200 m Temperature >150 °C
Application for an Exclusive licence to prospect (PER)	Administered by the prefecture Organisation of a public inquiry	Administered by the Ministry of Mines European competition Public consultation via a web platform
Permit is issued	Prefectural decree, valid for 3 years	Ministerial decree, valid for 5 years
Authorization of Exploration Work	Administered by the prefecture Organization of a public inquiry	
Commissioning of the plant	Administered by the prefecture Registry of public consultation	
Concession application	Administered by the prefecture Organization of a public inquiry (valid for 50 years, renewable for a period of 25 years)	

consultations only involve municipalities or groups of municipalities likely to be impacted by development projects. The publicity surrounding the consultation is rather limited and the documents made available to the public are generally difficult to understand by citizens unfamiliar with science and technology: "Their function seems to be more to satisfy legal requirements […] than to encourage participation" (Blatrix 1996, p. 302). However, these consultations are often seen as an indication of whether or not a project is accepted by inhabitants. Thus, according to prefectures and operators, low participation in EPs is equivalent to unconditional acceptance of the project. In practice most EPs for low temperature permits or projects have received few, if any, citizen input. As a consequence, all these projects have been validated by the relevant prefectures. However, the EPs can also become a platform for expressing protest, as was the case during the consultations on cogeneration projects in Alsace, Haute-Savoie and Reunion Island.

An examination of these protests reveals at least five types of criticism.

1. The inhabitants criticize deep geothermal energy because of the various consequences that drilling can have on their environment, such as induced seismicity, groundwater pollution, radioactive upwelling, and even the risk of explosion (related to the use of isobutene during the transformation of heat into electricity). It is in urban areas that the issue of risk is most sensitive and sometimes takes precedence over any other consideration. In Strasbourg in particular, a drilling project located within an industrial zone classified as high risk area, according to the Seveso European directive, where a large quantity of hydrocarbons and chemicals are stored, caused a wave of hostility. A consensus was quickly reached against the project leading the operator to back down.

2. The imprint of a project on its natural environment was at the heart of the criticisms of the project on Reunion Island in 2005. Drilling on dry rock (Hot Dry Rock) was to be carried out in *La plaine des sables*, a tourist zone classified as a natural park and for which the inhabitants hoped for UNESCO recognition as a world heritage site. Several local NGOs mobilized until the project was abandoned in 2010. The debate resurfaced in 2016, when a new exclusive licence to prospect was requested from the Ministry for the Salazie-Cilaos area outside the enclave of the natural park.
3. The lack of hindsight on the EGS type of deep geothermal energy is pointed out. Indeed, the cogeneration projects that were to see the light of day in Alsace and Haute-Savoie are the first of their kind in Mainland France. Hence, numerous opponents to these projects refer to uncertainties in regards to seismic risk and call for the application of the precautionary principle. This argument has taken on a particular dimension in Alsace, where local scientists have stressed that further research is needed to better understand the behaviour of naturally cracked rocks when by opponents exploiting deep aquifers. Referring to these statements, geothermal energy has often been qualified as a non-mature technology during public enquiries and the promoters as sorcerer's apprentices.
4. Several activist groups criticize the very idea of producing electricity from geothermal heat. Alsace Nature, which federates the main Alsatian environmental associations, points out the low expected returns (the rate of 10% is often brought up). Opponents and elected officials in Haute-Savoie, on the other hand, point out that their department already produces enough electricity via hydroelectric power stations, which have much better yields. Finally, and more generally, the economic model underlying cogeneration is usually criticized. Opponents argue that electricity generation is about enriching businesses rather than contributing to the evolution of local energy mixes towards more renewable energy.
5. Finally, many arguments attempt to discredit the companies involved: their youth and lack of experience, their inability to present clear files at the time of public enquiries, their quest for profits, etc. Many opponents argue that it would be dangerous to leave risky projects in the hands of unknown companies. In this context, locally based companies seem to be more protected from criticism, as is visible in Alsace in the competition established between the local operator *Electricité de Strasbourg* and the Aquitaine based Fonroche. In Haute-Savoie, groups of elected officials argue that the geothermal energy projects (considered as experimental) should be equally backed by the company, scientific laboratories and local authorities. Similar calls were made in Guadeloupe when the Bouillante plant was handed over to the American group Ormat.

These arguments are made by organized collectives. Leadership sometimes comes from residents' associations, sometimes from elected officials or environmental protection associations, who manage to mobilize citizens by various means: organization of public meetings, publication of the municipal council's or neighbourhood councils' deliberations, use of media platforms (blogs, local press or associative press). Citizens who are alerted and involved in this way are likely to make a significant contribution to public enquiries. What's more, their arguments demonstrate a form of technical, economic and political expertise towards the projects (Chavot et al. 2016). In these circumstances, the opposition thus formed may seem legitimate and credible in the eyes of the investigating commissioners in charge of the public inquiries: indeed, they come to a negative conclusion regarding the project in three out of four consultations conducted in spring 2015 within the Eurometropolis of Strasbourg,

These controversies have real implications for a project's dynamic. In Alsace, two projects that should have taken place in the Eurometropolis of Strasbourg (EMS) have been abandoned by the operators. In Haute-Savoie, no action is taken on applications for low and high temperature licences, which equates to a refusal by local prefecture and supposedly the ministry of mining. However, the public inquiry only has a consultative value. Thus, in Alsace, the prefecture invalidated the investigator's conclusions by deciding to publish a decree authorizing exploration works on one of the contested projects. The arguments put forward to justify this decision underline the project's value to the community and towards energy transition. In this case, the prefecture has taken little account of the criticisms expressed. It has considered them as expressions of individual interests or fears that could be addressed through appropriate communication. Thus, monitoring committees have been set up for this project as well as for two others who benefited from a favourable prefectural decree in 2017.

2.3 Acceptability Surveys and Sociological Work on the Public

Several types of studies have been carried out to have a better knowledge of the inhabitants, mainly in Alsace. They involve either the companies or social science researchers. The 2012 study on the "acceptability of risks related to deep geothermal energy" around the Soultz-sous-Forêts power plant is one of the first of its kind in France (Lagache 2012). The aim was for the ESG operator to understand how the inhabitants perceive the nuisances or risks associated with the operation of the plant. Indeed, until the hydraulic stimulation phase stopped in 2005, several micro-seismic events of up to 2.9 amplitude on the Richter scale were felt by the population. A quantitative survey was therefore carried out among the inhabitants of the two villages surrounding the power plant. This survey was also thought of as a moment of exchange and communication with the inhabitants. The latter obtained information about the power plant through investigators or various didactic materials.

On analysis, this survey gives the impression that the inhabitants are not bothered by the presence of the power plant. Noise (56.7%) and seismicity (55.7%) are the two most frequently cited “known nuisances”.[21] But only 25.6% of the population mention that the site’s activity could become troublesome, and 17.2% believe they are at risk. However, the installation of a geothermal power plant near one’s home does not seem to be widely accepted, since only a minority (32.2%) would not mind it. In a publication (Lagache et al. 2013), the authors of the study point out that the perception of geothermal energy is rather positive, while stressing that it remains difficult to measure the acceptability of risk, since the latter would remain subjective data. They also conclude from the survey that residents are little or poorly informed. According to the authors, this is evidenced by the fact that the inhabitants are not very sensitive to the site’s benefits (only 39.4% believe that the site has an economic impact on the territory). It is therefore important, according to the authors, to continuously inform the inhabitants so that they also become aware of the benefits of deep geothermal energy. Further acceptability studies will soon be carried out by operators in northern Alsace and near a planned site in the South West of France.

In the spring of 2015, following criticism of geothermal projects in the Eurometropolis of Strasbourg, the labex G-EAU-THERMIE Profonde of the University of Strasbourg set up a working group on social sciences. A first research project entitled «How to deal with a public inquiry? Views from residents and deep geothermal projects stakeholders in Alsace» (ORAGÉO) aims to study the public enquiries and in particular to follow the progress of those organized in spring 2015. Three *corpuses* are compiled and analysed. The first concerns all opinions and documents produced in the course of the public inquiries and observations made at the investigation sites. The second focuses on media discourses and the communication of the actors (daily regional press, blogs and documents from associations, declarations and public meetings…). Finally, a series of qualitative interviews was conducted with various stakeholders, whether or not they are engaged in the controversy (industrialists, scientists, representatives from the associations, elected officials, experts commissioned by the prefectural authorities, investigating commissioners, etc.).

Three important observations come out of this study. First of all, there is a significant gap between the discourse on geothermal energy from the project promoters and the way in which the inhabitants perceive these projects. The former speaks of geothermal energy in very general terms, highlighting the objectives pursued and its usefulness towards energy transition and building a local energy mix. However, the inhabitants are first and foremost interested in the concrete and local impacts of these projects on their territory, and in particular the risks and benefits for their community.

Secondly, the views and arguments of each party are publicized very differently. While the regional daily newspapers tend to follow local authorities and, to a lesser extent, the project promoters in their communications, the associative press and blogs are relays for the opposition. However, the information is not treated the same

[21]Corrected data based on Lagache 2012.

way in each of these media. On the one hand, the local news media talk about geothermal energy according to classical journalistic standards, claiming "objectivity". On the other hand, blogs and the associative press claim to be a partisan informant towards internet users or local residents and deliver content that is much more in-depth and argued, and above all closer to the readers' daily lives.

Thirdly, the organization of public enquiries plays a decisive role in the dynamics of a controversy, but does not allow projects to be renegotiated. The files submitted to the public enquiries by operators reveal well-defined projects. They specify the location of boreholes, the measures taken to control risks, as well as the possible impacts on the natural and human environment. The way in which these files are made can only arouse support or rejection by the local residents. And indeed, only a few citizens' contributions are aimed at making the projects evolve, with the notable exception of those coming from environmental protection associations. Most are aimed at discrediting the projects. In this context, the part played by the investigating commissioner may be crucial. Its role can be compared to that of a *gatekeeper* (White 1964): it selects, preserves, and rejects elements and arguments put forward by inhabitants, associations, elected officials and operators to draw up its own subjective opinion. In the case of the contested Strasbourg projects, the Commissioners rely heavily on citizens' contributions, stressing that the operators have not been able to provide sufficiently convincing and reassuring information. Moreover, their negative conclusions took into account the social and political context, notably the unfavourable social climate and the lack of commitment from the Eurometropolis of Strasbourg towards these projects.

The involvement of the social science working group in a second project, which is supported by the Labex, as well as in the European H2020 DESTRESS project, allows it to address the issue of the perception of geothermal energy more broadly. Researchers are now interested in the construction and circulation of views on deep geothermal energy in urban and rural contexts. This research calls for a variety of tools: exploratory interviews with the various stakeholders (industrialists, elected representatives, associations, journalists); survey by questionnaires of opinions and representations of deep geothermal energy in urban and rural areas; analysis of media discourses (press, television, radio, blogs, communications from local and regional authorities); organization of comprehensive interviews and focus groups with local residents.

Four zones are investigated, three within the EMS and one in northern Alsace, which correspond to locations where deep geothermal projects are being implemented at different stages of development. Two geothermal projects are supported by local operator ES and two others by its competitor Fonroche. This work makes it possible to test different hypotheses in order to better understand changes in attitude of the inhabitants towards geothermal energy:

- H1. The perception of the risks and benefits of geothermal energy varies according to the way people experience and give meanings to their territory of life.

The most contested project is the one that was to be set up in a Seveso area, while the inhabitants have been fighting for a long time to reduce the dangerousness of the area. Conversely, there is very little opposition to geothermal energy in northern Alsace, where pilot sites have been set up and new projects are being defined. This is an area where many oil wells have been drilled in the past, and residents and elected officials see the exploitation of underground resources as a real source of economic development.

- H2. The way in which local authorities invest in the field of RES, notably through their climate plan, plays an important role in adherence to deep geothermal projects.

Thus, to the south of Strasbourg, a project currently being drilled appears to be well integrated into local politics and there is little controversy, as with projects located in Northern Alsace. This is not the case in Haute-Savoie, where the exclusive licence to prospect application was rejected in part because the project went against the framework of the community climate plan.

- H3. More generally, the local roots of a project influence how it is perceived by the inhabitants.

Labex researchers distinguish between projects “anchored” in the territory, on the one hand, which are the outcome of a long concerted maturation between different actors, and “off-ground” or unrooted projects, on the other hand, elaborated in favour of economic advantages and/or national political programs, often ignoring the specificities of the local territory (Chavot et al. 2017). And it is very often the unrooted projects that prove to be the most contested, as is visible in Alsace and Haute-Savoie. This type of project is often viewed by people in terms of costs and benefits: the local residents consider that the risks incurred are higher than the benefits they could obtain from such projects.

As part of the DESTRESS project, the perception of geothermal energy is studied in connection with two locally anchored projects and two off-ground projects.

3 Conclusions

The national energy policy implemented in France since the beginning of 2010 has undeniably favoured the development of geothermal energy. It has notably enabled a renewal of district heating geothermal projects and assisted the first cogeneration projects. The targets for 2020 set by ADEME and BRGM are as follows[22]:

[22]Source: http://www.geothermie-perspectives.fr/article/production-denergie-geothermique-en-france#chiffres-pac (accessed on 02/26/2018).

- Individual ground-source heat pumps: 7000 GWh
- Intermediate geothermal energy (probe fields, groundwater heat pumps for collective buildings and for tertiary use, thermoactive foundations, etc.): 2900 GWh
- Deep geothermal energy (heat networks): 5800 GWh
- Electric geothermal energy: 80 MWe.

As we have seen, small and medium-scale projects have developed without controversy. This is not the case for those aimed at cogeneration of heat and electricity. The innovative and therefore potentially risky aspect of these deep geothermal projects is more or less well accepted locally. In addition, these projects involve state policy, local government policy and industrial interests. In this context, local elected officials and citizens feel they have a say.

However, deep geothermal energy projects depend on the Mining Code, which gives companies and the state full powers to exploit the wealth of the subsoil. Thus, this type of regulation tends to encourage "off-ground" projects, since it is not necessary, according to the Mining Code, to consult with local authorities ahead of the projects. Nonetheless, citizens are consulted alongside the environmental code since these projects are likely to have an impact on the environment or on the quality of life of local residents. Thus, the implementation of deep geothermal project generates a contradiction between the Mining Code and the Environmental Code in terms of "local democracy". And this contradiction is not without provoking political dissents at the local level.

But the new energy policy tends also to encourage local and regional authorities to draw up climate plans and develop a local energy mix, especially to supply heat to district heating networks. Within this framework, a number of locally anchored projects, based on cooperation between territorial and industrial authorities, have emerged, as is the case in the south of Strasbourg. Projects in Northern Alsace are also taking this form. Although these projects are not co-constructed with the population, they do reflect local identities and generate little opposition.

The controversies that emerged in the 2010s reveal the tensions between the imposition of off-ground projects and the dynamics already present at the local level. The outcome of the controversy will depend on how the local and regional authorities will be able to accommodate or not the projects initiated by industrialists. Thus, in Haute-Savoie, the projects were postponed due to unmanageable opposition from local authorities and local residents. In Alsace, the Eurometropolis of Strasbourg has opted to integrate off-ground projects into its energy policy. However, the adherence of local residents to this policy is not yet guaranteed, and controversy persists over certain projects.

The preliminary results of the social science studies carried out in Alsace show that local residents want to influence their territory's future, especially regarding the issue of energy. In what spaces will they be able to express themselves and be heard? An experiment is currently being carried out within the EMS: the public is invited to contribute to the definition of the future 2030 Climate plan through their participation in public meetings and online platform. Is this framework capable of fostering citizen participation? And will local residents most involved in the life or defence of their territory recognize themselves in this type of device?

Acknowledgements This chapter is based on research carried out within the context of the activities of the Social Sciences working group of the Labex G-EAU-THERMIE profonde (University of Strasbourg, CNRS, Electricité de Strasbourg) and was conducted within the framework of the WG 3.3 “risk governance” of the H2020 project DESTRESS, Desmonstration of soft stimulation treatments of geothermal reservoirs (http://www.destress-h2020.eu/en/home/). We would like to thanks Christine Heimlich for her critical reading of earlier versions and Nicolas Daignault for his work on the English version of the text.

References

AFPG (2016) La géothermie en France. Etude du marché en 2015. AFPG, Paris. http://www.afpg.asso.fr/telechargements/

Blatrix B (1996) Vers une démocratie participative? Le cas de l’enquête publique. In: Chevallier J (ed) La gouvernabilité. PUF-CURAPP, Paris, pp 299–313

Boissavy C, Rocher P, Laplaige P, Brange C (2016) Geothermal energy use, country update for France. Paper presented at the European Geothermal Congress 2016, Strasbourg, 19–23 Sept 2016. https://www.researchgate.net/publication/316828506

Chavot P, Masseran A, Serrano Y (2016) Information and public consultation exercises concerning geothermal projects. “The Strasbourg case”. Paper presented at the European Geothermal Congress 2016, Strasbourg, 19–23 Sept 2016

Chavot P, Masseran A, Serrano Y, Zoungrana J (2017) Penser l’énergie localement? Le cas de la géothermie profonde dans l’Eurométropole de Strasbourg. Paper presented at the 14th symposium of the Association française de science politique. Montpellier, 10–12 July 2017

Demarcq F, Vernier R, Sanjuan B (2014) Situation and perspectives of the Bouillante geothermal power plant in Guadeloupe, French West Indies. Paper presented at deep geothermal days, Paris, 10–11 Apr 2014

Guillou-Frottier L (2003) Compilation et analyse des données thermiques sur le champ géothermique de Bouillante. Rapport final. BRGM/MRP-52452-FR

Hecht G (1998) The radiance of France: nuclear power and national identity after world war II. MIT Press, Cambridge

Lagache L (2012) Étude sur l’acceptabilité des risques liés à la géothermie profonde. Master Dissertation, Université de Lyon

Lagache L et al. (2013) How is evaluated acceptability of an EGS project in Europe: the Soultz-Kutzenhausen geothermal project? Paper presented at the European Geothermal Congress 2013, Pisa, 3–7 June 2013

Laplaige P, Durimel H, Mompelat JM (2013) Développement de la géothermie dans la Caraïbe. Geosciences 2013:26–35

Labussière L, Nadaï A (2015) L’énergie des sciences sociales. Alliance Athéna, Grenoble

Topçu S (2013) La France nucléaire. L’art de gouverner une technologie contestée. Seuil, Paris

White DM (1964) The ‘Gatekeeper’: a case study in the selection of news. In: Dexter LA, White DM (eds) People, society and mass communications. The Free Press of Glencoe, New York, pp 160–172

Social Aspects of Geothermal Energy in Greece

Spyridon Karytsas, Olympia Polyzou and Constantine Karytsas

Abstract Greece is a country with high geothermal energy potential; through the research that started over 40 years ago, a significant number of geothermal fields have been identified. Yet, its utilisation is rather limited, as it is exploited solely through direct uses. This means that there is a total absence of power production through geothermal energy, which to a great extent is due to the local societies' opposition created by the bad experience of the Milos Island pilot power plant (1970–80s). Deficiencies and errors made during construction and operation led to environmental pollution, resulting to the strong reactions of the residents. This has affected the attitude of local communities and authorities against the large scale exploitation of high temperature deep geothermal resources (any use of geothermal energy with heat extraction, for resources with temperatures above 90 °C) until today in various areas; on the contrary, low temperature deep geothermal (any use of geothermal energy with heat extraction, for resources with temperatures between 25 and 90 °C) utilization is perceived much more positively. Until now most attempts made for the exploitation of geothermal fields are characterised by the lack of local societies' awareness, involvement and engagement. The conducted literature review shows that public attitudes and awareness are at a rather medium to low level. Exploiting the large potential of geothermal energy requires increase of awareness and improvement of the lost confidence of local societies towards high temperature deep geothermal exploitation.

Keywords Greece · Geothermal energy · Social acceptance · Public awareness

S. Karytsas (✉) · O. Polyzou · C. Karytsas
Center for Renewable Energy Sources & Saving, 19th km Marathonos Ave, 19009 Pikermi, Greece
e-mail: spkary@cres.gr

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_9

1 Geographic, Demographic and Economic Information

Greece is a south-eastern European country, located at the southernmost end of the Balkan Peninsula. It has common land boarders, from northwest to northeast, with Albania, FYROM, Bulgaria and Turkey respectively. Greece is strategically located at the crossroads of Europe, Asia, and Africa, at the east part of the Mediterranean Sea. The country is a member of the European Union (1981), Eurozone (2001), NATO (1952) and a founding member of United Nations (1945). It is a developed country with a high per capita income, human development index and quality of life. Administratively, Greece is separated into 7 decentralised administrations, 13 regions and 325 municipalities (Law 3852/2010). The population of Greece is around 10,800,000 (Hellenic Statistical Authority 2011); nation's capital and largest city is Athens.

The Greek terrain is mainly mountainous or hilly; a big part is dry and rocky, with only 20% of the land being arable. Greece is rich in mineral resources; it is a leading country in the European and international market in products such as lignite (EURACOAL 2016), bauxite, alumina, aluminium, nickel, magnesite, caustic magnesia, bentonite, perlite, pumice stone, attapulgite, huntite and marble [Ministry of Environment and Energy n.d. (a)]. Gold, copper (Tsirampidis and Filippidis 2013) and rare earth elements can be also found (Melfos and Voudouris 2012). Oil is extracted from the Kavala-Thassos area (Tsirampidis and Filippidis 2013), while explorations for extraction are being carried out in Western Greece and south of Crete (Ministerial Decree Δ1/A/12892/2014).

The Greek climate can be described as a Mediterranean type temperate climate, characterised by mild wet winters and hot dry summers. The country's climate can be divided into four main categories, namely: wet Mediterranean, dry Mediterranean, continental and mountainous.

Greece can be characterised as a medium power, due to its geostrategic importance, remarkable shipping sector, large tourism industry and unique cultural heritage; it is the largest economy in the Balkans and serves as an important regional investor. Greece has a mixed capitalist economy, which is based on the service sector (80.9%), followed by the industry (15%) and the agriculture sector (4.1%) (GDP 2016 estimates) [Central Intelligence Agency n.d. (b)]. Shipping and tourism are the most important sectors of the Greek economy, while the largest industries are food and tobacco processing, textiles, chemicals, metal products, mining and petroleum [Central Intelligence Agency n.d. (a)].

The Greek economy had an average growth of about 4% per year between 2003 and 2007. Since the end of 2009 Greece has been facing an economic recession, due to the world financial crisis, tightening credit conditions, and failure to address a growing budget deficit. Ever since, the country has signed three bailout agreements with the European Commission (EC), the European Central Bank (ECB), the International Monetary Fund (IMF) and the European Stability Mechanism (ESM). The bailout agreements came along with rigorous austerity, in order to control government spending; this policy has led to economic recession and high levels of unemployment. By 2013 the economy had contracted 26%, compared with the pre-crisis level of 2007. In 2016 Greece experienced a slight improvement in GDP and unemployment; however, the economy remains in stagnation due to incomplete economic reforms, the massive loan problem and continuing political uncertainty [Central Intelligence Agency n.d. (a)]. Major challenges of the Greek economy are the reduction of unemployment, facing productivity deficiencies, reforming social security, correcting the tax system, tackling tax evasion [some estimates put Greece's shadow economy at 20–25% of GDP (Schneider 2015)] and the minimization of bureaucratic imperfections.

1.1 Energy Statistics

The energy mix of Greece differs from the average of EU28, as there is a much higher use of oil and solid fuels, a lower use of natural gas, while no nuclear plants exist; the share of RES (Renewable Energy Sources) continuously increases during the last years. Primary production of energy in Greece during 2014 was 17.4 Mtoe, i.e. 1.6 toe/inhabitant (EU's average was 1.7 toe/inhabitant). In order to satisfy demand, Greece is reliant on primary energy imports; in 2014 net primary energy imports were 17.4 Mtoe. The energy dependence in 2014 was 66.2% (EU's average was 53.5%), being rather steady during the decade 2005–2014 (between 62.2 and 73.3%). Gross inland energy consumption in Greece in 2014 was 24.4 Mtoe, almost 30% lower than in 2010 and about the same level as 1995. Final energy consumption in Greece in 2014 was 15.6 Mtoe; it had been increasing slowly since 1990, peaked around 2005, and since then has been decreasing. The 2014 value is about 25% lower than the 2005 one. The structure of final energy consumption in 2014 by sector shows that 42% of energy was consumed for transport, 38% by households, trade, services, etc. and 20% by the industry. The impacts of the economic crisis are visible through the energy imports and energy consumption indicators, as the values are lower after 2009, compared to the pre-crisis period (Eurostat 2016).

The primary production of renewable energy in Greece for 2014 was 2.4 million toe; the proportion of produced renewable energy increased by 48% between 2004 and 2014. The most important RES was biomass and waste, accounting for 47.1% of primary renewable production in 2014. Solar energy (22.2%) was in the second place, followed by hydropower (16.5%) and wind energy (13.6%); geothermal energy (0.5%) accounted for a very small portion of primary renewable production. RES accounted for 10% of Greece's gross inland energy consumption in 2014 (biomass and renewable wastes, 5%; solar, 2.1%; hydropower, 1.6%; wind 1.3%). The share of renewables in gross final energy consumption was 15.3% for Greece in 2014, with the country's 2020 target being set at 18% (heating & cooling target set at 20%, electricity at 40% and transport at 10%) [Eurostat 2017; Ministry of Environment and Energy n.d. (b)].

Based on the same year's data, electricity generated from RES was 21.9% of the country's gross electricity consumption (EU's average was 27.5%). The increase in the percentage of electricity generated from RES between 2004 and 2014 is over 180%. This is mainly due to the large increase of PV and wind farm installations (Eurostat 2017). The share of RES in heating and cooling in Greece was 26.9% in 2014, with the EU-28 average being 17.7% (Eurostat 2016). The percentage of RES in transport fuel consumption in Greece was 1.3% in 2014, with the EU-28 average being 6.5% (Eurostat 2017).

1.2 Geological Background of Greece

Greece is a natural geological laboratory, which enables the understanding of the current geodynamic process of the Greek arc (including earthquakes, volcanoes, coastal movements, existence of faults and fracturing of rocks and other geological processes). The country presents a complex geological structure with a wide variety of geological formations, as a result of its complex geological history and evolution. Geotectonically, Greece is part of the southern edge of the Euroasiatic plate which has been fragmented due to the process that is taking place in the south Aegean, where the African plate is sliding under the European plate.

The Greek territory is characterized by high levels of heat flow (more than 80 mW/m^2), especially in the internal Hellenides (sedimentary basins of north-eastern Greece) and Aegean Sea, due to active tectonic and volcanic activity. The strong tectonic and volcanic activity has caused the appropriate geological conditions for thermal energy agglomeration, which is characterized as hydrothermal systems of low and high temperature geothermal fields (Fytikas et al. 2005).

High temperature geothermal fields are located along the Southern Aegean volcanic arc (Milos and Nisyros Islands), where low temperature geothermal fields are correlated with grabens (Central Aegean) and post-orogenic sedimentary molassic basins (southern boundaries of the Rhodope and Servo-Macedonian Massifs) (Fytikas et al. 2005). The deep water circulation along the faults in grabens has created a large number of low temperature fields (e.g. Easter Macedonia and Thrace, Chios Island, Euboea, Central Greece) in the whole country (Arvanitis 2011) (Fig. 1).

1.3 Geothermal Fields in Greece

The geological conditions in Greece have generally contributed to the creation of a significant number of geothermal fields, characterizing the country as one of the most favoured ones' in terms of geothermal potential.

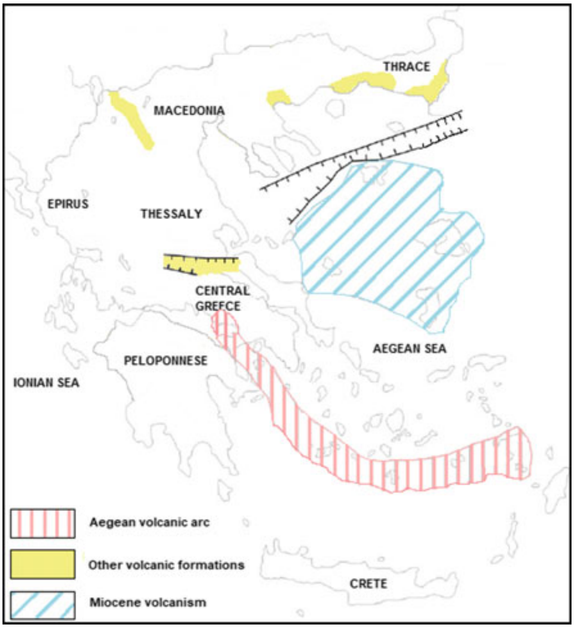


Fig. 1 Main geotectonic structures in Greece

Geothermal energy is distinguished depending on temperature fluids in (a) high temperature (>90 °C), (b) low temperature (25–90 °C) and (c) shallow geothermal (<25 °C), according to Greek Law 3175/2003.

Until now, more than 55 geothermal fields have been identified in total. According to their geographical characteristics, the geothermal fields in Greece are quite scattered and their distribution density differs due to different geological conditions in each region. The large number of geothermal fields in Macedonia, Thrace and the Aegean Islands (Fig. 2) should be noticed. In at least 50 geothermal fields the fluids' temperatures range from 25 to 90 °C, mainly in depths <500 m; their potential has been estimated to 1,000 MWth, although until now only 9% of it is being exploited (Papachristou et al. 2016). In more than 5 of the geothermal fields the fluids' temperatures range from 90 to 125 °C, while in two fields, the temperature is higher than 150 °C; 325 °C in Milos Island and 400 °C in Nisyros Island (Fig. 2), which are the most important high temperature deep geothermal systems in Greece. The proven geothermal potential of Milos and Nisyros Islands is over 30 MWe, while it is estimated that it can reach even a level of 230 MWe (Papachristou et al. 2016).

Geothermal energy is exploited in Greece exclusively through direct uses, in thermal spas, greenhouses, soil heating, fish farming, aquaculture, agricultural products drying and GSHPs (Ground Source Heat Pumps); most geothermal applications, with the exception of thermal spas, are located in northern Greece. The total installed capacity of geothermal applications in mid-2016 was 232 MWth, with GSHPs accounting for 64%, thermal spas for 18% and greenhouse heating for

Fig. 2 Geographical distribution of geothermal fields

14.5% of this capacity. During the last years, the Greek geothermal market has grown mainly due to the increase of GSHP system installations (Papachristou et al. 2016).

1.4 Stakeholders Involved in the Geothermal Sector

All high and low temperature geothermal fields in Greece belong to the state. The Ministry of Environment and Energy, assisted by the Institute of Geology & Mineral Exploration, is responsible for the exploration of all geothermal fields. Concerning exploitation permissions, the Ministry of Environment and Energy is responsible for the high temperature deep geothermal resources, while the Secretary-General of the corresponding decentralised administration is responsible for the possible and proven low temperature deep geothermal resources. Either public or private bodies can exploit high and low temperature geothermal fields through a lease for a specific period of time; in order to do so, a tender process is necessary. The tender procedure is initiated either by the state's plans for developing a field, or by the interest of a specific public or private body.

The permission procedures for utilizing shallow geothermal energy are simpler, as long as the application is not located within a proven or possible geothermal field. The permission is provided by the corresponding administrative region. There are several companies active in the GSHPs sector, offering drilling, installation and design services; there are also a small number of heat pump manufacturers.

Most of the proven geothermal fields with temperatures higher than 100 °C have been granted to Public Power Corporation Renewables S.A. for the construction of small (5–8 MWe) power plants; these fields are the ones of Milos-Kimolos-Polyaigos, Nisyros-Kos and Lesvos Islands, as well as Methana.

An international tender process was performed in 2011, for the exploration of high temperatures for the geothermal fields of Chios Island, Samothraki Island, Evros River Delta and Nestos River Delta. The fields were assigned to TERNA ENERGY S.A.—ITA, while the other companies participating in the tender were ENEL S.A., ORMAT, Hellenic Geothermal Holdings Corp., Public Power Corporation Renewables S.A. and Aegean Energy S.A. Until now, no progress has been made regarding the exploration of the fields, as the company withdrew from the project.

Concerning other stakeholders involved in geothermal activities, the Institute of Geology & Mineral Exploration contributes to the research and estimation of geothermal resources and their sustainable management. The Center for Renewable Energy Sources and Saving, which is the national centre for RES, rational use of energy and energy saving, also assists to the development of geothermal energy through research projects, the conduction of workshops, seminars, feasibility studies and other services (e.g. Thermal Response Tests).

2 Public Engagement Activities/Social Acceptance Assessment in Greece

2.1 Review of Social Science Studies on Geothermal and Other Renewable Energies

The literature review on social studies concerning geothermal energy -including public knowledge, acceptance and attitudes- revealed that there is a very small number of social studies focusing exclusively on geothermal energy; these studies are presented in Sect. 2.2. However, individual findings related to social issues of geothermal energy have been identified in studies and reports dealing either with RES in general, or with specific RES such as solar and wind energy—two energy sources rather popular in Greece. Based on the findings of these studies (Table 1), it is clearly indicated that knowledge, awareness and positive attitudes towards geothermal energy in Greece can be characterised as average to low. People are much more favourable of energy sources such as solar and wind power, with geothermal energy and its applications being one of the least preferred RES.

2.2 Social Studies Focusing on Geothermal Energy

2.2.1 Desalination Plant in Milos Island

A study investigating local residents' views and opinions on the effects of the construction of a desalination plant—basing its operation on geothermal energy—on Milos Island was released in 2004. A survey involving key informants from local government, state agencies, trade unions, social agencies and developmental policy-making agencies was conducted in 2000, leading to the collection of 100 responses. All respondents knew quite well the different geothermal fields that have been recorded on the island. The participants were quite cautious, even negative, regarding the exploitation of geothermal energy—in particular high temperature deep geothermal energy. This is due to the negative experience that Milos had with the geothermal pilot power plant that operated during the 1980s and caused great ecological impact to the local environment, extensive air pollution and soil contamination. According to the respondents, the most preferable energy needs that could be covered by geothermal energy are, in descending order, drinking water, irrigation, heating/cooling of buildings, development of winter tourism and production of electric energy (Manologlou et al. 2004).

2.2.2 Geothermal Development in Milos and Nisyros Islands

A social survey investigating the attitudes of Milos and Nisyros Islands' residents towards geothermal energy was conducted during 2004 (Polyzou 2007; Polyzou and Stamataki 2010); 250 and 90 responses were collected respectively from the two islands. Aim of the survey was to record and analyse the local societies' opinions regarding geothermal energy development, in order to identify the main factors that cause reactions against geothermal energy and to highlight the basic axes of the interventions that should be applied. The majority of Milos (M = 86.8%) and Nisyros (N = 95%) residents knew what geothermal energy is. Main source of information and knowledge was personal experience (M = 79%, N = 72%), while the effect of the imprint and electronic mass media was negligible, confirming the absence of state policy and interest to inform the public and to promote awareness intervention activities.

The vast majority in Milos (82.5%) believed that geothermal energy is a polluting activity. Tourism-related occupation was not found to be related to higher levels of environmental sensitivity. In Nisyros the situation was slightly different, as less (68.2%) respondents believed that exploitation of geothermal energy had an

Table 1 Studies and reports including individual findings related to social issues of geothermal energy in Greece

References	Aim of study	Sample type	Sample size	Time period	Findings
Tzanakaki and Mavrogioros (2005)	Public acceptance of various energy saving solutions and RES technologies	Participants of RES and Energy Saving themed open-days in 5 Greek cities	141	2001–2002	Importance of geothermal energy was evaluated with a mean of 3.5 on a 5-point Likert scale, thus ranking it 4th among 5 different RES
Eurobarometer (2006)	Knowledge, attitudes and perceptions of energy issues	General population of Greece	1,000	2006	In the context of energy production, 37% of the respondents had heard of geothermal energy
Spiropoulou et al. (2007)	Perceptions on environmental issues and attitudes	In-service primary school teachers	188	Not available	Most respondents identified geothermal energy as a non-renewable source
Liarakou et al. (2009)	Knowledge and attitudes towards RES, particularly wind and solar energy systems	Secondary school teachers of the town of Rhodes	121	2006	21.5% of the respondents knew that geothermal energy is a RES, thus having the 4th highest percentage among 6 different RES
Koundouri et al. (2009)	Public attitudes towards renewable energy generation and willingness to pay for the construction of a wind farm in Rhodes Island	Adult population of the area of the wind farm construction site in Rhodes Island	200	2007	19% of the respondents were informed on electricity production by geothermal energy (9th among 13 different energy production means), while 36% agreed with the use of geothermal energy in Greece (6th among 13 different energy production means)
Sardianou and Genoudi (2013)	Determinants of consumers' willingness to adopt renewable energies in the residential sector	Greek consumers	200	2009–2010	38% of the respondents were informed about the potential residential use of geothermal energy, thus ranking it 4th among 5 different RES

(continued)

Table 1 (continued)

References	Aim of study	Sample type	Sample size	Time period	Findings
Tampakis et al. (2013)	Satisfaction with the quality and availability of electricity on Andros Island and the installation of wind turbines	Electrical energy consumers of Andros Island	292	2010	Environmental friendliness of geothermal energy scored a mean of 6.71 on a 10-point Likert scale, thus ranking it 4th among 10 different energy sources and 4th among 5 different RES
Tsoutsos et al. (2013)	PV stakeholders' attitudes, perceptions and considerations	PV owners from Greece, Cyprus, Bulgaria, Romania, Croatia and Spain	Not available	2010	24% of PV owners would advise a friend to invest in GSHPs, with the corresponding percentages for PVs and solar thermal collectors being respectively 93 and 27%
Skoupra (2013)	Identification of factors for the acceptance of RES installations by consumers –with emphasis given on wind and solar energy	Population of Larissa, Lasithion and Attica Prefectures	396	2013	51.5% stated that knows geothermal energy, thus ranking it 3rd among 5 different RES, being slightly higher than hydro power (4th) and biofuels (5th)
Dimitriou and Pimenidis (2015)	Local authorities' knowledge and attitudes on energy production, energy management, energy consumption and RES, as well as their energy practices and intentions	Elected representatives of local authorities (municipalities and prefecture) of Rhodes Island	12	2015	In the context of application of RES technologies in public services, facilities and buildings in their area of responsibility, 20% of the respondents believed that geothermal systems can be absolutely applied, 40% that they can be considerably applied and the remaining 40% that they cannot be possibly applied
Ntanos et al. (2016)	Public awareness on various RES	Students and staff members of the Piraeus University of Applied Sciences in Greece	200	2015	Knowledge of geothermal energy was evaluated as rather low (4.5% very good; 14% good; 22% fair; 26.5% poor; 33% very poor), while importance of

(continued)

Table 1 (continued)

References	Aim of study	Sample type	Sample size	Time period	Findings
					geothermal energy was ranked 6th among 9 different energy sources (5th between 6 different RES)
Keramitsoglou (2016)	Knowledge, perceptions and attitudes towards RES, in order to detect specific educational needs of high school students	Two high schools of the town of Didimoticho	234	Not available	On a 5 point Likert scale, geothermal energy was evaluated mainly as very environmentally friendly, friendly and less or more friendly; it was ranked 7th among 15 energy sources and 6th among 9 different RES. 18.8% valued geothermal energy as very important, 22.6% as important, 35% as neither important nor unimportant, 16.7% as a little important and 6.8% as not important; thus, it was ranked 5th among 9 RES
Koutroumpi and Saltaoura (2016)	Social acceptance of RES and PVs in particular	Half from Attica Prefecture and remaining half from the rest of Greece	201	Not available	Knowledge of geothermal energy was average (mean of 2.54 on a 5-point Likert scale), ranking it last among 5 different RES; importance of geothermal energy had a mean of 3.16, thus being ranked 5th among 9 different energy sources and 4th among 5 different RES. The importance of geothermal heating and district heating had a mean of 3.02 on a 5-point Likert scale, ranked last among 7 different RES applications

(continued)

Table 1 (continued)

References	Aim of study	Sample type	Sample size	Time period	Findings
Fanourgaki and Mauroudi (2017)	Social acceptance of green investments and evaluation of green investments by consumers	Half from Attica Prefecture and remaining half from the rest of Greece	280	2015–2016	Knowledge of geothermal energy was below average (average of 2.1 on a 5-point Likert scale), thus being ranked last among 5 different RES; the importance of geothermal heating and district heating had a mean of 2.94 on a 5-point Likert scale (ranked 6th among 7 different RES applications)
Petrakopoulou (2017)	Use of renewable energy as part of an energy autonomy plan on Skyros Island	Residents of Skyros Island	183	Not available	Residents tended to be more open to new installations of solar, wind and geothermal energy, while they directly rejected nuclear power and coal plants

environmental impact. Respondents with an occupation related to tourism appeared to be more sensitive in terms of environmental concerns. In both areas, and based on personal experiences, air (M = 81%, N = 98%) and ground/water pollution were considered to create the main environmental impacts. In both islands, the economic activities that seemed to be most affected were those related to agriculture and fishing activities, while tourist activities appeared to be less affected.

In relation to the potential uses of geothermal energy, the public selected as most important those reflecting its everyday needs, i.e. power production and desalination. It should be mentioned that in Nisyros, these two options were the only answers provided. The fact that applications of geothermal energy in agriculture, fishery and tourism were not considered as possible choices may lead to the conclusion that in both local societies there was little knowledge of the multiple and combined uses of geothermal energy, and especially of low temperature deep geothermal energy. In Milos, a high percentage (73%) was in favour of the exploitation of the island's geothermal potential. The speculations about environmental impacts didn't seem to affect the receptivity for the development of the island. On the contrary, in Nisyros the public was divided (positive opinion = 51.1%, negative opinion = 48.9%). Environmental pollution and impact on the residents' health seemed to be the main reasons for the opposition on the implementation of investment plans for the development of geothermal energy in both islands. However, it should be mentioned that a significant part of Nisyros local society was negative without any justification. The majority of the public in both islands believed that a geothermal project would not be properly constructed, reflecting the lack of trust towards the State and its representatives, as well as towards the project operation's monitoring and control means.

2.2.3 Power Production in Lesvos Island

Another study that largely concerns geothermal energy was published in 2013, aiming on the investigation of individual preferences and social values towards specific RES technologies in Lesvos Island. Face-to-face personal interviews with permanent households were performed, with 312 responses being collected between July and September 2010. The survey's results indicate that 9% of the respondents selected geothermal energy as the appropriate solution for a 10% substitution of oil-fired electricity production in Lesvos, ranking it last between four different technologies (the alternative three being onshore wind energy, offshore wind energy and PV energy). The percentage in favour of geothermal energy was higher in the area of Polychnitos (33.3%), due to the respondents' knowledge of the existing geothermal potential in the area. Respondents selecting geothermal energy were characterised by high income and their satisfaction with their involvement in the decision-making process. State and municipal companies were preferred for the implementation of geothermal energy projects; the impacts of climate change were not a decisive factor for the selection of geothermal energy. The willingness to pay analysis showed that respondents were willing to pay the highest amount (among the four technologies) for substituting 10% of the electricity produced by fossil fuels with geothermal energy (Kontogianni et al. 2013).

2.2.4 Knowledge and Attitude Towards GSHPs

A social study including two different surveys was performed during 2011–2012, and concerned knowledge and attitudes on geothermal energy in general, and residential GSHP systems in specific. The first survey involved 203 residents of northeast Attica and was conducted through face-to-face questionnaires; the second survey used an electronically distributed questionnaire and involved consumers in general, with no restrictions in the area of residence; 533 responses were collected in this case. In the first case, 42% stated that knew geothermal energy, 35% knew that geothermal energy can be used for residential heating/cooling, 21% had heard of GSHP systems and 18% that GSHPs can be used for residential heating/cooling; in the second survey the corresponding results were 71% (geothermal energy ranked 3rd among 8 different RES), 56, 35 and 29% respectively. The knowledge levels were higher in the second case, due to the characteristics of the sample (younger, higher education). In both cases, around 7.5% of the respondents had considered installing a GSHP system in their residence. Factors affecting public's knowledge on the issues that were under examination, as well as intention of installing a residential GSHP system, were gender, age, level of education, employment, income, environmentally friendly behaviour, awareness of environmental issues, adoption of new technologies and the relevance of profession or interests with the environment, technology or engineering. In addition, the intention of installing such a system was affected by factors related to dwelling characteristics and factors associated with behaviour and consumer attitudes and preferences towards specific characteristics of heating systems. The study also included a third survey examining the views of people involved in the GSHP sector, regarding existing and future adoption level of residential GSHP systems, dissemination barriers and actions that can contribute to their diffusion; the survey was conducted in 2012, using both face-to-face questionnaires and electronically distributed ones. Among the main findings -based on 181 responses- of this survey was that one of the most important diffusion barriers of residential GSHPs is the lack of public awareness on the GSHP technology and its benefits (Karytsas 2016; Karytsas and Choropanitis 2017; Karytsas and Theodoropoulou 2014a, b).

2.3 Public Engagement Exercises

Until now, only a small number of relevant activities have been performed aiming to raise awareness of the local societies and stakeholders. These activities are limited to the organization of workshops, info days, public's visits to geothermal applications (e.g. greenhouses), etc. These activities aim usually to specific target-groups (local authorities, installers, manufacturers, engineers, etc.), while it is less common to focus on the local societies. They take place usually in areas of geothermal application interest (e.g. Milos, Nigrita), however it is not unusual to have such events organised in locations where deep geothermal potential does not exist (e.g. Athens) in order to inform a wider group of stakeholders. Talking about awareness activities specifically conducted in Milos Island, a workshop was organised concerning the future geothermal development in the island in 2008, 20 years after the local society reactions against the pilot power production plant.

2.4 Cases of Controversy

2.4.1 Milos Island

Milos is a volcanic island in the Aegean Sea. It is located at the northwest edge of Cyclades complex and is 86 nautical miles away from Piraeus. Milos covers a land area of 151 km^2 and is the fifth in size island of the complex. The total population of the island is 4,966 (National Statistical Service of Greece, 2011). The capital of Milos is Plaka and the largest port is Adamantas. Geologically, it belongs to the Attico-Cycladic massif, along with the entire Cycladic complex. It is located in the "Southern Aegean volcanic arc", where the European and African lithospheric plates converge, thus releasing large amounts of heat into the earth's crust.

Geothermal research in Milos Island started in 1973 as part of the Institute of Geology & Mineral Exploration (IGME) geothermal project. High (325 °C) and low (25–90 °C) temperature deep geothermal resources have been identified in the island. After the identification of the high geothermal potential of Milos Island, the Public Power Corporation (PPC) started the construction of a pilot power plant aiming to the power production for the island and the wider Cyclades complex. The main drillings were carried out in the area of Zephyria in 1982, very close to the largest city of the island, Adamantas, where tourism development had just begun. The negative experience of the residents due to existing industrial facilities (most of the island had already been affected by local mining activity), had as a result the strong reaction of the local society to the pilot power plant, with the simple slogan "no way!" (Polyzou 2007). In addition, mining enterprises based on the island were opposed to geothermal development, believing that it would create problems to their activities (Koutroupis 1992).

Furthermore, deficiencies and errors made during the construction and operation phases of the pilot power plant led to (a) air pollution due to the uncontrolled leakage of hydrogen sulphide and other hazardous gases from the drilling, (b) surface waters pollution (rain water and water reservoirs) with arsenic and sulphate ions and (c) the disposal of large quantities of liquids and solid wastes in the bay of Agia Kyriaki. This situation created additional reactions to the already negative opinion of the local society (Polyzou 2007).

The result of the effects mentioned above was the strong reactions of the local society, with protests and strikes, for about two years (1987–1989) leading to the closure of the pilot plant. In 1993, the walls of one of the geothermal drillings were disrupted leading to the uncontrolled spewing of large quantities of geothermal fluid, where heavy metal compounds, hydrogen sulphide and arsenic compounds were detected. After some months the well was sealed with the assistance of Italian specialists (Polyzou 2007).

Until now, about 40 years later, the negative reactions of the residents have not been resolved. The residents are still against the development of high temperature deep geothermal resources, while they believe that the state will try to overpass the local society's opinion. In addition, they still oppose to the participation of PPC Renewable S.A. in any exploitation of geothermal energy in the island. On the other hand, the island's municipality has made plans for the use of low temperature deep geothermal resources, which has the approval of the majority of the locals.

2.4.2 Nisyros Island

Nisyros is a volcanic island in the south-eastern Aegean Sea. It is part of the Dodecanese group of islands, situated between the islands of Kos and Tilos. Nisyros covers a land area of 42 km^2. The total population of the island is 982 (National Statistical Service of Greece, 2011). The capital of Nisyros is Mandraki, which is also its port. Geologically, it belongs to the Attico-Cycladic massif and is located in the "Southern Aegean volcanic arc". The island is composed of volcanic rock formations, with swelled elevations that were formed by previous volcanic activities.

Geothermal research in Nisyros Island started in 1973 as part of the Institute of Geology & Mineral Exploration geothermal project. High (400 °C) and low (25–90 °C) temperature deep geothermal resources have been identified in the island. In 1982 the PPC proposed the construction of a power plant in order to solve the problems of electricity supply for both Nisyros Island and its neighbouring island, Kos. In 1983, two drillings were constructed in the area of the volcano caldera, which is the main tourist attraction of the island (Polyzou 2007).

The residents reacted to the power plant construction. The aim of all objections and the negative opinion of a large portion of the local society were about the protection of the environment (air and water pollution) in combination with the possibility of seismic and/or volcanic activity by disturbing the balance of the volcano. The experience of the test drilling on the island, in addition to the bad example created by the Milos Island case, led the residents to express their opposition to any thought of exploiting geothermal potential of the island by a referendum held in May 1997 (Polyzou 2007) (Fig. 3).

Until today, there are reactions from the local community and authorities against the development of high temperature deep geothermal energy for power production. On the other hand, they are positive on the utilization of low temperature geothermal fields that would provide drinking and arable water, space heating/

Fig. 3 Protest against geothermal development in Nisyros Island, banner sign: "NO TO THE GEOTHERMAL POWER PLANT". Reproduced by kind permission of Nisyrian Studies' Society (n.d.)

cooling and domestic hot water. Locals believe that they are not informed and their opinion does not matter concerning the exploitation of geothermal energy, they do not trust PPC Renewable for the construction of such a power plant, while the small size of the island and its characterization as a Natura 2000[1] area are other reasons that lead to their negative attitudes. Their reactions are accompanied with actions such as residents' and politicians' awareness, dissemination activities concerning the arguments against the construction of a geothermal power plant and various other activities (meetings, protests, etc.). A phrase showing their position is: "We don't want and we will not allow the construction of any geothermal power plant in Nisyros Island".

Nevertheless, the Municipality of Nisyros has very recently re-examined its policy against the utilization of geothermal energy and is investigating the possibility of low temperature deep geothermal applications in Nisyros covering thermal MED (Multiple-Effect Distillation) seawater desalination, ORC (Organic Rankine Cycle) geothermal power production, greenhouses and public building heating.

2.4.3 Kimolos Island

Kimolos is a volcanic island in the Aegean Sea. It is located at the northwest edge of Cyclades complex, near to Milos and Poliaigos Islands, and is 86 nautical miles away from Piraeus. Kimolos covers a land area of 37 km^2. The total population of the island is 910 (National Statistical Service of Greece, 2011). The capital of

[1]According to the European Commission (n.d.): "Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. It stretches across all 28 EU countries, both on land and at sea. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive."

Kimolos is Chorio and its port is Psathi. Geologically, it belongs to the Attico-Cycladic massif, along with the entire Cycladic complex and is located in the "Southern Aegean volcanic arc".

After 1982, PPC carried out a preliminary geothermal survey in Kimolos, drilling eight wells at depths of 100 m. Later on, two geothermal wells were drilled by IGME for the operation of a geothermal seawater desalination plant. During 2009–10 a new Geophysical Research Program was implemented in the island, and new possible locations for drillings were found.

In 2014 PPC Renewables S.A. started planning the construction of a 5 MW power plant in the island. This led to the reaction of the local society and authorities, which were affected by the previous experience of Milos Island. Both residents and local authorities believe that PPC Renewables S.A. wanted to proceed with the development without having informed them and without their agreement.

3 Results and Discussion

Although Greece has a significant number of deep geothermal resources, the utilization of geothermal energy is quite limited; it is exploited exclusively through thermal applications (thermal spas, agricultural sector, GSHPs), meaning that there is no power production at all. Main reasons for the delay of geothermal resources development in Greece are:

- local societies' oppositions, especially against power production;
- inadequate regulatory framework and bureaucratic barriers;
- lack of financial capital;
- absence of financial/investment incentives (e.g. for covering geological risk);
- required infrastructure and installation cost of geothermal projects;
- absence of strategic planning for the rational exploitation of geothermal energy.

One of the main reasons for local societies' opposition against geothermal power production is the bad experience created by the Milos Island pilot power plant case. During the 1980s, deficiencies and errors made during the construction and operation phases of the newly constructed—by PPC—pilot power plant led to air, surface and water pollution, resulting to the strong reactions of the residents. The power plant was closed only two years after its first operation. Until today, the geothermal power generation in Greece is being affected by the negative outcome of the Milos case. There are still reactions from the local communities and authorities of Milos, Nisyros and Kimolos Islands against a large scale exploitation of high temperature deep geothermal resources, while there is no such opposition against low temperature deep geothermal utilization. The locals are sceptical against both the state and the PPC Renewable S.A., as they believe that their opinion does not matter, while they do not feel confident that any issues created by high temperature deep geothermal development will be treated properly.

Local communities' oppositions can derive from (a) lack of awareness, (b) perceptions of negative impacts, (c) absence of benefits, (d) lack of trust and (e) unfair development procedures. In this context, there are two factors affecting the conditions that create oppositions, which are characteristic for the case of Greece: existence of micropolitical interests and population peculiarities of the islands. Concerning micropolitical interest, it is identified that local authorities in many cases form their attitude towards any issue, depending on how they believe this attitude will affect their local power. For example, if the governing local authority supports the installation of a RES project, then the opposing political party will very possibly show great opposition, aiming to retain—or even increase—its power within the local community. In addition, if a local authority identifies a negative predisposition from a part of the locals towards a RES project, it is possible that it will try to benefit from it, by also openly adopting a negative attitude (Maraidonis 2008).

In regards to the population characteristic of the islands, that may affect the level of opposition towards geothermal development, it should be noted that in many cases people don't live all year around on the islands, but mainly reside on them during the summer; also, it is not uncommon for people only having real estate property on the islands, and rarely visiting them. All these people are not permanent residents, but however have a saying concerning the local issues. This can create a challenging condition in terms of acceptance of geothermal developments, since these people usually give much higher importance to the potential negative effects (e.g. aesthetic degradation of the local environment that can negatively affect the quality of their summer destination or their property), compared to possible benefits (e.g. economic development, business opportunities, job creation) that usually have low value for them.

In all attempts of exploitation of geothermal fields there is a gap of local communities' awareness, involvement and engagement. In this context a literature review on social studies is conducted, focusing on the themes of public knowledge, acceptance and attitudes towards geothermal energy. Only a small number of studies focuses exclusively on geothermal energy, while most identified studies aim on RES in general, or on sources such as solar and wind energy (both quite popular in Greece). Based on the findings, it can be concluded that knowledge, awareness and attitudes on geothermal energy in Greece are at a medium to low level. The studies show that people are much more aware and favourable towards solar and wind energy, while geothermal energy is one of the least favourite RES.

In addition, there seems to be a lack of awareness activities as, until now, only a small number of activities have been performed aiming to raise awareness of the local societies and stakeholders. These activities have to do mainly with the organization of workshops, info days and public's visits to geothermal applications (e.g. greenhouses).

However, specific advancements are currently occurring in regard to the exploitation of geothermal energy in Greece. The Municipality of Alexandroupolis (in Thrace) has received a license to exploit the low temperature deep geothermal resources of Aristino-Traianoupolis field, in order to create a district heating system and greenhouse heating network. This makes the Municipality of Alexandroupolis the first owner of a low temperature geothermal field license in Greece to receive permit from the Regulatory Authority for Energy of Greece (RAE) to distribute geothermal energy as a producer through a district heating system to end-users. Furthermore, the new law on Energy Communities which gives the opportunity to citizens, local authorities and private or public legal entities to produce, distribute and supply energy, can assist the further promotion of geothermal energy in Greece.

In order to increase social acceptance, actions have to be taken both from the part of the state and the developing companies. The state must promote policies and regulations that will ensure the avoidance of any negative impacts (e.g. environmental, health) and the provision of benefits (e.g. economic) for the local societies. In addition, awareness activities should be introduced, focusing specifically on geothermal energy, as well as on RES in general. From the part of the developers, it is important to follow a strategy that will lead to the engagement of the local society, minimization of potential negative impacts and provision of benefits to the locals.

4 Conclusions

Geothermal energy, despite its large potential, is under-utilised in Greece. It is exploited exclusively through direct uses (thermal spas, greenhouses, GSHPs, etc.), while power production is totally absent. One of the main reasons for the delay of deep geothermal resources development for power production is local societies' oppositions, which derives from the bad experience created by the Milos Island power plant during the 1970–80s. This experience affects until today the attitudes of local communities and authorities (Milos, Nisyros and Kimolos Islands) against the large scale exploitation of high temperature deep geothermal resources. On the other hand, there are no such oppositions towards low temperature deep geothermal utilization. In all attempts made for exploitation of the geothermal resources there is a gap of local societies' awareness, involvement and engagement, a fact that contributes to public reactions towards geothermal development, especially concerning high temperature fields. Moreover, the conducted literature review shows that public attitudes and awareness are at a rather medium to low level. In order to achieve future penetration into the energy mix of the country, it is really important to increase awareness on geothermal development and improve the lost confidence of local societies towards high temperature deep geothermal exploitation.

References

Arvanitis A (2011) Geothermal activities in Greece. International Trade Fair Energy 2011, Renewable Energy Industry and Export Forum, Hanover, Germany, 4–8 Apr 2011

Central Intelligence Agency [n.d. (a)] The world factbook—Europe: Greece. https://www.cia.gov/library/publications/the-world-factbook/geos/print_gr.html. Accessed June 2017
Central Intelligence Agency [n.d. (b)] The world factbook –GDP—Composition, by sector of origin. https://www.cia.gov/library/publications/the-world-factbook/fields/2012.html. Accessed June 2017
Dimitriou A, Pimenidis D (2015) Local authorities' views and attitudes on sustainable energy policy: the case of mayors of Rhodes Island, Greece (2010–2014). Int J Env Protect Pol 3 (2):20–30
European Association for Coal and Lignite aisbl (EURACOAL) (2016) EURACOAL Statistics—Coal in Europe 2016. https://euracoal.eu/info/euracoal-eu-statistics/. Accessed June 2017
Eurobarometer (2006) Energy technologies: knowledge, perception, measures
European Commission (n.d.) Environment. Natura 2000. http://ec.europa.eu/environment/nature/natura2000/index_en.htm. Accessed Feb 2018
Eurostat (2016) Statistical books—energy, transport and environment indicators. Publication Office of the European Union, Luxembourg
Eurostat (2017) Renewable energy statistics. http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics. Accessed June 2017
Fanourgaki I, Mauroudi IM (2017) Green investments/evaluation from the consumer's side. Bachelor's thesis, Technological Education Institute of Piraeus (in Greek)
Fytikas M, Andritsos N, Dalabakis P, Kolios N (2005) Greek geothermal update 2000–2004. In: Proceedings world geothermal congress 2005, Antalya, Turkey, 24–29 Apr 2005
Hellenic Statistical Authority (2011) 2011 population—housing census. http://www.statistics.gr/2011-census-pop-hous. Accessed June 2017
Karytsas S (2016) Heating and cooling of buildings with the use of renewable energy sources: socioeconomic factors that contribute to the diffusion of ground source heat pumps (GSHP) in the residential sector. Doctoral dissertation, Harokopeio University (in Greek)
Karytsas S, Choropanitis I (2017) Barriers against and actions towards renewable energy technologies diffusion: a principal component analysis for residential ground source heat pump (GSHP) systems. Renew Sust Energ Rev 78:252–271
Karytsas S, Theodoropoulou H (2014a) Public awareness and willingness to adopt ground source heat pumps for domestic heating and cooling. Renew Sust Energ Rev 34:49–57
Karytsas S, Theodoropoulou H (2014b) Socioeconomic and demographic factors that influence publics' awareness on the different forms of renewable energy sources. Renew Energ 71:480–485
Keramitsoglou KM (2016) Exploring adolescents' knowledge, perceptions and attitudes towards renewable energy sources: a colour choice approach. Renew Sust Energ Rev 59:1159–1169
Kontogianni A, Tourkolias C, Skourtos M (2013) Renewables portfolio, individual preferences and social values towards RES technologies. Energ Pol 55:467–476
Koundouri P, Kountouris Y, Remoundou K (2009) Valuing a wind farm construction: a contingent valuation study in Greece. Energ Pol 37(5):1939–1944
Koutroumpi M, Saltaoura I (2016) Renewable energy sources—photovoltaics. Bachelor's thesis, Technological Education Institute of Piraeus (in Greek)
Koutroupis N (1992) Update of geothermal energy development in Greece. Geothermics 21 (5–6):881–890
Law 3175/2003 (Government Gazette 207A)
Law 3852/2010 (Government Gazette 87A)
Liarakou G, Gavrilakis C, Flouri E (2009) Secondary school teachers' knowledge and attitudes towards renewable energy sources. J Sci Ed Tech 18(2):120–129
Manologlou E, Tsartas P, Markou A (2004) Geothermal energy sources for water production—socio-economic effects and people's wishes on Milos island: a case study. Energ Pol 32 (5):623–633
Maraidonis T (2008) Social acceptance and renewable energy sources: the case of south Euboea. Final thesis, National School of Local Governance (in Greek)

Melfos V, Voudouris PC (2012) Geological, mineralogical and geochemical aspects for critical and rare metals in Greece. Minerals 2(4):300–317

Ministerial Decree Δ1/A/12892/2014 (Government Gazette 2186B)

Ministry of Environment and Energy [n.d. (a)] Mineral resources. http://www.ypeka.gr/Default.aspx?tabid = 294&language = el-GR. Accessed June 2017

Ministry of Environment and Energy [n.d. (b)] National renewable energy action plan. http://www.ypeka.gr/LinkClick.aspx?fileticket=vBWJVY3FdTk%3D. Accessed June 2017

Nisyrian Studies' Society (n.d.) Reaction of Nisyros people. http://www.nisyriakesmeletes.gr/antidraseis.html. Accessed June 2017

Ntanos S, Ntanos A, Salmon I, Ziatas T (2016) Public awareness on renewable energy sources: a case study for the Piraeus University of applied sciences. Presented at the 5th international symposium and 27th national conference on operational research, Athens, Greece, 9–11 June 2016

Papachristou M, Mendrinos D, Dalampakis P et al. (2016) Geothermal energy use, country update for Greece. Paper presented at the European geothermal congress, Strasbourg, France, 19–24 Sept 2016

Petrakopoulou F (2017) The social perspective on the renewable energy autonomy of geographically isolated communities: evidence from a Mediterranean island. Sustainability 9 (3):327

Polyzou O (2007) Geothermal energy—sustainable development and local societies. Doctoral dissertation, National Technical University of Athens (in Greek)

Polyzou O, Stamataki S (2010) Geothermal energy and local societies—a NIMBY syndrome contradiction? In: Proceedings world geothermal congress 2010, Bali, Indonesia, 25–29 Apr 2010

Sardianou E, Genoudi P (2013) Which factors affect the willingness of consumers to adopt renewable energies? Renew Energ 57:1–4

Schneider F (2015) Tax evasion, shadow economy and corruption in Greece and other OECD countries: some empirical facts. http://www.amcham.gr/wp-content/uploads/2015/taxspeeches/friedrich%20schneider.pdf. Accessed June 2017

Skoupra M (2013) Social acceptance of renewable energy sources installations by consumers. Master's thesis, Harokopeio University (in Greek)

Spiropoulou D, Antonakaki T, Kontaxaki S, Bouras S (2007) Primary teachers' literacy and attitudes on education for sustainable development. J Sci Ed Tech 16(5):443–450

Tampakis S, Tsantopoulos G, Arabatzis G, Rerras I (2013) Citizens' views on various forms of energy and their contribution to the environment. Renew Sust Energ Rev 20:473–482

Tsirampidis A, Filippidis A (2013) Mineral resources of Greece: reserves and value. Department of Mineralogy-Petrology-Economic Geology, Department of Geology, Aristotle University of Thessaloniki (in Greek)

Tsoutsos T, Tournaki S, Gkouskos Z et al. (2013) Training and certification of PV installers in Europe: a transnational need for PV industry's competitive growth. Energ Pol 55:593–601

Tzanakaki E, Mavrogioros D (2005) Public acceptance of renewable energy sources and energy conservation. Paper presented at Heleco'05, TEE, Athens, 3–6 Feb 2005

Taming the Elements—The Use of Geothermal Energy in Iceland

Örn D. Jónsson, Bjarni F. Karlsson and Rögnvaldur J. Saemundsson

Abstract Harnessing geothermal water was an unlikely way to take on a pressing problem in Iceland: substitute oil and coal in the late thirties. As a reaction to the oil crisis in the 1970s, measures were taken by national authorities to substitute unsustainable energy. The transition was a success. The space heating system was and is based on a system for extracting and distributing geothermal water which had been strengthened in the early sixties and for the most part a fully publicly financed endeavour. In the turn of the century, as a part of the surge of privatisation in the neighbouring countries and the importance of competition, measures were taken to build technologically advanced large-scale geothermal power plants which turned to be a showcase of advanced technical knowledge but a financial disaster. In recent decades the diverging understanding of geothermal water as an energy source versus the embeddedness of the varied use of geothermal water is becoming ever more apparent and a pressing policy issue. Focus on sustainability, new technological solutions, such as smart micro-grids, and increased tourism are more compatible with the varied and embedded use of geothermal water as opposed to using geothermal resources to produce energy as a part of a large-scale technological system.

Keywords Iceland · Local embeddedness · Industrial production
Technological paradigms

Ö. D. Jónsson (✉) · B. F. Karlsson
School of Business, University of Iceland, Saemundargata 2, 101 Reykjavik, Iceland
e-mail: odj@hi.is

R. J. Saemundsson
Faculty of Industrial Engineering, Mechanical Engineering and Computer Science,
University of Iceland, Saemundargata 2, 101 Reykjavik, Iceland

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes
in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_10

1 Introduction

The wide-ranging and varied use of geothermal energy is a vital part of everyday life in modern Iceland. Despite being used for washing and bathing since the country's settlement in the 9th century, geothermal water was not used for industrial purposes or space heating until the end of the 19th century and the beginning of the 20th century. Distributed heating systems were introduced in the 1930s and were slowly expanding until the 1970s, but as a reaction to the oil crisis in the 1970s measures were taken to substitute fossil fuels with geothermal energy mainly by strengthening the already existing heat distribution system. The transition was swift and successful. In fifteen years, from 1970 to 1985, the use of oil for space heating went from 50 to 5% (National Energy Authority 2016).

Beginning in the 1970s, geothermal energy was being converted to electricity as a part of the process of harnessing overheated geothermal steam for heating. At the turn of the century advanced large-scale geothermal power plants were being built as components in a country wide system of electricity generation and distribution mainly serving heavy industry, such as aluminium smelting. In 2011 40% of geothermal energy use in Iceland was for space heating and 45% for electricity. The remaining 15% were used for industrial use of heat (e.g. fish farming and greenhouses), swimming pools, and snow melting (National Energy Authority 2018b).

In recent years the use of geothermal energy for the production of electricity on a large scale has become controversial. Originally perceived as a by-product in distributed heating systems based on high temperature wells it became perceived as a new primary energy source that could sustain the effort to expand electricity production for large scale industrial production once the major sources of hydraulic power were depleted. In the process, public utilities—who had built unique technical competences in harnessing geothermal energy for space heating and electricity production—were redefined as profit-optimizing firms to take advantage of new business opportunities both in Iceland and abroad. The economic meltdown in 2008 disrupted the process and revealed the enormous financial risks involved. Furthermore, the privatization of public utilities was increasingly being questioned as well as the sustainability of the large-scale utilization of geothermal energy.

In this chapter the aim is to describe the development of the wide ranging and varied use of geothermal energy in Iceland and the controversies about its future development. Using the social construction of technology (Bijker et al. 2012) as our point of departure we describe how the utilization of geothermal energy has been guided by two different and conflicting paradigms. Originally, the construction of geothermal system was a local public undertaking out of necessity. The systems were based on direct use of low temperature geothermal water for hygiene, space heating, and greenhouses. As these systems expanded the depth and the temperature of the geothermal wells increased which provided opportunities for electricity generation as a by-product of producing geothermal water for heating and other purposes. Subsequently, a new paradigm emerged for the utilization of geothermal energy. Instead of local systems focused on diverse means of local use of geothermal water for civilian and industrial heating purposes the systems were seen as providers of generic energy to a national electrical super-grid. While the bulk of the energy was provided to large-scale industrial production the existence of an extensive national grid was expected to reduce the risk of power failures and provide cost effective electricity to regions where harnessing geothermal resources had not been seen as technically or economically feasible. Critical views of the sustainability of large-scale geothermal electricity production together with advances in technologies for local harnessing of low temperature geothermal energy and flexible electricity production and distribution (smart grids), suggest a re-examination of the perception of geothermal energy as a generic source of energy distributed through a national super-grid and a future where the focus is again on the wide ranging and varied use of geothermal water.

The chapter is divided into five sections: A short overview of our frame of reference followed by two sections tracing the history of geothermal production guided by the two paradigms of local use of geothermal fluids for various purposes and its inherent qualities (quest for comfort), and a national distribution of electricity (quest for energy). Finally, we discuss the controversies about the future development of geothermal energy and offer our conclusions.

2 Theoretical Frame of Reference

In this chapter our point of departure is the social shaping of technology and the "seamless web" of society and technology (Bijker et al. 2012). Thus, while viewing the harnessing of geothermal energy as a technical problem that needs to be solved we acknowledge that the evolution of technology is not only driven by its own rationality, but rather by a range of social, political, and institutional factors which interact in a systemic fashion.

The systemic fashion in which social, political, and institutional factors interact to shape the evolution of technology can be conceptualized as a technological paradigm and the resulting outcome as a technological trajectory (Dosi 1982). Technological paradigms are forward looking in the sense that they define what technical problems are important and what knowledge and skills will lead to solutions that are both technically viable and economically feasible. In doing so, technological paradigms are seen to shape the organization of firms and industries leading to path dependent technological trajectories which are difficult to disrupt (Arthur 1989; David 1985; Geels 2002).

An important part of a technological paradigm is the relative role and importance of different stakeholders in determining the criteria for evaluating the performance of the technology. Of particular importance is the role of users in innovation. Another important part of a technological paradigm is the relative importance of practical knowledge and scientific knowledge (Arrow 1962; Polanyi 1966; Rogers 2003; von Hippel 1988).

Technologies, such as equipment methods needed to harness geothermal energy, do not evolve in isolation because their utility and economic feasibility is usually dependent on the development of other technologies. Firms and industries specialize in the development or use of certain technology and their products and services are prerequisites for the operations of other firms and industries. The evolution of technologies is therefore constituted of mutual adjustments across technologies that affects both technological paradigms and the organization of firms and industries (Rosenberg 1982).

When a new technology emerges, technology paradigms are likely to change. New challenges and stakeholders are likely to emerge or existing challenges are addressed in a different way by different stakeholders. The challenges may be local to a geographical area or industries, and in some cases they are general. New stakeholders may bring similar and complementary perspectives already held by existing stakeholders or they may bring with them contrasting and conflicting perspectives. Conflicting paradigm may compete and if a new paradigm supersedes an existing one it resembles Schumpeter's (1942) process of creative destruction. However, conflicting paradigm may also coexist for an extended period of time.

3 The Quest for Comfort

In this section we first present a brief overview of the utilisation of geothermal energy in Iceland in the last century, before examining in more detail how this natural resource is used to enrich everyday life in Iceland and improve living.

In the beginning of the 20th century, imported coal was the primary source of household heating. It was first during the prolonged crisis of the 1930s that systematic search for an alternative energy resources became a political priority. Hydropower had become a possibility but required considerable initial investments in power plants and distribution networks. Peat had been used from earlier times in rural areas and was for a while an option in towns instead of oil and coal, as peat fitted into the existing distribution system. Peat is however a notoriously inefficient energy source and making use of geothermal heat was an attractive alternative as some farmers had achieved to use natural hot-water supplies for house heating in close proximity to hot springs. The main problem was the building of a distribution system required to deliver the hot water to the urban centres around Iceland. It required a technologically novel and robust distribution system for which there was neither available on hand engineering expertise, practical knowledge nor sufficient economic means.

Due to the high prices of imported coal and oil and despite the challenges associated with the building of a distribution system, the Reykjavík city authorities decided to heat the whole city with geothermal hot water. In 1930 the Reykjavík Heating Utility was founded and by late 1930s a distribution system was operational in a section of the capital Reykjavík, exploiting resources situated a few kilometres east of the city. The early 1940s proved to be a phase of rapid economic growth, securing further investments in infrastructure.

Due to both the damaging effects of corrosion and the technical complexity involved, as well as limited financial resources at the time, a project solving the harnessing and distribution of geothermal water was prioritized by the Reykjavík authorities. An important part of providing sufficient geothermal energy for the city was dependent on the instalment of pumps in the boreholes. Available pumps at the time were however not designed to withstand temperatures of up to 150 °C. With help from European and American engineers these and other problems were solved through continuous on-site trials and sufficient hot water could be provided to serve households and industries in the greater Reykjavík area. Using geothermal heat as a substantive or widespread solution must be seen as a clear case of a ‘technological momentum’ where the capabilities are eventually realized by sufficient capital, innovative use of materials such as Teflon and urethane, and an appropriate organizational system. Based on these innovations a comprehensive system was created that was sufficiently reliabile and economical. The expensive part, the drills, were provided by the state while the construction, which to a large extent was labour intensive, was provided regional municipalities.

Today, Iceland is one of the most affluent countries in the world, a welfare state fashioned after the Nordic mould. In an interesting way, the utilization of geothermal water played a part in this as it became means to overcome harsh weather conditions and dependence on animal-based food. Although affluence and wellbeing were the objective it is possible to distinguish between two different paths achieving this, one Spartan the other hedonistic. The primary objective of the Farmers movement, which had a considerable say in the developing the policy, was to avoid what their representatives regarded as the corrupting and enslaving aspects of urbanization. Cleanliness took on a metaphorical meaning as well as a practical one. The aim was a good and clean disciplined world, which coincided with the libertarian value of a balanced egalitarian society. Foreigners and Icelanders educated abroad, which represent the hedonistic path, were looking for ways to cope with the overall harsh conditions in Iceland. For this group, the use of geothermal water was not only seen as merely functional. Using greenhouses to grow grapes (along with roses) and to enrich daily life could be understood as a protest by emerging urbanites. Flowers and fruits were signs of sophistication, a cultured attempt to survive under circumstances nearly unbearable for those who were at home with a better life abroad.

In a deliberately simplified manner it can be maintained that the utilization of geothermal resources has played a significant role in the quest for comfort exemplified by the success in space heating, food production and outdoor activities (Jónsson and Rastrick 2017). The quest for comfort is a universal goal and attaining greater control over the environmental settings; summer all year long. Due to the short summer growing root vegetables has been difficult while growing vegetables such as tomatoes, capsicum and cucumbers has been a part of the stable for decades. Iceland’s rapidly increasing capabilities and skills in utilizing geothermal water in a creative way, e.g. running a restaurant in a greenhouse where the locally produced food is consumed, go hand-in-hand with the global trend in production and consumption of food and the growth of tourism where the number of visitors grew from less than 200,000 in 1995 to over 2,000,000 in 2017.

One of the most surprising aspects of the utilization of the geothermal is the popularity of outdoor swimming pool where the Jacuzzi-like outdoor hot tubs have become one of the most frequented gathering places in the country, comparable to the Parisian café, the English pub, the Mediterranean church plaza, the ancient Turkish Hamman, and, closer to home, the Finnish sauna. The tubs are visited daily by young and old and social status is insignificant all year round (Jónsson 2009). Furthermore, the Blue Lagoon—and similar geothermal spas—are some of the most popular tourist attractions in the country. Outdoor bathing can in a sense be seen as a convergence of the Spartan and the hedonistic value sets; geothermal living, which has become a cultural identity valued by the local inhabitants and their foreign visitors.

Once systems for distributing geothermal water were in place and technical capabilities were developed to harness geothermal resources of higher temperature than before, further plans for the utilization of the country's geothermal resources were considered. This time the utilization was not driven by the quest for comfort, but rather by the quest for energy to power large-scale industrial processes.

4 The Quest for Energy

"It doesn't matter how much we build, the demand will always exceed the supply" said Hördur Arnarson, the CEO of the National Power Company (Landsvirkjun) at the company's annual general meeting in April 2016. These words reflect the belief that the demand for energy will continue to rise and that the company will always be able to find buyers for all the electricity that can be produced in Iceland.

This optimism is not new in Iceland. It drove ambitious entrepreneurs in the beginning of the 20th century when they planned to harness the energy in the country's waterfalls and was the basic premise of public policy in the 1960s which lead to the establishment of the National Power Company for the large-scale production of electricity for industrial processes using hydropower. In the beginning of the 21st century it was the guiding principles for the large-scale utilization of geothermal energy for electricity production.

The production of electricity using geothermal energy started primarily as by-product of generating geothermal water for heating. As local low temperature wells (temperature less than 100 °C) became fully utilized, public utilities looked for opportunities to harness sources of higher temperature containing overheated steam. Electricity is generated as the steam is cooled and then the resulting geothermal water can be distributed and used for space heating and other purposes.

The higher temperatures created new technical problems that were solved gradually in the period from the late 1960s and into the 2000s. These problems related to prospecting and the drilling of the wells and the chemical composition of the overheated geothermal fluid. In both cases there were large regional variation which made it difficult to transfer practical knowledge from one site to another and lead to increased dependence on scientific knowledge and the use of advanced engineering methods and materials.

At the turn of the century two public utility companies specializing in the extraction and distribution of geothermal water—Suðurnes Heating Utility (Hitaveita Suðurnesja) and Reykjavik Heating Utility (Hitaveita Reykjavíkur)—were successfully operating geothermal power plants producing both electricity and geothermal water. These power plants, which became online in 1978 and 1990, were improved and expanded until 2007 and 2005, respectively.

In the early 2000s there was a change in the organization and strategy of regional utility companies. Companies originally providing separate utilities, such as water, heating, and electricity, were merged into single entities and in some cases into publicly owned limited liability companies. Furthermore, changes were made to legislation related to electricity production and distribution opening up the state monopoly and creating opportunities for the regional utility companies to produce and distribute electricity beyond their own regional systems. Especially, this created opportunities for the regional utilities to provide energy to large scale industrial buyers. Subsequently, Reykjavik Heating Utility (now as the merged utility Reykjavik Energy) and Sudurnes Heating Utility built new geothermal power plants that are primarily intended for producing electricity for large-scale industrial producers and both started operation in 2006. In the period 2000–2017 the production of electricity by geothermal power plants increased from 1.300 to 5.200 Gwh,

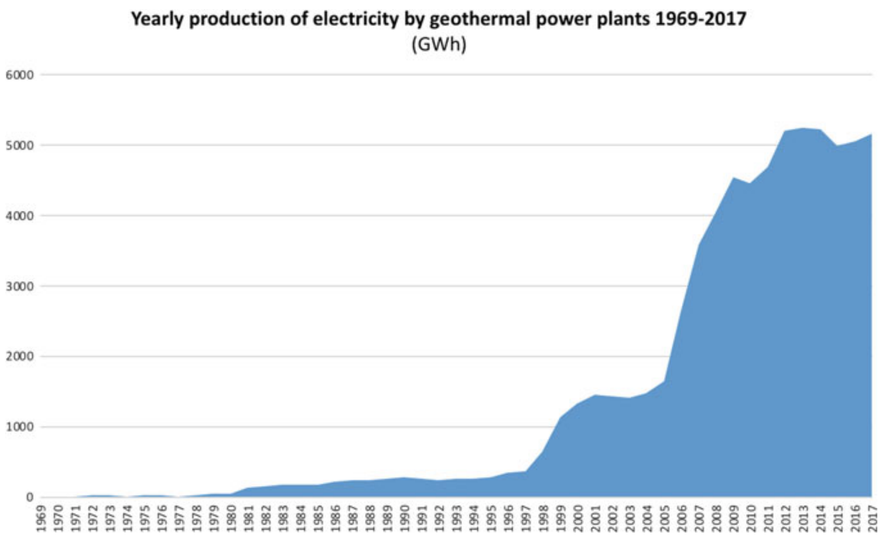


Fig. 1 Yearly production of electricity by geothermal power plants in Iceland 1969–2017. *Data Source* National Energy Authority (2018a)

which is a fourfold increase (see Fig. 1). In 2016 the total electricity production in Iceland was 18.500 Gwh where about 80% of the energy was used by large-scale industrial processes (mostly aluminium smelting), 15% was used by small and medium sized firms (SME), and 5% by households (National Energy Authority 2017).

The use of geothermal power plants for producing electricity on a large-scale not only increased the supply of electricity but it also changed the nature of the utilization of geothermal energy from the perspective of the relationship between primary energy and energy consumption. While 81% of the primary geothermal energy was harnessed through high temperature wells (mostly to produce electricity) less than half of it was consumed (National Energy Authority 2010). The reason is the low efficiency of the conversion from geothermal energy to electrical energy and the lack of demand for the excess hot water being created in the process.

The financial crisis of 2008 slowed down the expansion of the large-scale production of electricity using geothermal energy. Lack of access to capital reduced the rate of investment, but the crisis also exposed the financial risks taken by the utility companies because of the increase in the value of foreign debt. For example, Reykjavik Energy 2011 had to devise extreme measures ("The plan") in order to save the company from becoming bankrupt (Fig. 2). The price of hot water for household use was raised and special efforts were made to lower the debts. Furthermore, the crisis brought with it a change in mood and a more critical view about the profitability and sustainability of large-scale production of electricity using geothermal energy (Shortall et al. 2015; Shortall and Kharrazi 2017).

Even if the development of large-scale production of electricity using geothermal energy has slowed down the scientific and engineering competencies are still being developed and deployed. The National Power Company is building a new power plant, and planning another one, to provide electricity for large-scale industrial production in the northern part of the country. Several engineering firms

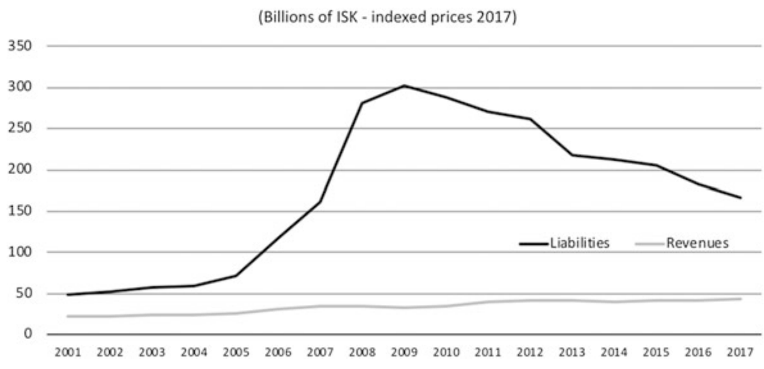


Fig. 2 The effects of the financial crisis in 2008 on the financials of Reykjavik Energy (Orkuveita Reykjavikur). *Data Source* Reykjavik Energy annual reports 2002–2018 (https://www.or.is/english/finance/financial-reports)

are designing and operating geothermal systems abroad, with recent projects in Ethiopia (Reykjavik Geothermal) and China (Arctic Green Energy). Furthermore, an international research project is prospecting and drilling geothermal wells at even higher temperature and length (Iceland Deep Drilling Project). However, most of the regional utilities, such as Reykjavik Energy, have returned to their core business of serving their local constituencies.

5 Future Development of Geothermal Energy

In the previous sections we have described how the use of geothermal energy in Iceland has been guided by two paradigms which we have labelled the quest for comfort and the quest for energy. In the former case the construction of systems for the distribution of hot water was a local public undertaking which was not a matter choice but out of necessity. The systems were based on direct use of geothermal water for hygiene, space heating, greenhouses, and drying—use which mainly improved comfort and the quality of life for citizens. In the latter case–initially driven by relatively large public utilities but later by the National Power Company and private engineering firms—systems were constructed to produce electricity for large-scale industrial use. While the primary motive was to monetize the country's natural energy resources it was also argued that large scale industrial use of electricity would justify the investment in an extensive national grid for electricity distribution. The existence of the grid would reduce the risk of power failures and provide cost effective electricity to regions where harnessing geothermal resources had not been seen as technically or economically feasible, thus increasing the comfort and quality of life in those regions.

What has been common to the two paradigms is gradual building of capabilities through learning and the creation of organizational systems. Early attempts in Iceland to harness geothermal energy for direct use of heat were governed by a pressing need, rather than a previously established technical or economic feasibility. Attempts at constructing a distribution system for space heating met with numerous challenges related to corrosion, pressure, and the loss of heat. Furthermore, the challenges were different for each geothermal area and the sources of these differences were not well understood. Thus, building each of these local distribution systems was a major practical as well as engineering accomplishment that was based on relatively low-cost experimentation and to a large degree on the accumulation of tacit knowledge that was difficult to transfer across sites. In comparison the learning related to the building of geothermal power plants for producing electricity was more codified and developed in the context of a large technical system. By converting the geothermal energy into electricity previous challenges of distributing geothermal fluids can be avoided. By subscribing to universal standards of electricity distribution an existing electricity grid can be used for distribution without any context specific learning. Geothermal energy simply becomes a commodity within a large technical system that operates independently of the energy sources being used. However, specific challenges still remained related to drilling and the handling of the geothermal fluid. In order to gain access to the vast amount of primary energy needed—due to low efficiency of conversion—deeper wells were needed that operated at higher temperatures and pressure. This environment is more difficult to control and direct experimentation is much more expensive with a higher risk of failure. Thus, the development of technical capabilities has become more science-based making extensive use of complex simulation models in order to reduce the uncertainty associated with direct experimentation without being able to eliminate the related risks. This has eventually turned into an "iron cage" where the actual purpose of producing a profitable product for large scale industry have been driven by instrumental rationality.

The main difference between the two paradigms concerns the generality of the energy source which affects the locality and scale of its utilization and concerns about sustainability. In the quest for comfort the emphasis was on the specificity of the energy source and how its characteristics can be used for multiple purposes. In the quest for energy the emphasis was on the generic aspects of geothermal energy and the how it could be converted into a universal energy source. In the former case the utilization was local on a limited scale, while in the latter case larger scale exploitation became economically feasible through access to a national—and even international—distribution networks. The larger scale, however, created concerns about the degree to which a geothermal resource is renewable and the limits of natural recharge given high rates of utilization.

The concerns about sustainable utilization of geothermal resources added to previous concerns and controversies about the extensive utilization of hydropower and the protection of the inhabitable Icelandic highlands. On one hand, the market and the state have since the 1960s sought to exploit the energy resources residing in the highlands, and on the other hand, parts of the civil society have resisted the exploitation by stressing the future value of conserving the unique nature of the highlands. The tensions between exploitation and conservation have influenced policy making and NGOs have played an important role in creating public awareness of environmental issues.

The first environmental laws in Iceland were established in 1956. An advisory committee was created, *The Nature Conservation Council*, and local committees for nature conservation were set up in every administrative district. The minister responsible was the minister of Education. Around 1990 there were large changes in environmental legislation in Iceland. The Ministry for the Environment was created and new laws were established requiring the evaluation of environmental impact of all construction projects. The application of the new laws was in focus in the largest hydroelectric dam project in the history of Iceland—the Kárahnjúkar dam—which in 2002 the National Power Company committed to build to service an Alcoa aluminium smelter in the eastern part of the country. The decision was very controversial and the opposition to the project mobilized a large number of NGOs, but at the same time the Nature Conversation Council was abolished and its office closed down.

The leading NGO for nature conservation and environmental protection is *The Icelandic Environmental Association* which was founded in 1969. Today, the association has over 40 member-societies all over the country with over 5000 individual registered members. Its role is to protect Icelandic nature and be an active participant in strategic planning, education, and informed decision-making in matters that relate to land use, natural resources and the environment. Recently, the association has played a key role in synchronizing the opposition of multiple NGOs. For example, *Iceland National Park* is a campaign advocating for the protection of the Icelandic highlands. The campaign has resulted in a coalition of 28 organizations and is still growing; environmental NGOs, outdoor recreational clubs and the Icelandic Travel Industry Association. The coalition wants to see the highlands turned into a national park. This campaign started as an aftermath to a concert organised in 2014 by a nature conservation association.

To reconcile the competing interests of nature conservation and energy utilization the Icelandic government has created a process called the Master Plan for Nature Protection and Energy Utilization (Master Plan 2018). While the idea had been around since the 1980s the work did not begin in earnest until 1999. The dual purpose of the process is to create a stable consensus about what areas should be protected and what areas are available for exploitation. The process is built around the classification of all options for energy utilizations, including geothermal options, into one of three classes: *permitted—possibly permitted—not permitted*. Expert committees evaluate the impact of each option and a steering committee integrates the results from the expert committees and classifies the option. The process is transparent allowing for inputs from all stakeholders. The process started its fourth phase in 2017 and is expected to finish in 2021.

Differently from other countries the current energy debate in Iceland has not been concerned with finding alternatives to fossil fuels. Instead it has focused on the future value of conserving the unique nature of the highlands, which, for many, has become an important part of the country's identity and valuable in itself (Cook et al. 2018). However, with an increased awareness of the need to improve the sustainability of the world's energy systems alternative modes of energy production along with the increasing sophistication of techniques used to monitor and control both production and use have come into the fore. By optimizing the inherent qualities of the different energy sources, such as solar cells and wind turbines, generation with a real-time coordination using a smartgrid, these grids a can function autonomously (as separate islands) or connect to a larger grid. These technological developments have co-evolved with the increasing role of the prosumer (Ritzer and Jurgensen 2010), i.e. a consumer that takes on tasks that hitherto had been an integrated part of the production and distribution process. In the Icelandic context these developments are compatible with the original paradigm—the quest for comfort—guiding the utilization of geothermal energy in Iceland. The municipalities, as a civil society or a village, can be seen as the prosumer, i.e. involved in both the production and consumption of geothermal water for improving the comfort of the collective. However, the paradigm guiding the use of geothermal energy for producing electricity seems to be the opposite, as it is based on clear separation between producers and consumers and is less dependent on regional characteristics and differences. Furthermore, many see it as destroying the future value of a preserved nature.

In recent years we have seen an increased interest in using local solution to address the energy provision for areas in Iceland where the harnessing of geothermal energy has not been deemed economically and technically feasible. For example, the National Grid Company (Landsnet) has experimented with the use of smart micro-grids in the north-western part of the country (Vestfjord) and recently it has been reported that dependence on oil and costs can be significantly reduced in the same region using heat pump technology. Another example is in the south-eastern part (Hornafjordur) when improvement in prospecting and drilling technology have led to the discovery of geothermal sources to use for space heating that is both technically and economically feasible. These developments, along with relatively few inhabitants that are without access to geothermal water—less than 7% of the total population—have made it less convincing that the large-scale production of electricity for industrial use is the best way to secure the delivery of energy at reasonable prices to areas without access to geothermal water.

6 Conclusion

While predictions about the future tend to be wrong it is tempting to predict that recent development in Iceland signals the decline of the quest for energy paradigm and the revival of the quest for comfort. A sustainable energy system for heating and electricity is almost in place in Iceland—the few “cold” areas that are left are likely to develop local solutions in the near future. The value-creation potential of locally produced geothermal water for varied direct use—the quest for comfort for inhabitants and their visitors—is currently much higher than for nationally produced electricity. Furthermore, the environmental impact and financial risks from exploiting this potential is much lower than exploiting geothermal primary energy at a large scale. At the same time scientific knowledge and technical capabilities have been built for harnessing high temperature geothermal energy sources—capabilities that may not be in high demand domestically but hold the potential of providing alternative energy sources to reduce dependency on fossil fuels abroad. The challenge for policy makers is to understand if it is desirable and feasible to continue to emphasize the development of knowledge and capabilities for the utilization of high temperature geothermal resources, while at the same time developing local capacity to continue the quest for comfort through varied direct use of geothermal water. In the former case the taming of the elements continues, but for use outside the country. In the latter the elements have already been tamed but value is created through creativity and innovation in their local use.

References

Arrow KJ (1962) The economic implications of learning by doing. Rev Econ Stud 29(3):155–173

Arthur B (1989) Competing technologies, increasing returns, and lock-in by historical events. Econ J 99(394):116–131

Bijker WE, Hughes TP, Pinch T (eds) (2012) The social construction of technological systems. New direction in the sociology and history of technology. MIT Press, Cambridge, MA

Cook D, Davíðsdóttir B, Kristófersson DM (2018) Willingness to pay for the preservation of geothermal areas in Iceland—the contingent valuation studies of Eldvörp and Hverahlíð. Renew Energy 116:97–108

David PA (1985) Clio and the economics of QWERTY. Am Econ Rev 75(2):332–337

Dosi G (1982) Technological paradigms and technological trajectories. Res Policy 11:147–162

Geels FW (2002) Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res Policy 31:1257–1274

Jónsson ÖD (2009) Geothermal living. University of Iceland Press, Reykjavik

Jónsson ÖD, Rastrick Ó (2017) Enjoying the outdoor pool in a cold climate. Appropriate technology, utilization of geothermal resources and the socialization of everyday practices in Iceland. Geotherm Energy 5:2–14

Master Plan (2018) The master plan for nature protection and energy utilization. http://www.ramma.is. Accessed 5 Apr 2018

National Energy Authority (2010) Use of geothermal energy for the production of electricity and direct use until 2009. National Energy Authority OS-2010/02

National Energy Authority (2016) Residential heating in Iceland by energy source 1970–2010. http://www.nea.is/the-national-energy-authority/energy-data/data-repository/. Accessed 16 Mar 2016

National Energy Authority (2017) OS-2017-T015-01: electricity consumption in Iceland 2016 [data file]

National Energy Authority (2018a) OS-2018-T005-01: installed electrical capacity and electricity generation of geothermal power plants in Iceland 1969–2017 [data file]

National Energy Authority (2018b) Use of geothermal energy in Iceland. https://orkustofnun.is/orkustofnun/orkutolur/jardhitanotkun/. Accessed 22 Mar 2018

Polanyi M (1966) The tacit dimension. University of Chicago Press, Chicago

Ritzer G, Jurgensen N (2010) Production, consumption, prosumption: the nature of capitalism in the age of the digital 'prosumer'. J Consum Cult 10(1):13–36

Rogers EM (2003) Diffusion of innovations. Free Press, New York

Rosenberg N (1982) Inside the black box: technology and economics. Cambridge University Press, Cambridge

Schumpeter JA (1942) Capitalism, socialism and democracy. New York, Harper & Row

Shortall R, Kharrazi A (2017) Cultural factors of sustainable energy development: a case study of geothermal energy in Iceland and Japan. Renew Sustain Energy Rev 79:101–109

Shortall R, Davíðsdóttir B, Axelsson G (2015) A sustainability assessment framework for geothermal energy projects: development in Iceland, New Zealand and Kenya. Renew Sustain Energy Rev 50:372–407

von Hippel E (1988) The sources of innovation. Oxford University Press, New Your

Örn Daniel Jónsson is professor on innovation and entrepreneurship at the School of business at the University of Iceland and has a Ph.D. in Economic Geography from Roskilde University, Denmark. In his research he has focused on, innovation, product development, food culture and the impact of the geothermal on everyday living.

Bjarni Frimann Karlsson is an assistant professor in accounting and auditing at the School of Business at the University of Iceland and has a master degree in public administration from SDU, Denmark. In his research he has focused on financial statement analysis and investigation the processes leading to the collapse of the savings banks in Iceland.

Rögnvaldur Saemundsson is an associate professor in Industrial Engineering at the University of Iceland and has a Ph.D. in Technology Management from Chalmers University of Technology. In his research he has focused on technology-based entrepreneurship and innovation including its history in Iceland.

Geothermal Resources in Italy: Tracing a Path Towards Public Engagement

Anna Pellizzone, Agnes Allansdottir and Adele Manzella

Abstract Italy has a pioneering role in the geothermal sector: from ancient Romans thermal baths, to the development of the first geothermal power plant, the Country has contributed to the development of this technology. Italian geothermal power plants are located in Tuscany, where part of the local population is opposing to old and new geothermal developments. In this chapter we describe the current expectations and concerns of the Italian citizens regarding geothermal energy and we report on two social acceptance assessment case studies conducted by the Italian National Research Council in Southern and Central Italy, applying both quantitative (survey) and qualitative (focus groups) methods. As the energy question is increasingly recognized to be both technical and social domains, public engagement experiences in the field are rapidly growing internationally and other studies are also mentioned and described. Our review show that the opinions around geothermal energy among the Italian public are shrouded in uncertainty and many participants ask for more information on pros and cons in order to contribute to the discussion. The debate on geothermal energy development in Italy is strongly entangled with values, ethics, local identity and political issues. Lack of trust in the decision makers was the main reason for public concerns even if the presence of environmental and health risks were also questioned by part of the population.

Keywords Italy · Public engagement · Trust · Responsible innovation

A. Pellizzone (✉) · A. Manzella
National Research Council, Institute of Geosciences and Earth Resources,
Via Moruzzi 1, 56124 Pisa, Italy
e-mail: anna.pellizzone@igg.cnr.it

A. Allansdottir
Fondazione Toscana Life Sciences, Via Fiorentina 1, 53100 Siena, Italy

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_11

1 Introduction

1.1 Italian Framework

Italy is a largely mountainous peninsula that goes from the Alps into the Mediterranean Sea and it also includes the Po plain and two large islands (Sicily and Sardinia). The Italian population is around 61 million people and the Constitution organizes the Country into 20 Regions (4 of them being autonomous). In 2001 a new framework for sharing regulatory competences, including energy, between the central State and local Regions was defined. A novel framework was also proposed in the last referendum (2016), but the Italian citizens chose to maintain the status quo. Italy is a Member State of the European Union and it is governed by communitarian, national and local norms.

Since Second World War, the energy demand in Italy constantly increased and peaked in 2008, when the economic and financial crisis abruptly interrupted this growth. Italy seems to slowly emerging from the last economic recession: the growth was again positive in 2015, but below the European Union (EU) average (IEA 2016).

In the first two decades after the war, the Italian energy production was mainly based on fossil fuels and a first tentative diversification of energy provision was made in the 1970s after the oil crisis. In the late 1970s Italy fostered nuclear power plants development and import from other countries also increased, but few years later, in 1987, after the Chernobyl disaster, the Italian citizens opted out from nuclear energy in a national referendum (the permanent dismissal of the nuclear program was definitely established after a second public consultation in the referendum of 2011).

In 1999 the Italian energy market was liberalised by a governmental decree, the oil resources used for thermoelectric production were progressively substituted by natural gas (mainly introduced from Russia, Algeria and Libya) and the import of energy was further increased. In 2010, Italy adopted the Renewable Energy Action Plan in order to reach the target described under the terms of the European directive 2009/28/EC. The target was to achieve 17% of final energy consumption from renewable sources by 2020 and Italy reached its goal in 2015, five years before the final term.

In 2016, for the first time in the last decades, the electric energy produced in Italy from renewables has slightly diminished (−1 TWh if compared to 2015), being around 108 TWh and depending on a modest fall of solar photovoltaic (−0.8%) and on a significant drop of hydroelectric (−3 TWh) productions. This trend was partly made up by a strong increase in wind energy production (+19.2%, 3 TWh), geothermal (+1.7%) and bioenergy (+0.6%). In 2016, on the whole national electric energy production (290 TWh), 68.8% was covered by thermoelectric, 15.3% by hydroelectric and 15.9% by geothermal, wind and photovoltaic. The electric energy demand of Italy in 2016 was 314.3 TWh, with a reduction of −0.8% compared to 2015. According to TERNA (2016a) this was mainly due to a positive trend in energy efficiency and to an increasing responsible use of electricity by consumers. In 2016, the electric energy demand was supplied by national production (88.2%) and by import from other countries (11.8%). In the same year, the national electricity production grew to 290 TWh (+2.4% compared to 2015) and the import of energy decreased to 43 TWh (−15.1%). The fall of import from France in the second part of the year was highly significant (−37.5%).

In 2014 (IEA 2016) the Country energy demand is split relatively equally between transport (31.7%), households (25.3%) and industry (27.9%) and according to Abate et al. (2014), 30% of the Italian energy consumption regards medium-low thermal uses that could be supplied by shallow geothermal resources.

As to the main electricity consumption sectors, in 2016 41.5% of the Country general electricity consumption were spent by the industrial sector, 102.9 TWh by services, 64.3 TWh by domestic consumption and 5.6 TWh by agriculture (TERNA 2016a).

1.2 Geothermal Energy

Italy can be considered a geothermal country for several reasons. Its geology is particularly favourable to geothermal resources, and geothermal natural manifestations are abundant. Geothermal fluids were used for centuries, for recreational, healing and industrial purposes, often with wide application and recognised technological excellence.

Italy is a tectonically active country, being located along the African-Eurasian plates convergent margin (Manzella et al. 2017). The complex tectonic regime produced the two mountain chains characterizing the country, the Alps and Apennines, and an oceanic basin in the western margin, below the Tyrrhenian Sea. The western sector of the Apennine and the Tyrrhenian margin shows the most favourable conditions for hosting geothermal resources. This area is characterized by a reduced crustal and lithosphere thickness, a widespread magmatic activity and high geothermal heat flow. The existence at relatively shallow depth of geothermal systems has been verified in several areas from north to the south of Italian territory and off-shore zones, thanks to the numerous deep wells drilled for oil and gas or geothermal exploration. High temperature at relatively shallow depth, suitable for electricity production and district heating, has been recorded in numerous areas (Fig. 1). Hydrothermal circulation was recognized in volcanic, sedimentary and crystalline rocks, and local rise of warm waters from deep formations through faults or lateral discontinuities produces numerous natural hot springs. The Italian Geothermal Union (UGI) esteems, on the base of the temperature distribution, a potential total production from geothermal resources within 5 km depth of 21 EJ, two third of which at temperature below 150 °C (Buonasorte et al. 2011).

Some of the most sophisticated ancient thermal baths were built in the peninsula by Romans 2000 years ago, the first geothermal power plant was developed in Italy in the beginning of the last century (1913), and the local power generation capacity

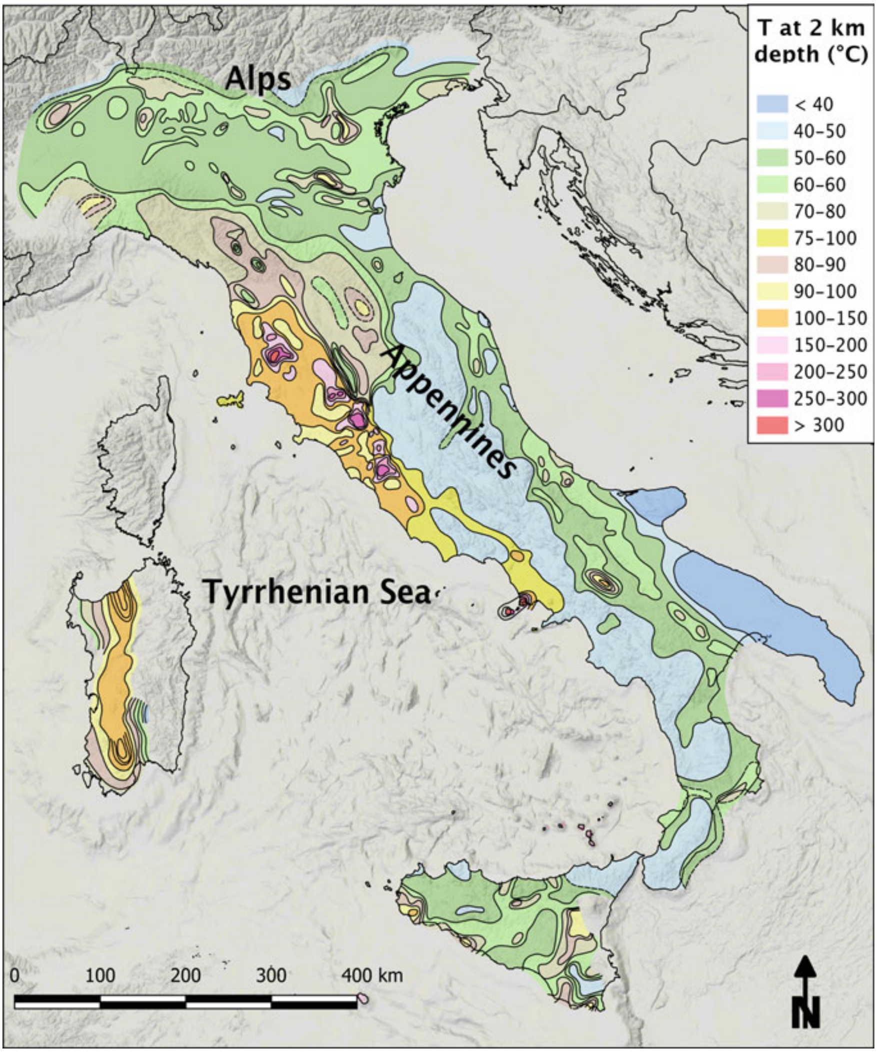


Fig. 1 Temperature distribution at 2 km depth in Italy. *Data source* Cataldi et al. (1995)

of from geothermal resource is at first place in Europe and at sixth place in the world. Since 2015 Italy is also pioneering the innovation of hybrid power plants that use geothermal energy and biomass, installed in Larderello. Overall, geothermal energy contributes to 1% of the Italian energy capacity and of 2% to the overall demand for energy (TERNA 2016b).

The Italian geothermal resources are nowadays mainly used for electricity generation and air conditioning by means of district heating (DH) and geothermal heat pump systems, which are experiencing an average annual growth rate of over

7% and are expected to further grow in the next years (Manzella et al. 2017). Direct uses of geothermal energy are widespread and in 2015 reached 1300 MWth, GSHP (Ground Source Heat Pump) accounting for 42% (around 580 MWth), followed by thermal balneology (32%), DH (10%), fish farming (9%), agricultural (6%), and industrial uses (1%) (Conti et al. 2016). Whilst thermal balneology—in the past provided by the public service and very used until 1980s—has slightly reduced its relevance, mainly due to the lack of public funds, geothermal DH has seen a renewed interest and is used in many urban centres, including large towns such as Ferrara and Milan.

Regarding electricity production, all the geothermal power plants in operation are located in Tuscany, in two areas—Larderello-Travale and Mt. Amiata—and are managed by Enel Green Power. In 2015 the gross electricity generation reached 5.9 TWh, with an installed capacity of 915.5 MWe, covering 30% of the electricity needs of Tuscany. As regard to EGS, Italy is not interested in developing the use of these resources at the moment, mainly due to social and environmental concerns (Manzella et al. 2017, 2018).

1.3 Legislative Framework

In Italy, the ownership of natural resources is regulated by the Civil Code (BBA 2017):

> The forests that by applicable laws constitute the forested domain of the State, mines, quar-ries and turf pits when their disposability is taken from the owner of the land […] are part of the non-disposable patrimony of the State (Article 826, para. 2);
>
> Ownership of the soil extends to the subsoil, with all that is contained therein, and the owner can perform any excavation or work that does not cause harm to a neighbour. This provision does not apply to that which is the object of laws on mines, quar-ries and turf pits […] (Article 840, para. 1).

The Legislative Decree No. 22/2010 states that geothermal energy qualifies as mineral resources that fall under the non-disposable patrimony of the Italian State or of the relevant region depending on the national or local interest of such resources (BBA 2017). It regulates the research and management of geothermal resources and defines the different geothermal resources based on temperature ranges of fluids: high enthalpy resources (fluid temperature >150 °C) are considered of national interest, heritage of state, whereas medium (fluid temperature of 90–150 °C) and low enthalpy (fluid temperature <90 °C) resources are declared of local interest.

The Decree describes relevant issues such as the role of landowners, institutions and producers; the licensing procedures; regulatory and information obligation; incentives and environmental impact assessment (EIA); participation and authority of local people (see also the next paragraph). For administrative functions about the exploration license and mining lease of local and national geothermal resources, including supervisory functions, the competent authorities are the Regions or the authorities delegated by them.

In addition, the Law Decree No. 28/2011 introduced and regulated “pilot plants”, each with nominal installed capacity not exceeding 5 MW, total reinjection of geothermal fluids in the same reservoir, and with zero emissions. These plants were introduced in order to promote research and development of new geothermal power plants with a reduced environmental impact.

Other norms governing the geothermal exploration and exploitation in Italy are the Presidential Decree No. 327/2001, which regulates the expropriation procedures in case of resources qualified as of public utility; the Presidential Decree No. 395/1991, which stipulates the documents and information that have to be submitted before and during both exploration and exploitation; the resolution of the Italian Regulatory Authority for Electricity, Gas and Water No. 111/2006 and the Resolution No. 444/2016 regulate the main aspects of the Power Purchase Agreements (PPA); the Ministerial Decree 6 July 2012, replaced by the Ministerial Decree 23 June 2016, regulates the geothermal power plants incentives; the Presidential Decree No. 395/1991 regulates other licenses (for geophysical survey, fluid injection, etc.).

The conjunction of liberalization of the research and exploitation activity of geothermal resources, established by Law Decree 22/2010 and favourable incentives for renewable sources, produced about 120 new requests processed on 2010 and 2011. Most requests were for new research permits in medium/high enthalpy geothermal resources suitable for power generation, cogeneration and district heating, and several new players tried to enter into the market. The later uncertainty of the market and the serious acceptability problems of local communities, concerned by to environmental issues, essentially nullified the market uptake. The Bill Law issued on July 2012 replaced the “Green Certificates” with an “Incentive Fee” similar to an all-inclusive fee decreased by zonal price of energy, to which additional premiums can be added, for new power plants with a capacity exceeding 1 MWe. As a result, with an average market price of electricity of approximately 4.7 Eurocent/kWh in 2015, the value of the net kWh generated from geothermal power plants awarded 9.9 or 8.5 Eurocent/kWh, for units having installed capacity under or above 20 MWe, respectively, whereas with “Green Certificates” it was around 13.7 Eurocent/kWh (Conti et al. 2016).

Another aspect that is also contributing to the slow development of geothermal electricity market in Italy is the lack of social consensus for new geothermal plants. The right to participate of local communities represents a minor issue for the Italian law (see next paragraph). However, the environmental issues and the land/resource management play an important role as precursory themes influencing the Italian normative scenario among public engagement (Pellizzoni 2016).

2 Public Engagement with Geothermal Energy in Italy: A General Framework

2.1 Geothermal Energy and Public Engagement: Hard Law and Soft Law

Historically, the first time that the Italian public institutions have recognized public participation and environmental rights was in the second half of the 1980s. According to the norm 349/1986 (Article 6), "every citizen can submit to the Ministry of the Environment, to the Ministry of Cultural and Environmental Goods and to the Regional Government, applications, observations or advices on plants under environmental impact assessment (EIA)". Later on, in 1997, the public participation among environmental issues has been officially introduced with regard to waste management.

Concerning geothermal energy, the right of local people to participate to decision making process is formally granted by the Presidential Decree No. 485/1994, stating that local communities and associations can rise objections that are taken into account by the competent authorities during the licensing procedures. Correct public information is of course essential in order to really embrace the opinions of the different stakeholders involved in the innovation process. Interested communities judging that their rights and interests have not been adequately considered during the licensing process can then appeal to a regional administrative court (TAR).

Another important document regarding geothermal resources management is a soft law document reporting the national guidelines on environmental features connected to geothermal development. The guidelines were released in July 2016, describing the best practice to be followed in the most important phases of a geothermal project, in particular for those related to electrical power generation and requiring the drilling of deep wells. Social acceptance information is also mentioned in the guidelines as useful information to be collected in a preliminary assessment (MISE-MATTM 2016).

In Italy, as well as in Europe, the governance of emerging technologies (geothermal included) is characterized by a growing integration of hard law and soft law (guidelines, best practices, various forms of non-mandatory certification or self-assessment tools). According to the literature, the motivation of this transformation lies in the "pervasiveness of uncertainty in science, technology and their governance", requiring new normative approaches "centred on the adoption and the practical implementation of (self-) regulatory instruments such as codes of conduct, guidelines, technical standards, reporting, and audits" (Arnaldi et al. 2016, p. 13).

Accordingly, as part of Europe, Italy approach to innovation, including energy innovation, is influenced by the Responsible Research and Innovation (RRI) narrative, which has increasingly fostered public engagement at the communitarian level. Many European scholars and Commission experts (Von Schomberg 2013) have emphasized the need to move from a model that addresses the responsibility in innovation ex post facto (i.e. sanctions, compensations, etc.) to a model that encourages the anticipation of technological impacts on society and a reciprocal responsibilisation within the stakeholders ecosystem (i.e. *ex ante* public consultation and engagement, ethics assessment, etc.).

2.2 Geothermal Energy and Society: Local Experiences and Existing Studies

2.2.1 Knowledge and Acceptance of Geothermal Energy: Italy Compared to Other European Countries

Some of the first data on geothermal energy and the public in Italy come from the Eurobarometer survey[1] literature. According to the Special Eurobarometer 364 (2011) on Public Awareness and Acceptance of CO_2 capture and storage (CCS), under a half of Europeans (47%) had heard of geothermal energy. The level of recognition of alternative energy sources was higher for 'solar photovoltaic' energy, with almost six in ten (58%) respondents had heard of it. Over a half (51%) had heard of 'nuclear fusion', whilst just under a half had heard of 'biogas' (48%) and the lowest recognition was of 'clean coal' (22%) and 'cogeneration' (21%). These rates vary among Countries and when it comes to Italy, the results show that the awareness around geothermal energy was much higher in Finland (94%), followed by Germany (78%) and France (69%). Surprisingly, a geothermal country like Italy has the second lowest level of awareness (25%), with only Bulgaria scoring lower (17%).

Another comparative exploration of the European views and knowledge on geothermal energy has been conducted within the framework of the Geothermal communities (GEOCOM)[2] project, focused on the use of geothermal energy for district heating with small scale RES (Renewable Energy Sources) integration and retrofitting measures, co-funded by the European Commission within the 7th Framework Programme from 2010 to 2015.[3] The research—aiming at a comparative assessment of public perception of geothermal energy among the seven countries involved in the project (Hungary, Italy, Macedonia, Poland, Romania, Serbia, and Slovakia)—is based on (1) quantitative methods (questionnaire surveys), (2) qualitative methods (open opinions, comments) and has involved appointed experts of the geothermal sector within the interested areas. The study aimed at understanding current public perception of geothermal energy in order to build an adequate promotion strategy of this energy resource and cannot be

[1]For more information on Eurobarometer surveys: http://ec.europa.eu/COMMFrontOffice/publicopinion/index.cfm.

[2]The project website: http://geothermalcommunities.eu/.

[3]See also www.geothermalcommunities.eu.

considered a public engagement exercise, however it provides several information about citizens attitudes towards geothermal energy. As in the case of the above-mentioned Eurobarometer on CCS, one of the main evidence of the survey is the lack of knowledge around geothermal energy by the Italian population. According to the experts, 80% of the Italian public lacks knowledge on geothermal energy and its uses (with the remaining 20% having a poor knowledge), a rate that is worst if compared to other renewables and to other Countries (Kępińska and Kasztelewicz 2015).

2.2.2 Geothermal Energy and Social Conflicts: The Case of Monte Amiata

While the majority of Italians seem to lack knowledge about geothermal energy and its applications, some of the local communities living in the neighbourhood of the geothermal power plants sites (Mt. Amiata) are strongly engaged with the subject. At the moment, no social scientific studies have been conducted in the area, however local newspapers (e.g. Il Tirreno[4]) and websites[5] show that a part of the population living in the Mt. Amiata area objects to geothermal developments, where civil society organizations, some of the local mayors and a portion of the local scientific community have organized in committees and networks (i.e. SOS Geotermia, Rete NOGESI). The Amiata social movements are conducting several activities, e.g. demonstrations, public debates, queries to the regional, national and European institutions, questioning if geothermal energy should be considered a clean and renewable energy resource or not. The main concerns of the local populations raised by geothermal energy are related to health, to water usage and pollution and to other environmental impacts (soil contamination). As can be seen in the SOS Geotermia Manifesto or in several videos and interviews available on the web,[6] the network is asking for a moratorium on geothermal activities in the area, while it is favourable to "non speculative" low enthalpy geothermal technologies.

A strictly political issue that is often mentioned in the documents and in the public declaration of the representative of the civil society organisations engaged in this battle—and that is also common to other territorial disputes in Italy, e.g. the No Tav[7] conflict—regards the decision making process, the right of local communities to determine the future of their land and the eventual fair distribution of benefits coming from local resources employment. The underlying narrative of the disputes is also based on a general distrust towards "energy lobbies": as many other science

[4]http://iltirreno.gelocal.it/grosseto/cronaca/2017/11/12/news/no-alle-centrali-si-alla-geotermia-pulita-1.16110761.

[5]https://sosgeotermia.noblogs.org.

[6]https://www.youtube.com/user/sosgeotermiaamiata.

[7]The territorial dispute regarding the development of an high speed train-way in North-East Italy.

and innovation arguments, the energy debate is also "interwoven with issues of meaning, values and power in ways that demand sustained critical inquiry" (Jasanoff 2004, p. 5).

The social conflict dealing with geothermal energy in the Monte Amiata area has been analysed by Borzoni et al. (2014) conducting asocial multi-criteria evaluation of alternative scenarios for geothermal development. The research explores the different legitimate perspectives of the actors involved in the local geothermal debate in order to provide policy making with evidence-based input. The empirical analysis conducted by the researchers considered 7 different scenarios for the following 30 years and evaluated them on a set of 11 criteria,[8] grounded in a detailed analysis of institutional settings. Results show that the scenarios involving binary cycles or total-reinjection technologies tended towards the most positive positions.

The echoes of the geothermal debate in the Monte Amiata have spread in the neighbour areas, mainly in Central Italy, and have recently reached also the national Government: in the last months of 2017, the discussion among new geothermal plant development has arrived also on the table of the Italian cabinet that in December has rejected the consent for the development of a pilot plant (5 MW) in Latium (Torre Alfina, Acquapendente).

At the European level, the opposition to geothermal energy starting from Tuscany has reached the European institutions and some exponents of the Italian 5 Star movement members of the Parliament in Strasbourg have drawn attention on geothermal power plants emissions.

The emissions of Monte Amiata power plants have recently (January 2018) been at the heart of a trial conducted by a Tuscany court. The judges are checking whether Italian plants in operation lack available technology for emission mitigation.

2.2.3 Public Engagement with Geothermal Energy in Central and Southern Italy: Two Case Studies

The first recent study focused on the social acceptance of geothermal energy in Italy was conducted within the framework of two national projects (VIGOR and Atlante Geotermico del Mezzogiorno) led by the Italian National Research Council that were oriented to describe the geothermal framework of Central and Southern Italy. As encouraged by the European Strategic Energy Technology (SET) Plan—which considers the understanding of the behaviour of social and political actors and the facilitation and enablement of public participation in the energy transition as two key actions towards the strengthening and the acceleration of the energy transition —these projects had conducted, besides technical, geological and economical

[8]The criteria were: (1) electricity produced, (2) profitability of the plants, (3) municipality revenues, (4) direct heat use, (5) avoided greenhouse gas (GHGs) emissions, (6) H2S emissions, (7) Hg emissions, (8) NH_3 emissions, (9) As emissions, (10) possible impact on the phreatic aquifer, (11) visual impact.

studies, also social investigations through two case studies. The first was conducted in October 2012 in Sicily (in the Palermo Province, Southern Italy, see Pellizzone et al. 2015) and the second in June 2014 in Latium (in the Viterbo Province, Central Italy, see Pellizzone et al. 2017). The two areas are characterized by high geothermal potential and different geographical and social contexts: the province of Palermo was undergoing rapid deindustrialization, and geothermal resources had never been used for energy production there; geothermal development with novel technologies has been proposed in the Viterbo province, but has experienced a growing opposition. We can position the activities conducted somewhere at the intersection between social acceptance assessment and public deliberative exercises and consider them as the first experiences of public engagement in the field of geothermal energy in Italy aiming at: (1) exploring the views and opinions of local communities regarding the eventual and real development of geothermal energy; (2) contributing to the growing scientific and social-scientific literature of the social acceptance of geothermal energy; (3) conducting public engagement exercises in the field of geothermal innovation towards the development of new policy tools.

The two case studies were composed by a mix of (1) quantitative (survey) and (2) qualitative (focus groups) methods. The survey involved 400 people and the sample population was calibrated by a series of variables including age, gender, job position, education and place of living. The focus groups lasted 1 h and 30 min and were composed by 8 participants. In Sicily the groups were composed by students, general public from Termini Imerese (a little village close to Palermo that has a long thermal bath history), decision makers and ex-workers from the FIAT plants, now closed. In Viterbo we involved students, general public, local decision makers and environmental activists.

3 Results and Discussion

3.1 *Public Perception on Geothermal Energy and Other RES*

In both case studies, knowledge and opinions about energy sources varies depending on the technologies, suggesting that in general respondents don’t have a priori techno-optimistic or techno-pessimistic positions. When asked “*Which one of these technologies will have positive, negative or no effect on our way of life in the next 20 years?*”, respondents have much clearer ideas around solar and wind energy and about nuclear power plants. In the Viterbo Province—where survey participants seem to have more formed opinions than in Palermo—86% of respondents thinks that solar energy will have a positive impact on our life in the next 20 years, and 84% thinks the same for wind energy, while these rates decreased to 54 and 46% respectively in Palermo. Past negative experiences regarding speculation around wind energy, described during the focus group discussion in Palermo, might have

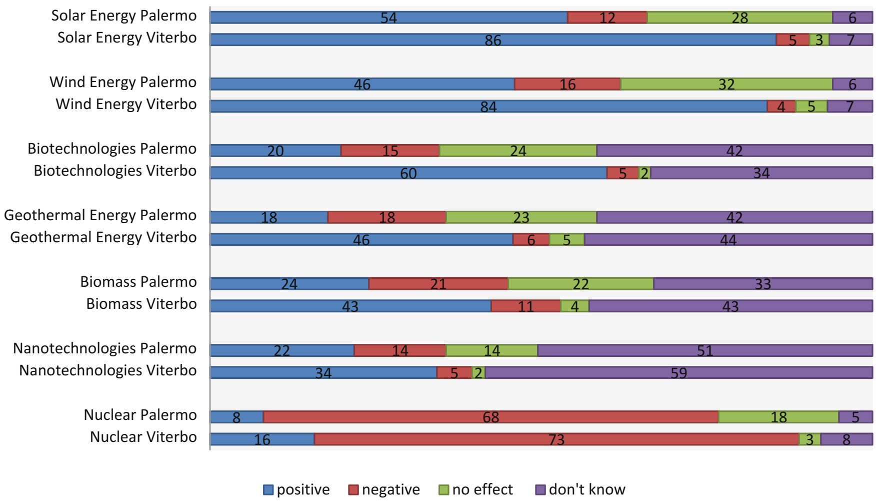


Fig. 2 Optimism towards a series of technologies. *Data Source* Pellizzone et al. (2016) (data in percentage)

influenced the public perception. In Viterbo, the public position against nuclear energy is also more evident than in Palermo: 73% of respondents in the first Province thinks that nuclear will have a negative impact on our life in the next 20 years, whereas in the second the rate decreases to 68%.

As regard to geothermal energy (Fig. 2), respondents of both Provinces show high levels of "*I don't know*": 42% in Palermo and 44% in Viterbo. Comparable or higher rates of the same answer were registered for other emerging technologies, i.e. biotechnologies, biomass and nanotechnologies. This suggests that geothermal energy behaves as an emergent technology when it comes to public hopes or concerns: almost one in two people living in the areas take a stand on the future impacts of geothermal energy. However, some differences between the two case studies are also present: in Palermo the rate of "optimistic" participants is identical to the rate of "pessimistic" ones (18%), while in Viterbo the former exceed the latter (46 and 6% respectively) and in Palermo the 23% thinks that geothermal developments will not have any impact on our future (5% in Viterbo).

As regards risk perception towards different geothermal technologies, the two communities involved don't make a great difference between power plants and heat pumps: in Palermo, a slight preference is made for heat pumps (even if the rate of "*I don't know*" answers is at 25%), while in Viterbo respondents seem to consider power plants a little less risky (Fig. 3). This is quite interesting, since during the focus group discussion, a few participants raise the issue of heat pump being much more preferable than geothermal power plants, mainly mentioning the water contamination issue:

> I think that low enthalpy could be interesting… but I disagree with the development of geothermal power plants (Politicians focus group in Viterbo).

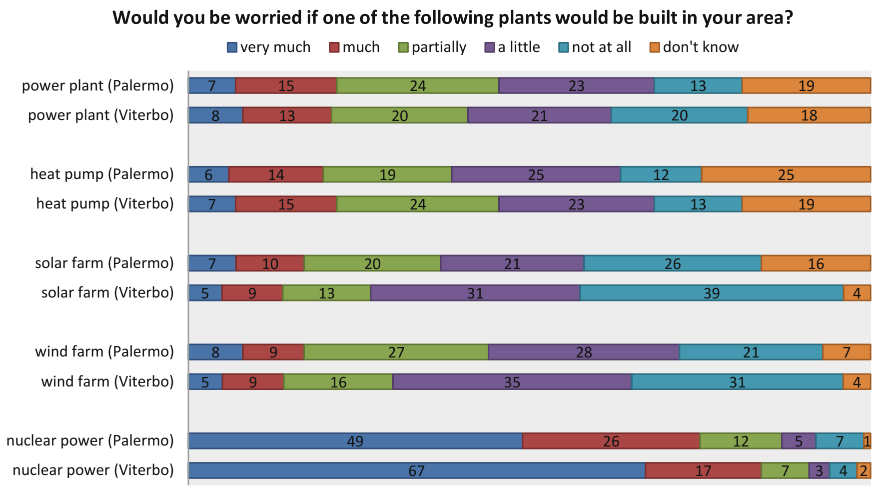


Fig. 3 Risk perception of a series of energy technology, included heat pump and power plants (data in percentage)

3.2 *The Right Information from the Right Sources*

As the Eurobarometer and the GEOCOM results also found, the lack of knowledge is a key issue for geothermal energy in Italy. It is quite surprising that in two areas where thermal baths are present since ancient times the people that at least "have heard" about geothermal energy are 17% in the Palermo Province and 42% in the Viterbo Province. Within them, 68% thinks that geothermal energy would be useful, much useful or very much useful in Palermo and 42% thinks the same in Viterbo; 54% thinks that geothermal energy should be encouraged—very much, much or partially—in Palermo and 51% in Viterbo (Fig. 4). Finally, when it comes to hazards, in Palermo 54% answered that geothermal energy would be hazardous —very much, much or partially—for their community and 73% of inhabitants of the Viterbo Province said the same.

During the focus group discussion, participants strongly requested more information and also gave some suggestions in order to guarantee that correct, impartial and complete data are provided to the public, discussing sources of information they would trust the most (e.g. young researchers, local scientists) and the kinds of knowledge they would like to include (expert and local knowledge). Web information are generally perceived as more impartial, since newspapers and television are described as strongly influenced by either political or private interests. However, the issue of the reliability of web information was also mentioned by focus groups participants.

> Reliable information [on the web] could be attested by some form of certification: the web site could be marked/certified by scientists or experts (Citizens focus group in Viterbo)

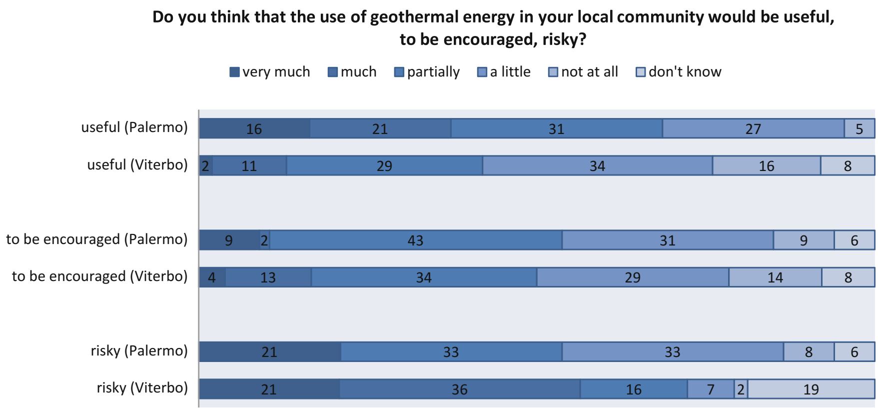


Fig. 4 Use of geothermal energy: is geothermal energy useful, to be encouraged or risky in your local community? (data in percentage)

> I would trust a new generation of young researchers (Citizens focus group in Viterbo).
>
> Universities could at least be impartial (Environmentalists focus group in Viterbo).
>
> In my opinion we should approach experts and local people because they are more informed about the area (Environmentalist focus group in Viterbo).
>
> I think we need information from experts that can evaluate pro and cons (Students focus group in Viterbo).
>
> To say if we are in favour of this kind of technology, we need to have all the information to balance pro and cons (Students focus group in Palermo).
>
> We lack public information, which is different from marketing information (Citizens focus group in Palermo).
>
> What I see is widespread ignorance and no efforts are made to overcome this ignorance (Stakeholder focus group in Palermo).

3.3 Distrust Toward the Technology Versus Distrust Towards the Decision Makers

The issue of lack of knowledge dominating the debate was strictly interwoven with the issue of distrust towards the decision makers. This is not new for social scientists: as we know from Beck (1992), trust act as substitute for knowledge in complex societies characterized by risks. If we consider trust as a dual concept (Siegrist et al. 2003) composed by (1) confidence (i.e. the fraction of trust related to competencies and to the technical ability to operate) and (2) social trust (i.e. the portion of trust related to common values), it was evident from our focus groups that the second was consistently missing, in particular when referring to current elites and establishment. The common ground among participants in both case studies is the idea that Italian decision makers (politicians, local administrators, companies) are not acting for the common good, which, in our case, would be the development of safe, clean and fair energy technologies and that the entrepreneurial-political-social system is locked-in by carbon based energy resources (see also Unruh 2002) and by private interests, opposing to collective needs.

> We lack a culture of the common good (Ex-Fiat workers in Palermo).
>
> We are badly administered (Citizens focus group in Termini Imerese).
>
> We have a very rigid system and if we want to introduce alternative sources of energy we have structural barriers (Stakeholder focus group in Palermo).
>
> Geothermal heat exploitation is a good idea, but we saw how it worked for wind farms: they took money from energy subsidies but many plants are not working (Citizens focus group in Termini Imerese).
>
> I am very pessimistic: there are too many interests (Citizens focus group in Viterbo).
>
> There is no political will to use the competences that are present in a good way (Students focus group in Viterbo).

Compared to politicians, researchers and scientists are perceived as more "impartial", at least when they are not working for private companies with specific interests. Both in the focus groups and in the surveys, scientists are indicated as the most competent actors and as the most reliable source of information: scientists are perceived as trustworthy as long as they are "independent". This is a very important message for the scientific community and together with the request for more information on geothermal energy it should be taken seriously by researchers and by public communication of science stakeholders.

3.4 What Future Do We Want to Live in? Public Engagement with Geothermal Energy as an Opportunity for a Long Term Vision

Another key issue emerging from the debate was about the future of involved communities and territories. Some participants lamented the lack of a perspective and long-term vision by local governments. In Viterbo, with the exception of environmental activists having a quite clear idea of the local priorities and of the world they want to live in and sharing also some input and suggestions, the different stakeholder clearly express their concerns about the lack of a vision for the socio-economic future of their communities. Taking position on geothermal energy concerns the future of citizens in terms of risks or uncertainty (the unknown unknowns), but also in terms of local identity.

> Viterbo used to be an agricultural, rural, city. Today it may be different. It has become an industrial city, but after the crisis some industries have declined. As regard to the touristic

sector, I don't think there is the will to pin on tourism, it is enough to see how scruffy the roads are (Citizens focus group in Viterbo).

Where do we want to go? We don't know. We would have the resources: the mountains, the sea, the lake, the enviable climate condition… (Citizens focus group in Viterbo).

A completely safe Bolsena lake can attract tourism, support the local economy and redevelop the area. This is a land that points at the environmental conservation and on agricultural activities, if you destroy water, you destroy everything.

Viterbo has several problems: it is a town of old people, but maybe the university is opening a new route… (Citizens focus group in Viterbo).

Termini Imerese has already an industrial area which is becoming a ghost town. We should convert it, instead of leaving it empty (Citizens focus group in Termini Imerese).

From this perspective public engagement is fundamental to foster a local development strategy aligned with social values and local features. Besides the common framework described above, participant are sensitive to some place-related issues. For example, Viterbo Province is characterized by high arsenic concentrations in aquifers because of the geological features of the area. Water contamination was a central issue in the focus group debate, even if it was associated with geothermal energy by few participants:

You don't know how deep they drill and there is the possibility that they contaminate "good aquifer" with waters that contain arsenic; this is a big question and the Bolsena lake is the only one with waters that don't have high arsenic content (Environmentalists focus group).

In the case of Palermo, the history of local economy and land management is aligned with the eventual development of geothermal plants: "*Since the [abandoned FIAT] industrial area is here, we could use it to develop new social opportunities*" *(Students focus group in Palermo)*. This resonates with the words of Devine-Wright (2011, p. 341): "Change in places is not inevitably disruptive, but may enhance place attachment in situation of good 'fit' between symbolic meanings associated with both place and project".

4 Framing the Italian Debate

To summarize, in both case studies we found significant openness towards geothermal energy, but also some potential for controversies, particularly in the area of Viterbo. Opinions and perceptions around the exploitation of Earth heat are not strictly fixed in the two areas and the absence of knowledge, together with an extensive lack of trust in decision makers, could potentially lead to social disputes as it is significantly happening in Tuscany. Some concerns related to environmental issues and risks have been mentioned during the discussion, especially in Central Italy, but the most evident source of concern in both case studies was the lack of trust towards the political and economical system but not necessarily the technology itself. Notwithstanding the poor knowledge on the issue, participants were happy to have their voice heard and to share their views on the energy issue, contributing a lot to the discussion, for instance conveying values and experiences to be included in the decision making process and in the first stages of the local development design. At the same time, citizens seemed to take public engagement seriously, asking for competent, complete and transparent information, in order to better contribute to the debate and according to our results, the most reliable information sources would be scientists and researchers independent from political and commercial interests.

The results of this study suggest that the engagement of different stakeholders in the decision making process could help in rebuilding trust towards the different social actors in the long-term. Benefits would be at different levels. (1) Upstream engagement of different actors can improve the quality of future geothermal projects, bringing knowledge and experiences in the project itself. (2) Empirical research on wind energy shows that the perception of unfair decision making process can reinforced opposition towards single projects, whilst collaborative decision making is more conducive to the eventual developments based on shared values, enhancing the democratic legitimacy of the choices adopted. (3) Public engagement could also be integrated with information activities, contributing to increase the awareness of the public and other relevant stakeholders on geothermal energy. (4) Last, but not least, considering that participants request a clear vision for the future of their communities, public engagement could foster a collective commitment on the subject. In a sense, it is what Alvin Toffler named "*anticipatory democracy*", meaning "*a continuing plebiscite on the future*" (Toffler 1970), a concept that we find also in the framework of Responsible Research and Innovation (RRI).

According to RRI process dimensions, practicing a more responsible research and innovation requires that processes are (also): (1) *Anticipative & reflective*, envisioning impacts and reflecting on the underlying assumptions, values, and purposes to better understand how research and innovation (R&I) shapes the future, yielding to valuable insights and increasing our capacity to act on what we know[9]; (2) *Diverse & inclusive*, involving early a wide range of actors and publics in R&I practice, deliberation, and decision-making to yield more useful and higher quality knowledge, strengthening democracy and broadening sources of expertise, disciplines and perspectives. In this sense, traditional public engagement methodologies (e.g. deliberative focus groups, public consultations, consensus conference, etc.) could be integrated by foresight, technology assessment and scenario development, stimulating the reflection on eventual impacts and the sustainability of new developments.

This approach is further sustained by the concept of geoethics, consisting "of research and reflection on the values which underpin appropriate behaviours and practices, wherever human activities interact with the Earth system".[10] As the human interference with the geosphere increases, the need of upstream integration of public concerns into research and innovation requires open approach to inclusive governance (Meller et al. 2017).

[9]https://www.rri-tools.eu/about-rri.

[10]http://www.geoethics.org/.

Considering the extensive distrust and the central role played by local values and experiences emerged from the social acceptance studies conducted so far in Italy, a further suggestion is that public engagement would benefit from a polycentric approach[11] (Ostrom 2010) based on social capital. Social innovation theories and several communities experiencing a self-, collective-, decentralized-, participated-, management of resources show that local engagement in resources management improves the community wellbeing (Pretty 2003), providing cumulative benefits at the global level. "Polycentric systems tend to enhance innovation, learning, adaptation, trustworthiness, levels of cooperation of participants, and the achievement of more effective, equitable, and sustainable outcomes at multiple scales" (Ostrom 2010, p. 552). According to this approach, the development of a public engagement based level of governance could contribute to the development of an essential relationship of trust among societal actors operating in the geothermal energy field in Italy.

Acknowledgements Two authors acknowledge the project DG-ETIP, Co-funded by the European Union's HORIZON2020 research and innovation programme (GA. No. 773392).

This chapter is partly based on research carried out within the context of the activities of the Italian projects VIGOR and Atlante Geotermico del Mezzogiorno d'Italia (Geothermal Atlas of Southern Italy). VIGOR Project, coordinated by CNR, aimed at assessing the geothermal potential and exploring geothermal resources of four regions in southern Italy, was part of the activities of the Interregional Programme "Renewable Energies and Energy Savings FESR 2007–2013—Axes I Activity line1.4 "Experimental Actions in Geothermal Energy". Atlante Geotermico del Mezzogiorno d'Italia, funded by the Italian government, coordinated and carried out by CNR, focused on the characterization, classification and mapping of conventional and non conventional geothermal resources of southern Italy for power production.

The authors would like to express a particular thanks to Roberto De Franco and Giovanni Muttoni for their fundamental contribution and enthusiasm in starting this research on geothermal and society in Italy.

References

Abate S, Botteghi S, Caiozzi F, Desiderio G, Di Bella G, Donato A, Lombardo G, Manzella A, Santilano A, Sapienza A (2014) VIGOR: Applicazioni geotermiche per uno sviluppo sostenibile. Produzione di calore ed energia elettrica. Ed. CNR – IGG, Pisa ISBN: 9788879580120

Arnaldi S, Gorgoni G, Pariotti E (2016) RRI as a governance paradigm: what is new? In: Linder R, Kuhlmann S, Randles S, Bedsted B, Gorgoni G, Griessler E, Loconto A, Mejlgaard N

[11]"Polycentric" connotes many centers of decision making that are formally independent of each other.… To the extent that they take each other into account in competitive relationships, enter into various contractual and cooperative undertakings or have recourse to central mechanisms to resolve conflicts, the various political jurisdictions in a metropolitan area may function in a coherent manner with consistent and predictable patterns of interacting behavior. To the extent that this is so, they may be said to function as a "system" (Ostrom et al. 1961, pp. 831–832).

(eds) Navigating towards shared responsibility [Online]. Available at http://pure.au.dk/portal/files/98634660/RES_AGorA_ebook.pdf. Accessed 26 Mar 2018
BBA, with contributions from Allen & Overy, Anjarwalla & Khanna, Baker McKenzie, Bonelli Erede, Bezen and Partners, Carey, CMS Hasche Sigle, DLA Piper (Canada) LLP, Hiswara Bunjamin & Tandjun (in association with Herbert Smith Freehills), Hogan Lovells, Latham & Watkins, Russell McVeagh, SyCip Salazar Hernandez & Gatmaitan, Teshome Gabre-Mariam Bokan and Van Ness Feldman (2017) Geothermal transparency guide, an overview of regulatory frameworks for geothermal exploration and exploitation [Online]. Available via ISSUU. http://issuu.com/bba3/docs/geothermal-transparency-guide_web?e=23738478/43095423
Beck U (1992) Risk society, towards new modernity. SAGE, London
Borzoni M, Rizzi F, Frey M (2014) Geothermal power in Italy: a social multi-criteria evaluation. Renew Energy 69:60–73
Buonasorte G, Cataldi R, Franci T, Grassi W, Manzella A, Meccheri M, Passaleva G (2011) Previsioni di crescita della geotermia in Italia fino al 2030 – Per un Nuovo Manifesto della Geotermia Italiana. UGI and Ed. Pacini, Italy, p 108
Cataldi R, Mongelli F, Squarci P, Taffi L, Zito G, Calore C (1995) Geothermal ranking of the Italian territory. Geothermics 24(1):115–129
Conti P, Cei M, Razzano F (2016) Geothermal energy use, country update for Italy (2010–2015). Paper presented at the European Geothermal Congress 2016 (EGC 2016), Strasbourg, France, 19–24 Sept 2016
Devine-Wright P (2011) Place attachment and public acceptance of renewable energy: a tidal energy case study. J Environ Psychol 31:336–343
IEA (International Energy Agency) (2016) Energy policies for IEA countries: Italy, 2016 Review [Online]. Available at https://www.iea.org/publications/freepublications/publication/EnergiePoliciesofIEACountriesItaly2016Review.pdf. Accessed 26 Mar 2018
Jasanoff S (2004) The idiom of co-production. In: Jasanoff S (ed) States of Knowledge. The coproduction of science and social order. Routledge, London, pp 1–12
Kępińska B, Kasztelewicz A (2015) Public perception of geothermal energy in selected European countries. Paper presented at the world geothermal congress, Melbourne, Australia, 2015
Manzella A, Donato A, Gola G, Santilano A, Trumpy E (2017) The Italian challenge for geothermal energy. In: Bertani R (ed) Perspectives for geothermal energy in Europe, 1st edn. World Scientific Publishing Europe Ltd., pp 127–155
Manzella A, Bonciani R, Allansdottir A, Botteghi S, Donato A, Giamberini MS, Lenzi A, Paci M, Pellizzone A, Scrocca D (2018) Environmental and social aspects of geothermal energy in Italy. Geothermics. https://doi.org/10.1016/j.geothermics.2017.11.015
Meller C, Schillb E, Bremer J, Kolditz O, Bleicher A, Benighaus C, Chavot P, Gross M, Pellizzone A, Renn O, Schilling F, Kohl T (2017) Acceptability of geothermal installations: a geoethical concept for GeoLaB. Geothermics 128(2):165–172
MISE-MATTM (2016) Linee Guida per l'Utilizzazione della Risorsa Geotermica a Media e Alta Entalpia [Online]. Available at http://unmig.sviluppoeconomico.gov.it/unmig/agenda/upload/174_375.pdf. Accessed 26 Mar 2018
Ostrom E (2010) Polycentric systems for coping with collective action and global environmental change. Glob Environ Change 20:550–557. https://doi.org/10.1016/j.gloenvcha.2010.07.004
Ostrom V, Tiebout CM, Warren R (1961) The organization of government in metropolitan areas: a theoretical inquiry. Am Polit Sci Rev 55:831–842
Pellizzone A, Allansdottir A, De Franco R, Manzella A, Muttoni G (2015) Exploring public engagement with geothermal energy in southern Italy: a case study. Energy Policy 85:1–11
Pellizzone A, Allansdottir A, Manzella A, De Franco R, Muttoni G (2016) Geothermal energy, social acceptance and responsibility in Italy: two case studies. Paper presented at the European Geothermal Congress, Strasbourg, France, 19–24 Sept 2016
Pellizzone A, Allansdottir A, De Franco R, Manzella A, Muttoni G (2017) Geothermal energy and the public: a case study on deliberative citizens' engagement in central Italy. Energy Policy 101:561–570

Pellizzoni L (2016) Dispensa di sociologia dei processi partecipativi [Online]. Available at https://people.unipi.it/luigi_pellizzoni/wp-content/uploads/sites/380/2017/11/Pellizzoni-Dispensa-di-Sociologia-dei-processi-parecipativi-aa-2017–18.pdf. Accessed 26 Mar 2018

Pretty J (2003) Social capital and the collective management of resources. Science 302 (5652):1912–1914. https://doi.org/10.1126/science.1090847

Siegrist M, Earle T, Gutscher H (2003) Test of trust and confidence model in the applied context of electro magnetic field (EMF) risks. Risk Anal 23(4):705–715

TERNA (2016a) Electrical power production in Italy 2016 (in Italian) [Online]. Available at http://download.terna.it/terna/0000/0994/85.PDF. Accessed 26 Mar 2018

TERNA (2016b) Power production plants in Italy (in Italian) [Online]. Available at http://download.terna.it/terna/0000/0964/25.PDF. Accessed 26 Mar 2018

Toffler A (1970) The shock of the future. Random House, New York

Unruh GC (2002) Escaping carbon lock-in. Energy Policy 30(4):317–325

Von Schomberg R (2013) A vision of responsible research and innovation. In: Owen R, Heintz M, Bessant J (eds) Responsible innovation: managing the responsible emergence of science and innovation in society. Wiley, London, pp 51–74

Anna Pellizzone is a science writer and researcher. In 2017 she got a scholarship at the Italian National Research Council, Institute of Geosciences and Earth Resources. Natural scientist, she holds a master in Science Communication and a Ph.D. in Earth Sciences, obtained with a thesis on the social aspects of geothermal technologies in collaboration with the Italian National Research Council. Since 2012 she has been conducting research activities for the CNR and has participated in several projects (VIGOR, ATLANTE, GEOELEC, ETIP-DG) on geothermal energy, with contributions aimed at deepening the relationship between innovation, research and society. Her research interests are focused on Responsible Research and Innovation (RRI) and she is author of several academic papers related to public engagement with geothermal energy. Since 2010 she has been writing also for generalist newspapers, magazines and websites and since 2016 Anna has been collaborating with Fondazione Bassetti on the SMART-map project (projectsmartmap.eu) and with Fondazione Eni Enrico Mattei.

Agnes Allansdottir is a social psychologist researcher who studied at the London School of Economics and Political Science. She has extensive experience of empirical research on societal dialogues on science and technology. From 1996 she lectured on psychology of communication, science communication, bioethics and science in society at the University of Siena. She has been a principal investigator on a series of EC funded international research projects on life sciences and society, climate change, public engagement, ethically sensitive technologies and public ethics. She has repeatedly given advice to international and national policy making bodies and has presented and published widely in high-level international journals, including Nature, Nature Biotechnology, Plos One, PNAS and Energy Policy.

Adele Manzella is a Senior Scientist at the Italian National Research Council (CNR), working as a geophysicist and conducting field and theoretical investigations of geothermal systems in Italy and abroad. She coordinated for CNR the most recent national geothermal evaluation projects and led the CNR participation in many EU funded projects in the geothermal sector related to geothermal exploration, research coordination and outreach. She is President of the Italian Geothermal Association (UGI) and participates to the Steering Committee and Secretariat of the European Technology and Innovation Platform for Deep Geothermal (ETIP-DG). Nowadays her activity tackles all fields of research, training, information and promotion of geothermal energy.

Issues Around Geothermal Energy and Society in Japan

Kasumi Yasukawa

Abstract From 1967 geothermal power generation in Japan increased rather rapidly till 1999. The main players had been private sector supported by government's subsidies. However various socio-economic reasons prevented private sectors from investing in new geothermal development in the 21st century. Legal frameworks and regulations kept geothermal power generation in Japan quite costly and opposition by local people involved in "hot-spring business" delayed geothermal projects. Then finally after the great east Japan earthquake and its following nuclear accident in 2011, the federal government renewed economic supports for geothermal development and modified some regulations which had been limiting geothermal development. Therefore, the currently remaining biggest barrier to geothermal development is social acceptance especially by local hot-spring business people. Although social study on this matter has just started recently and has not been applied to real system yet, experience from the past failure project enables us to consider possible solutions to apply to the society. Thus the federal government has begun supporting activities by developers or local governments for social acceptance.

Keywords Japan · Hot spring · Social acceptance · Local stakeholder

1 The Geothermal Resource in Japan and Its Potential to Meet Energy Demand

1.1 Geothermal Framework in Japan and Other Energy Sources

Located along Circum-Pacific Volcanic Belt "Ring of Fire," Japan is blessed with geothermal energy. Its theoretical potential to a depth of 3 km is over 20 GW_e

K. Yasukawa (✉)
Advanced Industrial Science and Technology (AIST), 2-2-9 Machiikedai,
963-0298 Koriyama, Japan
e-mail: kasumi-yasukawa@aist.go.jp

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_12

Table 1 Electric power source mix in Japan: before and after the nuclear accident in 2011, and target in 2030

	2010 (just before nuclear accident)	2014 (for total, 2013)	2030 (Target)
Total power demand	n.a.	966.6 TWh	980.8 TWh
Coal (%)	25.0	31.0	~26
Oil (%)	6.6	10.6	~3
LNG (%)	29.3	46.2	~27
Other gas (%)	0.9	0	0
Nuclear (%)	28.6	0	~20–22
Hydro (%)	8.5	9.0	~9
Other renewable (geothermal)	1.1% (0.25%)	3.2% (0.2%)	~13–15% (1%)

Data source ANRE (2016)

(Muraoka 2009). However the use of geothermal energy in Japan is quite limited; its contribution to national power supply is merely 0.2% with a total installed capacity of 518 MW_e (Yasukawa and Sasada 2015). Although the use of renewable energy, especially solar PV, rapidly increased after the nuclear accident triggered by great east Japan earthquake in 2011 (Table 1), use of geothermal power has not been increased yet because of its long leading time. The federal government has a target energy mix for 2030 in which drastic increase of renewable energy is expected, but a modest target is given for geothermal power mainly because of its long leading time and other social issues (ANRE 2016). Still, this modest target is a challenge to triple its capacity from 510 MW to 1400 MW, producing 9.8 TWh annually.

In addition, there is a long-term target toward 2050 by implementing "Supercritical geothermal power generation." Cabinet Office, government of Japan placed supercritical geothermal power generation as one of the eight most prioritized technologies to drastically reduce CO_2 emission in "National Energy and Environment Strategy for Technological Innovation towards 2050" (Council for Science, Technology and Innovation 2016). This technology is considered having the potential to increase Japan's geothermal power generation volume by an order of 10 or even greater, although there are diverse scientific unknowns and necessary technological breakthroughs. It is expected that plural commercial power plants fed by supercritical geothermal resources will be in operation in 2050 with a total capacity of 50–100 GW.

1.2 Short History of Geothermal Energy Development in Japan

1.2.1 Beginning

Geothermal energy has been historically used for bathing "*onsen*" for a millennium or more and it has been playing a quite important role in tourism for centuries in the nation. The first experimental geothermal power generation in Japan was built in 1925 in Oita by Tokyo Electric Light Co., Ltd., with a capacity of 1.12 kW by using steam produced from an 80 m deep well (GRSJ 2000). Geological Survey of Japan (GSJ) began geothermal resources assessment in 1947. With geoscientific support of GSJ, Japan Metals & Chemicals Co. Ltd. began operation of the first geothermal power plant, the Matsukawa power plant, in 1967 with a capacity of 9,500 kW for domestic use in their firm. Triggered by oil crises in 1970s, The Agency of Natural Resources and Energy (ANRE), Ministry of International Trade and Industry (presently the Ministry of Economy, Trade and Industry, METI) settled New Energy Development Organization (present New Energy and Industrial Technology Development Organization, NEDO) in 1980. NEDO conducted nationwide resource assessments and geothermal technology development with the support of national institutes and private sectors. Subsidies for geothermal drilling had been given by METI through NEDO to private sectors. Thus, seventeen geothermal power plants had been developed with a total capacity of 530 MW by 1999. The main players were always domestic companies although overseas technologies were partially hired in many cases. Note that the key players had not been electric power companies (except for Kyushu Electric Power Co., Inc.), but subsurface resource developers such as metals or oil & gas companies who provided steam to electric power companies. This business model was due to the Electricity Business Act of the time, which allowed electricity production and sales only for existing electric power companies certified by the government.

1.2.2 Stagnation

After 1999, no new geothermal power plant was put in operation for more than a decade mainly because of legal and socio-economic barriers explained below. Under the federal policy pushing nuclear power, laws and regulations which limit geothermal development had not been improved. For example, equipment and operation of geothermal power plant needs to meet the same safety regulations as nuclear or thermal plant in a category of "steam turbine", which is extremely over-spec and costly for geothermal plant. Geothermal development in Japan is not conducted under Mining Law which gives licence for regional development but under Hot Spring Law[1] in which each drilling needs to get permission from local government. This process is so time consuming that a development project may be delayed for months or even for a year especially if the site is closed in snow season that is very common in geothermal prospects in northern Japan. Furthermore, electric power companies imposed penalties to geothermal developers when they could not provide enough steam for rated output in their contract. Even with a reservoir decline, geothermal business could be economically sustainable if a same company operate subsurface reservoir and power plant, but it was not the case.

Other reasons which discourage geothermal development are restriction in natural parks and negative campaign by hot spring owners. Eighty percent of geothermal resources in Japan are present inside natural parks, where development was strictly prohibited, while resources outside parks have generally low quality. On the other hand, many hot spring owners running *onsen inn* business are concerned about potential degradation of their springs due to geothermal development. They often make negative campaign against geothermal development influencing the other local residents. It results in social acceptance of geothermal power generation from local residents extremely difficult. Therefore, private sectors found geothermal business not economically attractive even with governments' subsidies for drilling.

1.2.3 New Opportunity

In summary, the three major reasons of stagnation of geothermal development in Japan were; (1) regulations on natural parks, (2) high development risk and cost and (3) negative campaign by hot spring owners.

The former two problems have been somewhat mitigated after the nuclear accident caused by great east Japan earthquake in 2011: the federal government changed several regulations on natural parks (Nature Conservation Bureau 2015) and gave new economic incentives to geothermal developments through Japan Oil, Gas and Metals National Corporation (JOGMEC, a funding agency of METI) such as subsidies for exploration or drilling and debt guarantee for construction (JOGMEC 2016). Liberalisation of electricity market, which had been in slow

---

[1]Hot Spring Law was originally made for protection of hot spring resources because enlargement of hot spring business had endangered hot spring aquifers. Legally in Japan, geothermal fluid is considered as hot spring fluid so that geothermal drilling should be conducted under Hot Spring Law. This law prohibits to drill a new well within 300 m from existing hot spring wells. Each new drilling needs agreements from nearby hot spring well owners to get drilling permission from the authority. Its drilling permission is given from prefecture government after decision by local committee which assembly is only once in few months and the decision would be postponed if they cannot conclude in one assembly. Therefore, the drilling permission process is quite time consuming for geothermal developers. For a drilling permission, the location of the new well should be precisely indicated. Since the location of each geothermal drilling is carefully decided based on the available data at each stage, geothermal developers get drilling permission one by one, waiting for few months or more each time.

progress since 1995 but accelerated after the nuclear accident, also encouraged geothermal developers. Cabinet Office decided to fully liberalize rights for generation and sales of electricity from April 2016 and transmission will be liberalized in 2018 as well (METI 2015a) so that any geothermal developer is able to generate and sell electric power.

Although the third problem, resistance of hot spring owners may not be easily mitigated by the government's regulations, but at least the Ministry of Environment (MOE) made a new guideline for geothermal drilling under Hot Spring Law in 2014, in which standard procedure of discussion among stakeholders is indicated (Nature Conservation Bureau 2014). The guideline also set a time limit for issuing drilling permission, which is a great help for developers. Given such supports from the government, private sectors started moving toward geothermal development.

Thanks to geothermal Feed in Tariff (FiT) that started in 2012, dozens of new geothermal power plants have opened in Japan. However, the total capacity of these new power plants is merely 10 MW in 19 regions (as of 2016) while that of plants in operation before FiT took place is 510 MW in 17 regions. Only small power plants could make quick start because they didn't need to spend time for resource assessment, environmental assessment and social acceptance activities. Two full scale geothermal power plants, 7.5 MW or larger that need environmental assessment, are under construction in Akita and Iwate, and are planned to start operation in 2019. Several other large ones are currently under exploration or construction.

1.3 Current Energy Demand in Japan

The current total energy demand in Japan is around 15×10^{18} J (ANRE 2017). According to METI (2015b), 75% of energy demand is heat and the rest is electricity in 2013 as shown in Fig. 1 (left). This 75% includes gasoline and diesel for transportation. Since transportation section occupies 23% of the total energy demand of the nation (ANRE 2017) as shown in Fig. 1 (right), the genuine heating demand would be around 52% of the total energy demand.

Although Japan is one of the biggest direct use countries (Lund and Boyd 2016; Yasukawa and Sasada 2015), most of them are contribution from bathing in hot springs and there exist no official data of geothermal heat energy use. The data of heat energy use for bathing in Yasukawa and Sasada (2015) is obtained by calculation from the annual number of visitors to hot spring inns. Such direct heat use of geothermal energy is not included in the official energy demand and supply data explained in the former paragraph as shown in Fig. 1.

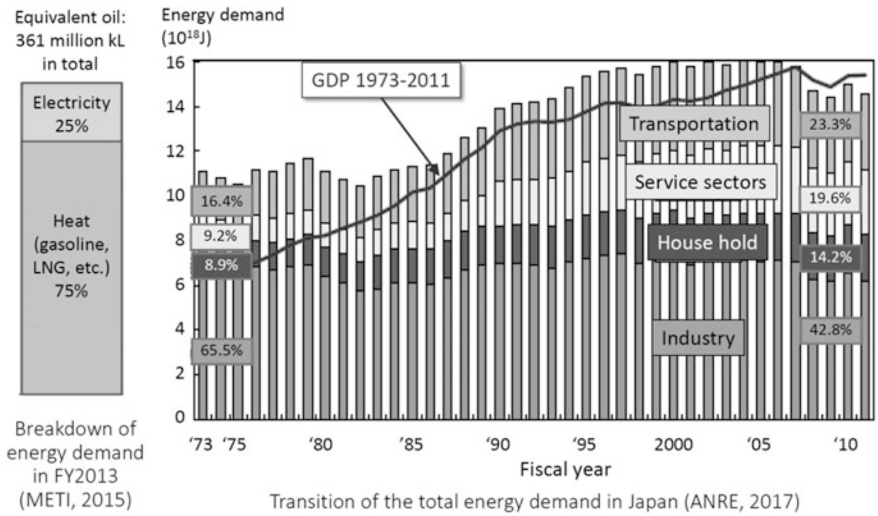


Fig. 1 Transition of the total energy demand (right) and breakdown of energy demand (left) in Japan. *Data source* METI (2015b) and ANRE (2017)

2 Public Engagement Activities/Social Acceptance Assessment in Japan

2.1 Activities Being Conducted on Issues Around Geothermal Energy and Society

ANRE has been giving subsidies for social activities held in regions of geothermal prospects to share right knowledge of geothermal energy among local people since 2012. Its purpose is to promote geothermal development by achieving better social acceptance. Either a private developer or a local government (prefecture or municipal) is able to apply for this scheme if there is an on-going development project of geothermal power generation in the region. Involvement of a local government is mandate even if the main player is a private sector. The activities are categorized into hardware and software. The former is to construct a showcase-type of heating facility using excess geothermal heat, such as foot bath or greenhouse which is beneficial for local citizens. The latter is to hold educational events for local citizens, such as series of seminars and/or excursions to understand advantages of geothermal energy use and to learn best practices.

Since geothermal development in Japan is conducted under "Hot Spring Law" controlled by MOE, the concept of "mining area" is not applied and developers needs to get permission from authority (= prefecture government) for each drilling (no matter exploration well or production well, as long as a borehole is drilled in a region where geothermal water is expected). This decision making process by local authorities was unclear and sometimes it took longer than a year. MOE made a guideline for this permission process especially for geothermal drilling in 2014, appointing a time limit for the decision making. The guideline requests local authority to organize a council which consists of local stakeholders and neutral academia(s) who can give scientific advice on subsurface systems for the judgement of each drilling. Therefore, at present prefecture governments organize such council when a drilling permission is requested by geothermal developer and respond by the time limit set by the guideline.

2.2 Social Science Studies for Promotion of Geothermal Energy Use

2.2.1 Studies Related to Social Acceptance

The role of governance in geothermal business has been studied by a group in the Tokyo Institute of Technology (Suwa et al. 2018). Out of this group, Uechi et al. (2013) studied the factors that could influence community acceptance of geothermal development by comparing two geothermal projects in Japan, a successful case in the Yanaizu-Nishiyama area, Fukushima, and a failure case in the Oguni town, Kumamoto. The noticeable difference between the two cases are recognition of benefits and risks and equity in process, although expected benefits and risks were equivalent and communication with the local communities had begun at a quite early stage for both projects. In Oguni, a larger diversity of the stakeholder opinions on the benefits of geothermal energy use was observed. For risk recognition and equity in process, the developer at Oguni had simply explained that there was no risk of impacts on the hot springs while the developer in Yanaizu-Nishiyama had concluded a written agreement on risk management with the local stakeholders at an early stage of construction. These results show the importance of open information on both benefits and risks as well as equity in process.

An approach of agent-based model for social acceptance of geothermal development has been studied by a research group in Tohoku University (Bahr and Nakagawa 2016) with collaboration with the Colorado School of Mine. The model shows the patterns of connections of the local people and how the information reaches to each person in the region. The results suggest effective ways to distribute information for each type of connection pattern. It may be applied for real cases by geothermal developers to distribute information on geothermal energy and make better relationship with local residents.

Kubota et al. (2013) in Central Research Institute of Electric Power Industry (CRIEPI) identified the variation in local residents' risk and benefit recognition to facilitate the resolution of the problem related to social acceptance of geothermal development. They conducted a census to local hot spring owners and general public on recognition of risk and benefit of geothermal energy use. The result shows that there is a controversy among hot spring owners regarding the benefits of geothermal development depending on the conditions and locations of hot spring wells, in addition to the business scale and to the structure of hot spring facilities. A subset of general public who enjoy hot spring visits tend to appreciate geothermal power generation more than the rest. Thus, it would be better for hot spring owners and municipal governments to realize that their customers are generally positive about geothermal development. Awareness of geothermal power generation by the general public is lower than that of solar and wind power although another form of geothermal energy use, hot spring, is quite popular (Kubota 2015). This study has been extended to survey of local stakeholders' attitude (Yasukawa et al. 2017). Since stakeholder attitudes and needs are diverse, developers' approach for social acceptance should differ for each geothermal prospect accordingly to the condition. The results of this study suggest that governments and developers should continue providing information to improve social acceptance. An analysis of the life cycle CO_2 emission, an important information affecting geothermal power generation stakeholders' opinion, was carried out by Imamura et al. (2016) in CRIEPI and showed that small hydro power and geothermal power have lowest CO_2 emission among all power sources in Japan.

From National Institute of Advanced Industrial Science and Technology (AIST), Soma et al. (2015) introduced concept of Overall System Design (OSD) aiming at maximizing both developer's profitability and local people's acceptance. The most appropriate design of the geothermal utilization system may vary with time because different exploration stage gives different level of accuracy in subsurface systems and longer interaction among stakeholders gives different level of social acceptance. When trade-offs between social acceptance and developers' profit occurs, the concept of "Pareto optimal solution" may be applied to find out acceptable solution for both sides. Soma et al. (2015) shows only concept of OSD: for its realization, intensive survey to collect "objective data", such as drilling cost, surface system cost, expected local economy effect, etc., is needed. AIST has also been introduced geochemical approach which is useful to explain relationship between geothermal reservoir and hot spring aquifers to hot spring owners. Yasukawa et al. (2018) categorizes hot spring fluids into seven types based on geochemistry and shows possible influence of geothermal development onto each type of hot spring.

2.2.2 Socio-economic Analysis

Socio-economic analysis has been done by CRIEPI. Hienuki et al. (2015) analysed life cycle employment of solar, wind and geothermal power generation in Japan using an extended-input-output model. The calculated embodied employment intensity of a 50 MW geothermal power plant is 0.89 person-year/GWh of which 66% is for operation and maintenance. The employment intensity for solar and wind powers are 2.8 and 0.69 person-year/GWh, respectively but these employments are mostly outside the local area: major employment is for manufacturing in other region and even operation and maintenance are done from remote region. From this paper, the following may derive: local employment for geothermal power would be 0.59 person-year/GWh because operation and maintenance are normally done by local employee. It suggests that its local labor intensity is higher than solar or wind power although total labor intensity is rather low, meaning that energy cost of geothermal power is lower but good for local economy. Since Hienuki et al. (2015) applies capacity factor of 80%, 0.59 person-year/GWh is easily converted into 4.12 person/MW. Interestingly, this number shows good match with the actual geothermal power plant in Japan. Soma et al. (2015) shows that the number of local employee for Yanaizu-Nishiyama geothermal power plant is 156. Since its running capacity is approximately 30 MW, its labor density is 5.2 person/MW. A larger plant capacity used in the model calculation might result in slightly lower local labor intensity than the real case at Yanaizu-Nishiyama.

2.3 Citizens and Stakeholder Participation Activities

As was explained in Sect. 2.1, ANRE has been giving subsidies for activities to disseminate sound knowledge on geothermal energy use among local people and developers. Here, "knowledge" includes scientific/technological aspects and social aspects, such as case study from other regions where win-win relationship has been made between developer and local residents by economically feasible cascade use, etc. Either a developer or a local government is able to apply for this scheme. These activities typically include a series of seminars, inviting geothermal (and sometimes environmental, legal or economic) experts as lecturers from outside the region, who are neutral about the development project. In many cases, especially when the main player is the local government, local stakeholders hold discussions through the seminars on what kind of geothermal development is most suitable in the region. Since there are many different opinions on geothermal development even among local citizens, representatives of local industry (shops and factories), local tourism, local agriculture, and hot spring owners are invited to such discussion and any citizens are able to attend as observers.

Moreover, as written in Sect. 2.1, MOE made a guideline for permission process of geothermal drilling, which requests local authority to organize a council to judge each case. Since the council, to which developer explains the whole geothermal development project and specific drilling, consists of local stakeholders and neutral academia(s), it is another chance that stakeholders of the both sides share information and discuss intensively.

2.4 Geothermal Debate/Controversies in Japan

Although lots of efforts have been done for social acceptance of geothermal energy use, it might not be enough. Delay and termination of geothermal developments, due to opposition by group of local people are still occurring recently. After a catastrophic accident at Fukushima Daiichi nuclear power plant in March 2011, the federal government announced a new large scale geothermal development in Fukushima in 2012. When a group of hot spring owners in the region reacted with a negative campaign, putting a full page advertisement saying “we are against geothermal power generation by deep drilling” in a local newspaper,[2] the large development project disappeared (in another words “postponed without any specific time schedule”. Nothing has been clarified by the government to avoid further troubles). There were probably two factors behind this “successful” negative campaign: (1) A strong advocator of negative campaign in the nation lived in this region, and (2) citizens in Fukushima consider the federal government not trustworthy because of its non-transparent attitude after the nuclear accident. Possibly, the large-scale power plant reminded them of the traumatic nuclear power incident.

In Ibusuki city, Kagoshima, a geothermal development was planned by the municipality with an agreement of the local assembly. However, it was stopped by a new city mayor in 2016 without sufficient discussion in the assembly. The new city mayor was against all policies made by his political opposition including the former city mayor who led the geothermal project. It looks that no real debate has been done in this case, but it can be taken that the project was abolished due to potential controversies among citizens. Similar stories, termination of project by a purely political reason without sufficient discussion, have been heard from other regions, too.

Other controversies are emerging among geothermal developers. The price of geothermal FiT in Japan is JPY40 + tax/kWh for plants of capacity below 15 MW and JPY26 + tax/kWh for capacities of 15 MW or larger.[3] High price is set for smaller units because exploration is still necessary for smaller systems, which is costly in principle. However, some private companies started new businesses using high FiT price, buying a land close to already existing geothermal power plants and drill wells without any systematic subsurface survey. Interference of such wells to surrounding hot springs and nearby geothermal wells is a new matter of concern. In some case hot spring owners also have such small geothermal power plants, and are positive about small power plant using shallow hot spring wells. But in most cases they are quite negative about large scale geothermal development.

3 Results and Discussions

Social science studies related to geothermal development have just started in Japan. Their major approaches are opinion surveys, analysis of past cases and modelling of human connection and thus their results have not been applied to real cases yet. Nevertheless, solutions to problem against geothermal developments have been

[2]Fukushima Minpo dated October 4, 2014.

[3]http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/fit_kakaku.html.

considered and conducted based on the experience in the past geothermal development projects.

For the problems among stakeholders, such as possible interference to existing hot spring wells caused by the new geothermal business, the federal government (ANRE, METI) made a new rule on submission of FiT, requesting monitoring of at least three surrounding hot spring wells in 2017. Also local municipals, such as Oguni town and Minami-Aso village in Kumamoto, Beppu city and Kokonoe town in Oita, Kirishima city and Ibusuki city in Kagoshima, and Hachijo-town in Tokyo set their own regulations partly regarding this problem and partly promoting geothermal developments (JOGMEC 2017). JOGMEC made up an "advisory committee" by a group of geothermal experts from academia and national institute in order to give neutral technical advises to local governments (both prefecture and municipal) in 2016. Local governments request advices on specific development project (if they should issue permission or not, etc.), or on new geothermal regulations of the region.

Existence of strong negative advocator is unavoidable and unreliability of federal government may not be released in short time. However, it may be solved in the future by careful explanation and continuous discussion among developer and local stakeholders by providing transparent data. Through such steps, study of social acceptance may be applied for actual cases.

Role of environmental NGO has not been taken account in socio-economical study yet. Activity of environmental NGO is not all that powerful in Japan, but some local environmental NGO are against geothermal development. Cooperation with environmental NGO with global environmental viewpoint could give a new perspective to geothermal developers.

4 Conclusions

The government promotes geothermal development by subsidies for drilling and giving economic incentives by FiT. Social acceptance, especially co-existence with hot spring business, has been a matter of concern in Japan for decades and still is the biggest barrier of geothermal development. Geothermal development projects have been delayed or stopped by negative campaign by group of hot spring owners. Some studies on social acceptance of geothermal use have been done in recent years, but their results have not been applied sufficiently for the time being.

Federal government, especially METI recognized that geothermal development has not been well accepted by local people yet and started giving subsidies for activities to raise social acceptance if the activity is led by or collaborated with the local government. Its effect is not clear yet, but at least more citizens are aware of benefit of geothermal energy use than before. MOE gave guideline for geothermal drilling, which recommend to establish a local council consisting of stakeholders and neutral experts. High price of geothermal FiT raise new problem of resource development interference, which gives troubles to local government in issuing permission. JOGMEC made an advisory committee composed by geothermal experts to give technical advice to local government.

The involvement of local government into geothermal project is getting prominent than ever before. Thus, cooperation of developers, academia, local and federal governments are gaining importance and their roles are getting clearer.

References

Agency of Natural Resources and Energy (ANRE) (2016) Energy in Japan—20 Questions. Available online at http://www.enecho.meti.go.jp/about/pamphlet/pdf/energy_in_japan2016.pdf. Accessed 26 Mar 2018

Agency of Natural Resources and Energy (ANRE) (2017) Comprehensive energy statistics 2016. Available online at http://www.enecho.meti.go.jp/statistics/total_energy/pdf/stte_023.pdf. Accessed 26 Mar 2018

Bahr K, Nakagawa M (2016) The effect of bidirectional opinion diffusion on social license to operate. Environ Dev Sustain 1–11. http://doi.org/10.1007/s10668-016-9792-9

Council for Science, Technology and Innovation (2016) National energy and environment strategy for technological innovation towards 2050 (NESTI 2050). Council for Science, Technology and Innovation, Cabinet Office, Government of Japan, April 19, 2016. Available online at http://www8.cao.go.jp/cstp/nesti/honbun_e.pdf. Accessed 26 Mar 2018

GRSJ (2000) Available online at http://grsj.gr.jp/en/geothermalinJ/history/index1_4.html. Accessed 26 Mar 2018

Hienuki S, Kudoh Y, Hondo H (2015) Life cycle employment effect of geothermal power generation using an extended input-output model: the case of Japan. J Cleaner Prod 93:203–212

Imamura E, Iuchi M, Bando S (2016) Comprehensive assessment of life cycle CO_2 emissions from power generation technologies in Japan. CRIEPI Socio-economic Res Cent Rep Y06:73 (in Japanese with English abstract)

Japan Oil, Gas and Metals National Corporation (JOGMEC) (2016) Available online at http://geothermal.jogmec.go.jp/support/index.html. Accessed 26 Mar 2018

Japan Oil, Gas and Metals National Corporation (JOGMEC) (2017) Available online at http://geothermal.jogmec.go.jp/local/info.html. Accessed 26 Mar 2018

Kubota H (2015) Social acceptance of geothermal power generation in Japan. In: Proceeding, world geothermal congress 2015, vol 02055, Melbourne, Australia, p 7

Kubota H, Hondo H, Hienuki S, Kaieda H (2013) Determining barriers to developing geothermal power generation in Japan: societal acceptance by stakeholders involved in hot springs. Energy Policy 61:1079–1087

Lund J, Boyd T (2016) Direct utilization of geothermal energy 2015 worldwide review. Geothermics 60:66–93

Ministry of Economy, Trade and Industry (METI) (2015a) Cabinet Decision on the Cabinet Order to Specify the Enforcement Date of the Amended Electricity Business Act (2nd stage) and Other Cabinet Orders. Available online at http://www.meti.go.jp/english/press/2015/0630_01.html. Accessed 26 Mar 2018

Ministry of Economy, Trade and Industry (METI) (2015b) Long-term energy supply-demand outlook 2015. Available online at http://www.meti.go.jp/press/2015/07/20150716004/20150716004_2.pdf. Accessed 26 Mar 2018

Ministry of Economy, Trade and Industry (METI) (2017) Available online at http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/fit_kakaku.html. Accessed 26 Mar 2018

Muraoka H (2009) Resource assessment, geothermal power generation. Thermal and Nuclear Power Engineering Society, pp 61–69 (in Japanese)

Nature Conservation Bureau (2014) Guideline for protection of hot spring resources (on geothermal power generation) (amended). Nature Conservation Bureau, Ministry of Environment, December 2014. Available online at https://www.env.go.jp/nature/onsen/docs/chinetsu_guidekaiseikou.pdf. Accessed 26 Mar 2018 (in Japanese)
Nature Conservation Bureau (2015) Handling geothermal development inside national parks. Nature Conservation Bureau, Ministry of Environment, October 2015. Available online at http://www.env.go.jp/nature/geothermal_np/mat02.pdf. Accessed 26 Mar 2018 (in Japanese)
Soma N, Asanuma H, Oikawa Y (2015) Conceptual study of overall system design of geothermal energy systems for achieving universal use in Japanese social condition. In: Proceedings, world geothermal congress 2015, vol 02033, Melbourne, Australia
Suwa A et al. (2018) Geothermal energy use in co-existence with community (in Japanese). Gakugei Publication, pp 232, ISBN: 978-4-7615-2678-8
Uechi J, Murayama T, Nishikizawa S (2013) An analysis of factors influencing community acceptance on geothermal power development—the cases of Yanaizu-Nishiyama and Oguni geothermal power plants. Pap Environ Inf Sci 27:283–288 (in Japanese with English abstract)
Yasukawa K, Kubota H, Soma N, Noda T (2018) Integration of natural and social environment in the implementation of geothermal projects. Geothermics 73:111–123
Yasukawa K, Sasada M (2015) Country update of Japan: renewed opportunities. In: Proceedings, world geothermal congress 2015, vol 01042, Melbourne, Australia

Kasumi Yasukawa is the Deputy Director of the Renewable Energy Research Center, National Institute of Advanced Industrial Science and Technology (AIST). Since joined to the Geological Survey of Japan (present AIST) in 1987, she has been studying numerical modelling of geothermal reservoirs. The National Institute of Science and Technology Policy (NISTEP) selected her as one of 11 NISTEP Researchers Award winners in 2012 for her public communication activities on geothermal energy. She is an ExCo member of the International Energy Agency—Geothermal Implementation Agreement (IEA-GIA) from 2013.

New Zealand's Public Participation in Geothermal Resource Development

Katherine Luketina and Phoebe Parson

Abstract New Zealand has a unique regulatory regime to sustainably manage its geothermal resources. Public and stakeholder consultation is required in geothermal policy development, and individual geothermal developments require notification to and consultation with these stakeholder groups. In addition to providing brief descriptions of New Zealand's current geothermal resource uses and development, this paper outlines geothermal regulation and policy with a focus on public opportunities to participate in the development of geothermal resources. Brief case studies show historic failure and lessons learnt in public and stakeholder participation, particularly in relation to New Zealand's indigenous Maori people. Regulatory management of geothermal resource information and data is also discussed in the context of public participation.

Keywords New Zealand and Maori · Resource management · Sustainable management · Environmental information

1 Introduction

New Zealand is an island nation in the south-west Pacific Ocean, made up of two large islands and approximately 600 smaller islands. It occupies approximately 268,000 km^2, and has a population of 4.8 million, comprising 74% people of European extraction, 15% people who identify as the indigenous Maori people, with the rest made up of Asian, Pacific, and other ethnicities. English and Maori are

K. Luketina (✉)
Waikato Regional Council (WRC), Private Bag 3038, Hamilton East,
Hamilton 3240, New Zealand
e-mail: katherine.luketina@waikatoregion.govt.nz

P. Parson
Te Piringa - Faculty of Law, Research Centre for Environmental,
Energy and Resources Law, University of Waikato (Te Whare Wananga o Waikato),
Private Bag 3105, Hamilton 3240, New Zealand

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_13

the official spoken national languages. New Zealand is a member of the British Commonwealth and has a stable parliamentary democracy.

New Zealand is a member of the Organisation for Economic Co-operation and Development and ranks highly in international comparisons of national performance, such as health, education, economic freedom, transparency in Government and business dealings, and quality of life. Tourism, dairy produce, meat, timber products, wool, fruit, fish, and wine are New Zealand's main export products. A mild climate and fertile soils lend themselves to primary production. The country's abundant natural energy resources include a mixture of high and low-temperature geothermal resources. It pioneered geothermal energy development, being the second country world-wide to harness geothermal energy for electricity production, and the first to use two-phase fluid. Currently, 17% of the nation's electricity is from geothermal resources. New Zealand is the world's largest user of geothermal heat for direct primary energy supply, used in wood processing, horticulture, aquaculture, apiculture, and commercial and domestic space and water-heating. Geothermal tourism is also a major user of geothermal resources.

1.1 Energy Demand

Geothermal energy provides stable baseload electricity, which is important in New Zealand's context of phasing out coal and gas, and with its fluctuations of hydro and wind renewable energy sources. Broadly, there is secure access to electricity throughout New Zealand except for a very few remote and sparsely populated locations, which generally have their own private energy supply. Electricity production amounts to approximately 132,000 GWh per annum (MBIE 2017).

Currently, energy supply meets demand and there are no large electricity plants under construction. Although resource development permits have been issued for some additional geothermal and wind power stations, these developments are either partially implemented, on hold, or have been relinquished. Increases in efficiency of electricity conversion have led to a decline in demand. This is mainly due to the replacement of incandescent light bulbs with LEDs, increased use of air-sourced heat pumps instead of electric heaters, government subsidies for domestic retro-fitted insulation, and new rules for energy-efficient building. In addition, the future of the country's largest electricity user, the Tiwai aluminium smelter, is in doubt and closure of the company would create an excess of generating capacity. However, there is likely to be an increased demand for clean energy sources to replace electricity generated by fossil fuels under the Labour-led coalition Government.

Because New Zealand has an equable climate without extremes of heat or cold, in the past space heating or cooling has not been a particular consideration. In addition, electricity and natural gas have traditionally been relatively inexpensive, and many people have had free access to firewood for domestic heating. However, with populations becoming more urbanised, and greater comfort being expected, ground-sourced heat pumps are increasing in popularity in the colder South Island.

This is particularly so for large buildings such as airports, libraries, and swimming pool complexes. In the North Island, in the three towns sited on geothermal systems, Rotorua, Taupo, and Tokaanu, many buildings have a shallow geothermal bore supplying hot water or steam for spa bathing, water heating or space heating. However, mainly due to high upfront installation costs and the complexities of coordination between potential users, there has been little uptake of more energy-efficient district heating schemes (Lind 2012).

1.2 New Zealand's Geothermal Resource

New Zealand sits astride the boundary between the Pacific Plate and the Australian Plate, and is prone to earthquakes and volcanic activity. The Taupo Volcanic Zone (TVZ), a band of active volcanism stretching from Mt. Ruapehu in the central North Island northeast to White Island (Whakaari) in the Bay of Plenty and beyond, contains all but one of the country's twenty recognised high-temperature geothermal systems (Fig. 1). The other large, high-temperature geothermal system is at Ngawha in the Northland Region.

Geothermal resources are used for a variety of purposes, falling into four main categories: electricity production, heat applications, tourism, and ecosystem services including provision of habitat and mediation of toxic inputs to other ecosystems.

1.3 History of Geothermal Electricity Development in New Zealand

New Zealand has fifteen geothermal power stations on eight geothermal fields, as shown in Fig. 2. Together they have an installed capacity of approximately 1000 MWe and produce 17% of New Zealand's electricity. Hydroelectricity accounts for 61% of the nation's electricity, natural gas provides 12%, wind, 6%, and the remaining 3% is provided by coal and biomass (MBIE 2017). This means that electricity is 84% from renewable sources, a figure the central government intends to increase to 90% by 2025 and to 100% by 2035, with gas and coal being replaced by geothermal and wind. New Zealand has never developed nuclear energy for electricity generation, and successive governments have promoted nuclear-free policy since the mid-1980s.

The Wairakei Power Station (Wairakei), commissioned by the government in 1958, was the second commercial-scale geothermal electricity station in the world, the first being at Larderello, Italy. Wairakei was the first geothermal power station to process geothermal fluid in two phases, in a mixture of steam and liquid water, as Larderello is on a dry-steam field. In the mid-1990s a privately owned geothermal power station commenced operating on the Wairakei geothermal field, the first

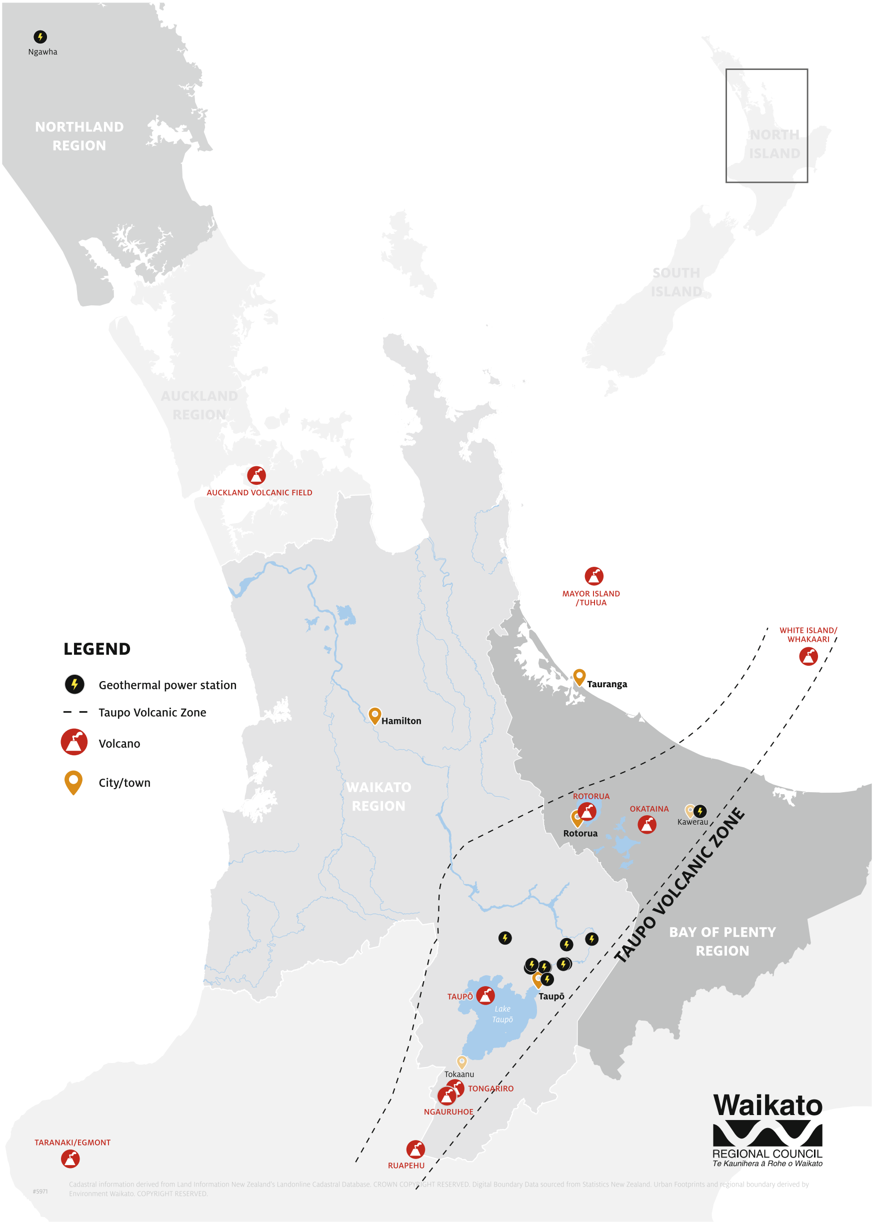


Fig. 1 Map of the geothermal resources of New Zealand

power station of any kind in New Zealand that was not solely government-owned. Since the 1990s the government has corporatised and partly sold off most of its geothermal generating capacity, but retains full control of the central electricity

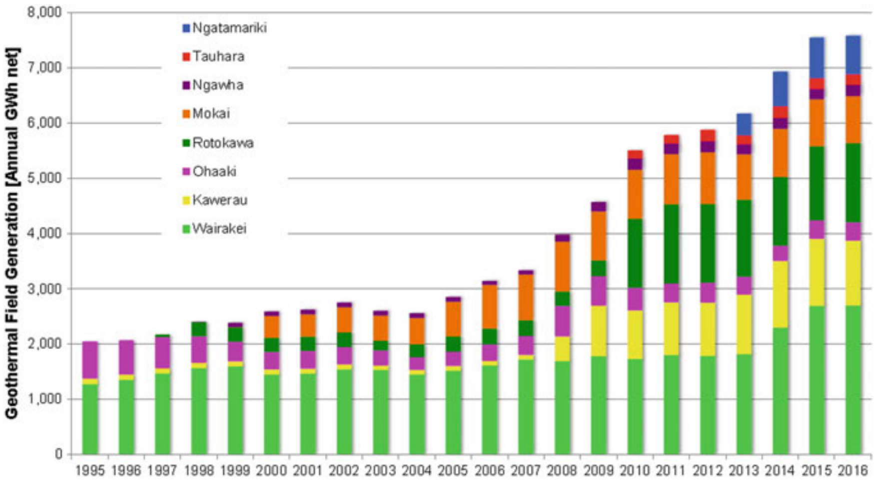


Fig. 2 New Zealand geothermal generation by field since 1995. Reproduced by kind permission of New Zealand Geothermal Association

transmission grid. Electricity is bought and sold on an open market (with some regulatory control over price maxima), consistent with New Zealand's strongly free market economy, and there are no electricity generation tariffs or subsidies.

Contact Energy Ltd (Contact Energy) and Mercury Energy Ltd (Mercury) are now the two main geothermal electricity producing companies. They are publicly listed companies that were previously government-owned, and the government still retains the majority shareholding in Mercury. Most of Mercury's geothermal power stations are joint ventures between Mercury and local Maori groups who own the land overlying the geothermal resource or who have indigenous rights regarding the geothermal resource. Contact Energy does not have a majority shareholder. There are several smaller geothermal operators at Kawerau (Bay of Plenty Region) and at Ngawha (Northland Region), mostly New Zealand-owned.

1.4 Industrial Heating Application Strategy

In January 2017, the New Zealand Geothermal Association launched the *Geothermal Heat Strategy for Aotearoa NZ, 2017–2030* (Climo et al. 2017). The Strategy, which has the support and financial backing of central and local government, economic development agencies and industry, provides a pathway to grow direct industrial geothermal energy use in New Zealand. It seeks to achieve significant primary energy and job targets between 2017 and 2030, through such measures as:

- creating new businesses that grow and diversify the use of geothermal heat
- converting more heat-intensive industries from fossil fuels to geothermal energy
- supporting regional economic and social development by fostering job-creating industries, and
- increasing the uptake of renewable low carbon energy.

By the year 2030, the strategy aims to increase annual direct primary geothermal energy use by 7.5 PJ in new projects, thereby providing direct and indirect employment for an additional 500 people. This will require the creation of four or five larger heat use projects over the next decade: for example, for timber processing and large greenhouses; as well as a range of smaller projects, such as for bathing and smaller-scale greenhouses. The Strategy focuses on the higher temperature Central North Island and Northland geothermal resources, but does not exclude lower temperature resources in other regions.

2 Geothermal Energy and Society in New Zealand

2.1 Introduction

Since the time New Zealand was first settled by Maori and then Europeans, people have lived among geothermal resources, and used them for a variety of purposes, including heating, bathing, cooking, and balneology. Geothermal features are highly valued for their spectacular colours, exciting and dynamic geysers and erupting mud pools, and the experience of seeing, smelling, hearing and feeling the earth's energy (Fig. 3). Geothermal tourism is a major contributor to New Zealand's large tourism industry, with many tourism facilities based around the TVZ, each facility providing a unique natural experience, often with the addition of traditional Maori cultural interactions.

In the Waikato Region, there are approximately 50 geothermal tourism sites, including bathing facilities, nature tourism, and technology-related tourism. The Bay of Plenty Region also has many sites undertaking similar activities, in particular in Rotorua District where cultural geothermal tourism is a key feature, including Te Puia, one of the country's most visited tourism businesses.

Geothermal direct heating applications in the TVZ include heating greenhouses to grow flowers, vegetables and native plants; timber drying; production of honey and associated products; process heat for a timber mill; a milk drying plant, and space and water heating for domestic, municipal and commercial uses. The Kawerau geothermal system supports the world's largest use of geothermal heating application, with several industrial facilities producing wood pulp, paper and heat-treated timber (Bloomer 2015).

Regionally, geothermal ecosystems are recognised and protected as rare and extremely fragile, as many are impossible or almost impossible to restore once damaged. The ecosystems buffer the biosphere from the high temperatures and

Fig. 3 Geothermal tourism contributes to the economy and provides employment © WRC

toxic chemicals in geothermal outflows (Fig. 4). As a geothermal discharge flows over sinter terraces, it cools and adds to the sinter, depositing minerals in the process. Thermally tolerant plants and micro-organisms living in the outflow extract further minerals. Geothermal biota and animals make significant contributions to biological diversity, scientific understanding, scenery and aesthetic enjoyment. Regional policy for geothermal resources is based on scientific resource assessment; ecological studies; social, economic, and environmental research; and on stakeholder consultation to ensure the views of interested and affected parties are taken into account.

Fig. 4 Geothermal ecosystems are highly valued © WRC

2.2 Maori and Geothermal Resources Overview

From the time the Maori people arrived in New Zealand between 1250 and 1300 CE, they have used geothermal resources for many purposes including the provision of hot water and steam for bathing and cooking, timber treatment and dyeing, cosmetic, healing, and ceremonial purposes. Geothermal resources are considered to be a treasure of great cultural and spiritual value. Maori oral histories and legends have geothermal and volcanic resources intertwined in the narrative of the creation and history of the land of New Zealand, known in the Maori language as Aotearoa.

Aotearoa-New Zealand's human history can be divided into two segments, pre-European and post-European. European settlers started to arrive *en masse* in the early 1800s, mainly from Britain. The nation of New Zealand was subsequently founded after the signing of the Treaty of Waitangi 1840 (the Treaty) between representatives of the British Crown and a majority of Maori chiefs in 1840. The Treaty recognised the sovereignty of Maori as 'first peoples' and provided the Maori people with the Crown's protection and with rights of citizenship as subjects of the Crown. Maori were to retain sovereign control of their lands, forests and fisheries and other taonga (treasures) while the Treaty agreement enabled settlement by British and other settlers. However, once the New Zealand Parliament was established, the Treaty became marginalised by lawmakers and successive governments. Wars were waged by the Crown against various Maori tribes, which deprived Maori of their lands, and laws were passed that further enabled land confiscation or other forms of Maori land dispossession.

In 1975 the Government set up the Waitangi Tribunal (Treaty of Waitangi Act 1975) to investigate claims by Maori relating to actions or omissions of the Crown in respect of breaches of the Treaty by the Crown. As a result of Treaty claims made by Maori, many geothermal areas have been returned to Maori ownership, and in those cases Maori tribes are now able to fully participate in the use and development of geothermal resources for the benefit of their people, whether it be through electricity production, tourism ventures, or direct heat application.

The country's first four geothermal power stations were built at Wairakei (1958), Kawerau (1989 and 1996), and Ohaaki (1989), where Maori-owned land was either sold or leased to the Government under compulsory land acquisition for 'public works'. Wairakei and Ohaaki power stations caused the extinction and depletion of geothermal geysers and springs highly valued by the Maori people. At Wairakei, the historical adverse effects on valued geothermal features by the Wairakei power station (originally Government-owned) are now addressed through cooperation between Contact Energy Ltd and Te Kupenga Charitable Trust, which was set up by members of the Ngati Tuwharetoa tribe in 1996. The Trust has established a Maori geothermal tourism operation, Wairakei Terraces, using bore water supplied by Contact Energy to create and maintain artificial geothermal features and bathing pools. The Trust has also set up Netcor, a Maori training organisation with three training facilities. Its key focus in relation to education and training has been to create opportunities and employment for Māori in education, health and tourism (Netcor 2017).

The Orakeikorako geothermal system in the Waikato Region, was also compulsorily acquired by the Government for the development of the Waikato River's Ohakuri hydroelectric dam in 1961. Approximately three-quarters of the area's geysers, sinter springs and other geothermal features were submerged underwater, as was the site of the Ngati Tahu tribe's traditional primary marae (meeting houses). Since then, groups within the tribe have either bought back or had much of their land returned, although the hydroelectric dam remains and still covers the geothermal features. The tribal land owners lease the main area of geothermal features to a tourism concessionaire.

One Maori geothermal development venture that did not need any Waitangi Tribunal intervention is at Mokai (Waikato Region), where the Tuaropaki Trust, a collection of Maori land owners, formed the Tuaropaki Power Company Ltd (Tuaropaki) and developed a geothermal power station in 1999 using wells previously drilled by a government research programme. Tuaropaki has used profits generated by the power station to build twelve hectares of greenhouses growing vegetables, providing further profits and, equally importantly, employment for its tribal members and other people in the surrounding districts. In a rural area of low employment, this has had a significant positive effect on the local community and economy. Tuaropaki has expanded the power station, with the assistance of Mercury Energy Ltd, which is now a minority shareholder in Tuaropaki Power Company Ltd. Since then, Tuaropaki has established the Miraka milk drying plant in a joint venture with other commercial entities. Tuaropaki Trust is a multi-million dollar entity, and also has extensive farming operations including dairy, beef, sheep, and deer farms. Organic waste from the milk plant and greenhouses is used for growing indigenous trees for riparian planting to restore the indigenous habitat along streams on its land, so that traditional inland fisheries and land health generally can be restored. Tuaropaki have developed many other business interests including viticulture and digital communications.

At Rotokawa, the Tauhara North Number 2 Trust, made up of Maori landowners from the Ngati Tahu tribe, have taken a different approach to the business model for using geothermal resources on their land for economic development. In a joint venture arrangement with Mercury Energy Ltd they own the Rotokawa and Nga Awa Purua geothermal power stations. They return the profits to their Trust beneficiaries, tribal members and the wider community through grants for many purposes including education and health initiatives.

At Te Puia, (Bay of Plenty Region), one of the country's major tourism attractions also combines geothermal tourism with the Maori cultural experience. Te Puia is owned and operated by members of the Te Arawa tribe, and some tribal members live within the site, continuing to use geothermal pools for heating and cooking as in pre-European times. Te Puia provides tourism experiences involving natural geothermal features, Maori arts, crafts, and culture, and conservation of rare native animals.

Maori-owned and operated geothermal tourism ventures occur in the Rotorua and Taupo districts of the Bay of Plenty and Waikato Regions, and at Ngawha in the Northland region, and elsewhere. In some places Maori focus is less on providing tourism facilities, and more on using the geothermal resource in a traditional way while living in a modern Maori society. At Ohinemutu in the Rotorua district, and Tokaanu and Waihi villages in the Taupo district, predominantly Maori settlements based around a marae, the geothermal features are used communally for bathing, heating, cooking and other purposes.

2.3 Regulatory Management of Geothermal Resources

Under the Resource Management Act (RMA) 1991 and the Local Government Act 2002 (New Zealand Parliament, 1991, 2002), the central government devolves responsibility for the sustainable management of natural and physical resources, including geothermal energy, water, surface features and ecosystems to Regional Councils. Dickie and Luketina (2005) describes the local government structure and environmental legislation in New Zealand, particularly in relation to geothermal resources, in more detail. A founding principle of the RMA was that greater involvement by the public in resource management processes would reduce community alienation, improve decision making and environmental outcomes. Public participation enables democratic legitimacy, which requires the needs of participants to be heard, and is founded on the principle that those affected by a decision have a right to participate in decision-making. Public access to environmental information used in decision-making processes is also an important component of good environmental governance (see in Sect. 2.6).

The RMA provides the public a wide range of opportunity to participate in environmental decision-making. This occurs at a strategic level, in the preparation of planning documents (Regional Policy Statements and Regional Plans), and at an operational level, in the consideration of resource permit applications. The most important time for public participation is during plan development because plans specify which activities will require resource permitting. Broadly, plans provide the opportunity for public participation in shaping the needs of communities and regions. The hierarchy of planning instruments and decision making by regional or district (and city) councils under the RMA represents a deliberate decision to place decision making closest to whichever community is affected by an activity. However, if a proposed plan change is found to be a matter of national significance, it may be directed to either the Environment Court or a central government-appointed Board of Inquiry in the first instance. A plan change may be initiated by the public, by an individual, or by a local or regional council.

The geothermal systems of the Taupo Volcanic Zone are administered by the Waikato and Bay of Plenty Regional Councils, which are concerned with the environmental effects of the proposed development, while another tier of local government, City and District Councils, is concerned with effects on people and property, including noise, dust, visual amenity, and potential damage to property from subsidence that a geothermal development may have. The Waikato and Bay of Plenty Regions both have geothermal chapters in their Regional Policy Statements

(RPS) and Regional Plans (RP) (Bay of Plenty Regional Council 2008, 2014; Waikato Regional Council 2011, 2016), and their policy and regulatory regimes for the management of geothermal resources are broadly similar and abide by RMA requirements. The development process for the geothermal chapters of the Waikato RPS and Waikato RP has been described in Dickie and Luketina (2005), Luketina and Dickie (2006) and Luketina (2010). Policies and rules require sustainable and efficient use of geothermal resources and these are implemented through the resource permitting process described below.

The Waikato and Bay of Plenty Regional Councils aim to ensure through robust policy and rules that a balance is maintained between large-scale development and environmental protection. Geothermal systems are classified for different usage types depending on the size of the system, existing uses, and the vulnerability of significant geothermal features such as geysers, sinter springs, and geothermal lakes to extractive uses. In systems where there are few vulnerable geothermal features, large-scale development may occur and any such development must show that it will operate at a rate that provides for the energy needs of several generations at least. Some other systems are set aside for small-scale development that does not harm the geothermal features. Systems that have a large number of highly valued and vulnerable features are protected to ensure the preservation of those features, and there can be no new extractive uses. These Protected Geothermal Systems are maintained in their natural state for their intrinsic, ecological, scientific, and tourism values. These are protected by the RPS, whereas the other geothermal systems are categorised in the RP. This makes their protected status more secure, because any person may request a change to a RP but only a local authority or Minister of the Crown may request a change to a RPS.

The mandatory policy documents through which geothermal resources are managed are the RPS and RP, and these are reviewed every ten years according to RMA processes. The RPS is a high-level document that sets out the resource management issues, objectives and policies for the region. The RP implements the RPS through further policies, rules and other implementation methods. Both documents are developed with community participation and input, through a process of several stages prescribed under the RMA. Generally a regional council consults voluntarily with the public within its region before producing a draft RPS or RP. Further consultation on the draft document then leads to a proposed document, which has some legal status. Formal, written submissions are received from the public, and may be heard by either elected councillors or a commissioned hearing panel of policy and resource management experts. When decisions are released, the revised policy document becomes operative. Those members of the public or groups who made submissions on the proposed document may appeal policy decisions to a specialist Environment Court on matters within the policy document on which they made earlier submissions. Decisions of the Environment Court may only be appealed on matters of law to a High Court, where no new evidence may be admitted. Throughout the policy development process, regional councils are required to consult particularly with Maori.

2.4 The Resource Permitting Process

Before permission for resource use can be given for a geothermal development, a developer must apply to the Regional and District Councils for various permits known as resource consents (or a "consent") to obtain a right to use or develop the geothermal resource. The RMA is effects-based legislation; that is, it is the environmental effects of resource use that is regulated rather than resource use itself. A developer must supply a description of the proposed activity and a detailed assessment of environmental effects (RMA 1991 sch. 4), as well as a record of community consultation.

A resource consent provides an applicant with permission to use or develop a natural or physical resource or to carry out an activity that affects the environment. Various activities related to geothermal resource use or development or activities that may affect geothermal resources are classified in Regional and District Plans. Such activities include geothermal water takes and discharges, drilling and testing deep bores, and earthworks. These match a range of activity classifications under the RMA, and include for example: allowed and controlled activities; discretionary and restricted discretionary activities; non-complying and prohibited activities. An applicant may apply for a resource consent to carry out activities under all these classifications, except for prohibited activities.

The resource consent application process is generally a public process. There is usually a public hearing in which public submissions are heard and considered, and hearings are usually held jointly with the relevant District Council. Therefore, there are only two regulatory bodies that a developer must apply to for consents to develop a geothermal resource, and only one hearing that an applicant must undergo.[1] Appeals on hearing decisions may be made to a specialist Environment Court.

A resource consent authority must publically notify a resource consent application if it decides the activity will have or is likely to have adverse effects on the environment that are more than minor; if the applicant requests public notification; or if a rule or national environmental standard requires public notification of the application. Legislative amendments to the RMA in 2009 removed a former presumption that resource consent applications must be notified (unless for a controlled activity or where adverse effects were minor). Now notification may be public notification by notice in prescribed forms in an entire area likely to be affected by the resource consent proposal; and notice may be served on every 'prescribed person'. Applications may be processed on a non-notified or limited-notification basis if the adverse effects of an activity on the environment are no more than minor. If the effects are no more than minor, then only those who may be directly

[1]Other regulatory requirements, such as those that fall under building, and health and safety regulation, are a matter of compliance with existing standards and are not subject to discretionary hearings.

affected must be served with notice, and no other person can participate in the decision-making process.

Legislative amendments removing opportunities for public participation in the planning and resource consent application processes were made in an effort to simplify and streamline processes to reduce administrative costs and delays.[2] Such amendments to the RMA are usually the result of a change of Government. Although such amendments have reduced some aspects of participation, the rebalancing and streamlining of decision-making processes has arguably not affected the fundamental, underlying philosophy, purpose or principles of the Act. RMA amendments also allow for applicants to lodge a resource consent application (or change or cancel resource consent conditions) directly with the national-level Environmental Protection Authority (EPA) or with the Environment Court, and require consent authorities to grant direct referral requests for projects that meet certain investment thresholds set by regulations. Parties who wish to make submissions on a resource consent application that is directly referred to the Environment Court may become a party to be heard if that party (person) has an interest in the proceedings that is greater than the interest that the general public has. In such cases, the local or regional council may become a submitter like any other interested and affected party and has no special status.

Before applying for a resource consent to develop a geothermal reservoir, a developer must obtain access rights from the land owner, where a private contract will usually include the land owner's charge for an access fee and a rental charge for the land used in the geothermal development. Individual resource developers may negotiate private agreements with affected and interested parties to satisfy the concerns of various community groups or land owners. Such side-agreements are not part of the statutory process, but are made to reduce the number of potential appeals against a proposal.

2.5 Geothermal Community Stakeholders and Case Study Examples

There are several types of groups who involve themselves in the public process of policy development and resource consent hearings for large-scale extractive geothermal developments, and these are not limited to the following, or to the following issues:

- **Environmental interests** concerned about the effect of geothermal developments on fresh water resources, geothermal features, ecosystems generally, and hunting and fishing resources. This can include the government Department of Conservation.

[2]Resource Management (Simplifying and Streamlining) Amendment Act 2009; Resource Management Amendment Act 2013; and Resource Legislation Amendment Act 2017.

- **Resident groups** who are concerned about how a development will affect their quality of life or property values through effects such as noise, dust, increased traffic, visual effects, land subsidence, and increased seismicity.
- **Maori groups** who claim some association with the geothermal resource. This can include those with special claims over the land in question and the geothermal resource.
- **Commercial and community users of resources** that may be affected by geothermal development. For example, development-related subsidence may damage roads and infrastructure, and discharges to surface water may affect community water supplies. These parties can include local or downstream District and City Councils.
- **Extractive users or potential users** of the geothermal resource. For a resource consent hearing, although the RMA cannot consider issues of commercial competition, existing users may seek to limit the effects on the geothermal resource of the proposed development, or other new contenders for the resource may seek to demonstrate that their competing application would be more efficient.
- **Economic development and business groups** who want to see geothermal projects go ahead for economic reasons. This group is normally made up of local and regional economic development agencies, but can include the Ministry of Business, Innovation and Employment and the Energy Efficiency and Conservation Authority.

Before the enactment of the RMA 1991 and resulting regional policy, an example of poor participation enablement occurred on the Ohaaki geothermal field in 1967 (Stokes 2004). At the time, central government was engaged in an ambitious national development scheme to ensure security of energy supply, and wished to develop a geothermal power station on land owned collectively by members of the Ngati Tahu tribe. The participation processes for the tribal land owners were inadequate, providing Ngati Tahu little time or resources to respond to government's intentions for geothermal development. After five years of negotiation and appeal processes, the government acquired a compulsory lease of the Maori land, where under development, the geothermal resource depleted quickly due to cold water intrusion and other reservoir management issues. In addition, the land area, adjacent to the Waikato River, has had significant inundation as a result of land subsidence induced by depletion of the geothermal resource (Clotworthy et al. 1995). Spectacular and culturally significant geothermal surface features were destroyed. Under current regional policy such features would be classed as Significant Geothermal Features and therefore could be subject to protection from development. Contact Energy Ltd, the Ohaaki Power Station's present owners since 1996, are now engaged with Ngati Tahu, in compensation and protection dealings, including protecting their riverside marae (meeting place) from inundation.

Controversy and public participation issues in relation to the use or protection of geothermal resources were not limited to the establishment of large-scale extractive uses, as is demonstrated by the Rotorua geyser decline of the 1980s. The town of Rotorua, now a city, was established to service the tourism industry that developed around the many geothermal local areas. The city itself has a plethora of attractive geothermal features within the central business district and sits atop a shallow hot water aquifer, which feeds many bores for commercial and domestic spas. Initially the use of the geothermal resource was relatively low impact, but an increasing demand for energy in the 1950s led to extraction on a larger scale, with over 1000 geothermal wells by the 1970s. As a result of this unregulated extraction, many of the geothermal features that the tourists came to experience were becoming depleted in their activity, particularly geysers, which are the feature type most vulnerable to reservoir pressure decline. By the mid-1980s the adverse effect on geysers was critical and led to public outcry, including from several highly regarded geothermal and other scientific experts. On the other hand, many bore owners wanted to protect their free hot water supply. Eventually, central government directives resulted in forced bore closures and a prohibition of fluid extraction within a 1.5 km radius of the city's major geothermal tourist attraction. Today, most of the affected features have not yet shown any recovery in activity, although the aquifer has shown some pressure recovery (Doorman and Barber 2017).

These two case studies briefly demonstrate some of the environmental and public participation challenges that contributed to the development of the RMA. During the more recent policy development process for the Waikato and Bay of Plenty Regional Councils' geothermal resources, vociferous debate and millions of dollars were spent on litigation by various parties in council hearings and legal appeals.[3] Matters that raised particular controversy included concerns about the potential for development-induced land subsidence, where this had occurred historically (Luketina 2010; Burnell et al. 2016); and, decisions about which geothermal systems should be classified as Protected Geothermal Systems and therefore unavailable for extractive uses. Electricity developers sought to limit new requirements for fluid reinjection, which changed the previous practice of discharging fluid into rivers. Matters of whether single or multiple developers should be allowed on a Development Geothermal System, and the extent to which a developer should be required to show the geothermal system could produce electricity for several generations instead of attempting to use the system's energy up within the plant life of 25–30 years, were also controversial. Since these policies were finalised in 2007, installed capacity for geothermal electricity generation has doubled. This increase has been driven by market demand for electricity, and supported by a stable regulatory environment.

[3]See for example, Geotherm Group Ltd and Others v Waikato Regional Council NZEnvC, Auckland, A047/2006, 13 April 2006.

2.6 Public Access to Environmental Information

In New Zealand, water, including geothermal water and steam, as it occurs naturally (untapped) is not owned by anyone: water use rights are vested in the Crown. As the regulator, regional councils are responsible for allocating resource use rights, and resources used for electricity development are resources that are available broadly for the benefit of all citizens, including present and future generations. Policy and resource consent conditions require sustainable resource use, so that use will not deplete the resource to the extent that it would detrimentally affect the resource for future generations' reasonably foreseeable needs, either through excess extraction or through induced changes such as cold water intrusion. Accordingly, for electricity developers to gain the social licence to develop and use the resource, it is arguable that resource consent holders should provide environmental resource information and data (environmental information) to the regulator, which in turn could be made available to the public and wider research community. Currently, and historically, the public does not have full access to environmental information concerning geothermal resources used in electricity production. The RMA recognises regulators need full access to environmental information and data generated by resource consent holders, and the Act promotes public access to environmental information, including information regarding resource consents (RMA 1991 s 35). The Act also encourages public hearings for environmental decision-making. Any protection of commercially sensitive information provided under the Act, which may form part of a resource consent application, is at the discretion of the regulator and only where it concerns information that may form part of a public hearing or proceeding (RMA 1991 s 42). A regulator's decision to protect information rests on whether the public interest in making information available outweighs the commercial interest in denying public access to it. An information protection order (s 42) can be appealed to the Environment Court by any party to the proceedings. Full public access to environmental information produced under geothermal resource consents has not been tested in the Environment Court in recent years. When developers do not request a (s 42) information protection order, the regulator applies New Zealand's general law for official information under the Local Government Official Information and Meetings Act 1987 and the Official Information Act 1982. Decisions to withhold commercially sensitive information from the public under this Act may be appealed to the Ombudsman.

The regulator's statutory duty to manage geothermal resources on behalf of the public is crucial to the ongoing health and sustainability of the resource. However, in some instances under the RMA regulatory authorities have been held liable for environmental damage where a regulator failed to acquire the necessary information to manage a resource or resource consent appropriately. Accordingly, to ensure the regulatory duty is carried out, statutory information requirements and resource reporting and monitoring processes are essential. This is particularly so where complex environmental management issues occur, such as with geothermal resources. Also, because regional councils are not directly involved with geothermal electricity production and the routine monitoring of its environmental effects, which the consent holder is required to undertake and report on, information asymmetry exists between the resource consent holder and regulator.

The duty of the Regional Council to monitor resource consents and the ability to require any environmental information and data relating to a resource consent can be in tension with the desire of a consent holder to protect information and data from being accessible to the public for commercial sensitivity reasons. The public is broadly unaware of this tension or whether developers may be using geothermal resources in a sustainable way. As with hydro and wind renewable energy resources, general public perception sees geothermal resources as indefinitely renewable and that commercial users and regional and district councils carry out their monitoring and resource management duties comprehensively. And largely, they do. However, it is arguable that were the public and wider research community to have full access to environmental information, better sustainable management and environmental outcomes would ultimately result. Full public access to environmental information could act as a regulatory safeguard. This is particularly so in New Zealand, where the regulator is the Regional Council and is therefore the promoter of regional development, fulfilling multiple resource management roles, such as policy developer; resource allocator; and resource consent approver, monitor, and enforcer. This may be especially the case as there is yet no national-level strategy for geothermal resource development in New Zealand.

Full public access to environmental information (and data) is resisted from a commercial perspective, which focuses on retaining commercial advantage. The now-majority privately-owned commercial geothermal operators may argue that the public interest is better served by maintaining competition in order to keep electricity prices down. Additional, the costs in obtaining geothermal resource information and data can be substantial. In 2018, it costs approximately NZ $20 million (US $16) to drill a deep geothermal well, so it is commercially expedient for a consent holder to protect its investment, including the data obtained from it. Geophysical remote sensing surveys can cost up to NZ $1 million, and while this is a lesser amount, it still could be of benefit to a competitor. However, there are no instances in New Zealand where such information has been placed on the market and its hypothetical value realised. The cost is recovered in the price of electricity or other product produced and sold. Additionally, where multiple users extract geothermal resources from the same geothermal system, such as at Kawerau in the Bay of Plenty region, competition for access to the resource and competition over maintaining commercially optimum levels of the extractible resource can be fierce.

Regional councils allocating geothermal resources must take into account the energy efficiency and renewable energy legislation and policy of the RMA 1991, the Energy Efficiency and Conservation Act 2000, and the National Policy Statement for Renewable Electricity Generation 2011. It is largely acknowledged that within the confines of the RMA and the above-mentioned national-level policy, that economic demand and competition is adequate to direct geothermal development. However, from a long-term resource sustainability perspective, it is arguable that reliance upon an economic model to direct resource use and allocation, and a regulatory stance that protects commercially sensitive resource consent environmental information, may be at odds with optimal environmental governance. Although provided for under the RMA, to date geothermal electricity developers are not charged resource rental fees nor are royalty payments paid by resource consent holders to local or central government. Resource sustainability outcomes could be improved were resource royalties required (Malafeh and Sharp 2015).

While full access to environmental information and data produced under resource consents is not available publicly the role of the mandatory 'peer review panel' acts somewhat as a regulatory safeguarding mechanism. Regional policy requires resource consents for electricity developments to be managed by a technical peer review panel (PRP). The PRP is an independent panel of geothermal experts contracted by the regional council to monitor development of the geothermal resource to ensure that development is continually undertaken according to resource consent conditions. The purpose of the PRP is to assist the regulatory authority to ensure the necessary knowledge and skills are available for auditing the consent conditions. The primary function of a PRP is to ensure the science and technical understanding and interpretations of the consent holder are scientifically and technically robust. Peer review panels are an environmental management tool developed by the regulator, which continues to evolve since the early 1990s when the management of geothermal resources transferred from central government to regional councils with the enactment of the RMA. Then, as now, councils recognised they lacked the internal capacity to manage large-scale use of geothermal resources, and that it would be prohibitively expensive to retain highly-trained scientists and engineers as staff. Peer review panel members are contracted as needed, members must disclose any conflicts of interest and are selected and remunerated by the regulator, although the regulator recovers remuneration cost from the consent holder. Institutional management of the peer review process has evolved; for example, originally, some peer review panel members were remunerated directly by the resource consent holder. The function, make-up, and boundaries of the PRP role continue to evolve, and as a mandatory policy requirement (since the mid-2000s) it is acknowledged their role is crucial to ensuring geothermal resource sustainability.

3 Economic and Social Value of Geothermal Resource Use

In 2011, Waikato Regional Council investigated the contribution of geothermal resources to the regional economy, considering four uses: Tourism, Direct Heat Applications, Electricity Production and Ecosystem Services (Barns and Luketina 2011). Tourism and Electricity production together provided NZ $488 million (ca. $US 373 m) annually. The value of direct heat applications to the regional economy was not able to be assessed at that time, because of the complexity of assessing the economic value of the multiple products, and the difficulty in obtaining confidential production data. However, it was found that Tourism and Direct Heat Applications provided much more direct employment than geothermal electricity production. Tourism employed the fulltime equivalent of 412 people, direct heat applications 532, and geothermal electricity production 80.

Bay of Plenty Regional Council undertook a similar survey in 2014, finding that the value of geothermal resources to the regional economy including from direct heat applications was NZ $482.5 million (ca. $US 368 m), almost 5% of the region's Gross Domestic Product (Conroy and Donald 2014). Fulltime equivalent employment numbers were: tourism, 1194; heat applications, 750; and electricity production, 42.

In 2017, the councils jointly updated and expanded on these studies. Results for Waikato Region indicate a substantial increase in tourism visitor numbers, with a gain of 18% in the 2016–2017 year, and a projected increase of 24% for the 2017–2018 year (Luketina et al. 2017). With these increasing numbers, pressure on infrastructure and on fragile geothermal features and ecosystems is becoming a significant issue for tourism providers and the regulatory authorities tasked with sustainably managing the natural character of the geothermal resource.

In 2016, there were 905,000 visits by domestic tourists to geothermal sites in the Waikato Region (excluding accommodation providers with geothermal spas), up from 450,000 in 2011. Geothermal attractions account for more than 16% of domestic tourism in the Waikato Region, up from 13% in 2012. In 2016, the Waikato Region had a total of 472,000 international visits to geothermal attractions, up from 290,000 in 2011.

Data used in this analysis comprised on-site interviews at geothermal tourist attractions in January 2017, a nationally representative poll of domestic visitors in November 2016, and the international and domestic visitor surveys run by Stats New Zealand and the Ministry of Business, Innovation and Employment (Stats NZ 2016; MBIE 2017). In the Waikato Region, the total non-market value per year is estimated to be NZ $43 million (ca. $US 33 m) for domestic visitors and NZ $14.2 million (ca. $US 11 m) for international visitors. Non-market value is based on the cost of site access (travel cost plus admission) incurred by visitors. For multiple-purpose trips, the travel cost is apportioned among all purposes and activities.

Spending by visitors to geothermal attractions contributes to both regional economies, both directly and indirectly through industry linkages. After adjusting for multiple-purpose trips, total annual spending by visitors to Waikato geothermal attractions is NZ $103 million (ca. $US 79 m) for domestic visitors and NZ $58 million for international visitors. The contribution to Gross Regional Product (GRP) is NZ $80 million (ca. $US 61 m), or NZ $146 million (ca. $US 111 m) including multiplier effects. The direct contribution to employment is 1163 employees including all goods and services purchased by visitors, not just on-site employment. With multiplier effects for indirect and induced employment, the employment contribution is 1689.

The environmental costs of the different sources of electricity generation were assessed in 2012 (Denne 2012). Geothermal was found to have the lowest environmental cost of all electricity sources, but higher carbon dioxide emissions than other clean energy sources.

However, an earlier life-cycle analysis of carbon emissions from renewable energy technologies in New Zealand put geothermal on a par with hydro-electricity (Rule et al. 2009). The value of geothermal tourism is also compared to the value of geothermal electricity generation. Electricity generated from geothermal energy in the Waikato Region was 6230 GWh in 2016. Associated wholesale electricity revenue was NZ $379 million (ca. $US 290 m). Geothermal electricity generation contributes NZ $106 million (ca. $US 81 m) to GRP but only 106 employees. Geothermal tourism contributes less to GRP than geothermal electricity generation ($80 million vs. $106 million) but employs more than ten times as many people.

An unpublished 2017 analysis of compliance costs for businesses in the Waikato Region that use geothermal resources was undertaken using the Institutional Grammar Tools framework (Siddiki et al. 2012; Crawford and Ostrom 1995). It found that complying with Waikato Regional Council's Objectives, Policies and Rules was considered by businesses to be minimal compared with costs imposed by central government, such as health and safety rules, building rules, and for food products such as vegetables and honey, biosecurity rules.

It is acknowledged that not all ecosystem services can be appropriately measured in monetary terms, using internationally recognised assessment frameworks (Haines-Young and Potschin 2012). The information from studying the ecosystems services of the Waikato Region, and from other sources, was used to characterise and assess the ecosystem services that individual geothermal sites in the Waikato Region provide. In addition, the study has explored the way Maori value geothermal resources for cultural reasons, as part of their world view. This body of Maori knowledge and interaction with the natural world is known as Matauranga Maori.

4 Conclusions, Policy Implications, Further Studies and Future Prognosis

Despite New Zealand's relative youth as a country, it is considered a mature geothermal nation. The legislative framework of the RMA 1991 provides for public participation in policy making and geothermal resource development, and has empowered Regional Councils to develop geothermal policy that allows large-scale sustainable use of geothermal resources while protecting valued geothermal features for their intrinsic, ecological, cultural, scientific, and tourism value. In the last decade, this has enabled a doubling of installed geothermal electricity generation capacity. Prior to the enactment of the RMA, failures by successive governments to appropriately consult with local communities, and Maori people in particular, has been given redress via the Treaty claims process and via specific legislative provisions for consultation and public participation under the RMA and related legislation. The Maori world view is expected to play a bigger part in assessing ecosystems services in the future, as further tools are developed to improve the interface between economic analysis and the multi-faceted Maori world view of geothermal resources. Perceptions about the regulatory management of environmental resource information and data, and public access to such information, are also likely to evolve in coming years.

Electricity production from geothermal sources is not expected to increase in the next ten years because of flat demand for electricity. In addition, geothermal electricity production emits more carbon dioxide than most other electricity sources classed as renewable, and this may become an issue in a carbon-constrained world (Denne 2012). Direct heat applications are expected to increase as the Geoheat Strategy is implemented, enabling regional job growth, economic development, and reduction in the use of fossil fuels for heat production. Although tourism spending benefits the regional economy, visitor growth may cause problems such as traffic congestion, habitat damage and reduced visitor enjoyment. Future research may be required to investigate the costs and challenges associated with visitor growth. There are technical difficulties in fully assessing ecosystems services and natural capital, and philosophical issues with quantifying such services in monetary terms. The methods and tools used in natural capital assessment continue to evolve, and future assessments are expected to be more comprehensive.

Acknowledgements Phoebe Parson's contribution to this paper is sourced from research carried out at the Research Centre for Environment, Resources and Energy Law, at Te Piringa—Faculty of Law, University of Waikato, New Zealand. Her research was funded with the support of the Waikato Regional Council (New Zealand), and the International Bar Association Section on Energy, Environment, Natural Resources and Infrastructure Law. Katherine Luketina's participation in this project was supported by her employer Waikato Regional Council, with able assistance from staff in the provision of Fig. 1.

References

Barns S, Luketina KM (2011) Valuing uses of the Waikato regional geothermal resource Hamilton. Waikato Regional Council, Report nr TR 2011/15. Available via http://www.waikatoregion.govt.nz/tr201115. Accessed 8 Jan 2018

Bay of Plenty Regional Council (2008) Bay of Plenty regional water and land plan. Available via https://www.boprc.govt.nz/plans-policies-and-resources/plans/regional-water-and-land-plan/. Accessed 22 Aug 2017

Bay of Plenty Regional Council (2014) Bay of Plenty regional policy statement. Available via https://www.boprc.govt.nz/plans-policies-and-resources/policies/operative-regional-policy-statement/. Accessed 22 Aug 2017

Bloomer A (2015) Kawerau industrial direct heat use: recent developments. In: Proceedings of the World Geothermal Congress 2015, Melbourne, Australia, April 2015. Available via http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2015/28026.pdf. Accessed 10 June 2018

Burnell J, van Campen B, Kortright N et al. (2016) Sustainability of TVZ geothermal systems: the regulatory perspective. Geothermics 10. Available via http://www.sciencedirect.com/science/journal/03756505/59/part/PB?sdc=1. Accessed 22 Aug 2017

Climo M, Bendall, S, Carey, B (2017) Geoheat strategy for Aotearoa-NZ, 2017–2030. New Zealand Geothermal Association. Available via http://nzgeothermal.org.nz/geoheat/. Accessed 22 Aug 2017

Clotworthy A, Lovelock BG, Carey B (1995) Operational history of the Ohaaki geothermal field, New Zealand. In: Barbier E (ed), Proceedings of the World Geothermal Congress 1995, pp 1797–1802. International Geothermal Association, Florence, 1995

Conroy and Donald Consultants Ltd (2014) Valuing uses of the Bay of Plenty regional geothermal resource. Bay of Plenty Regional Council, Tauranga

Crawford SES, Ostrom E (1995) A grammar of institutions. Am Polit Sci Rev 89:582–600

Denne T (2012) Environmental costs of electricity generation. Waikato Regional Council Technical Report 2012/18 Series Hamilton, Waikato Regional Council. Available via http://www.waikatoregion.govt.nz/tr201218. Accessed 22 Aug 2017

Dickie BN, Luketina KM (2005) Sustainable management of geothermal resources in the Waikato Region, New Zealand. In: Proceedings of the World Geothermal Congress 2005, Antalya, Turkey, April 2005

Doorman P, Barber J (2017) rotorua geothermal system: current and future management. In: Proceedings 39th New Zealand geothermal workshop, Rotorua, New Zealand, 22–24 Nov 2017

Geotherm Group Ltd and Others v Waikato Regional Council NZEnvC, Auckland, A047/2006, 13 Apr 2006

Haines-Young R, Potschin M (2012) Common international classification of ecosystem services (CICES, Version 4.1). European Environment Agency

Lind L (2012) Rotorua geothermal home heat investigation. GNS Science Consultant Publication 2012/120 for BOPRC, Geological and Nuclear Sciences Ltd, Wairakei

Luketina KM (2010) Sustainability and the democratic process. In: Proceedings of the World Geothermal Congress. Bali, Indonesia, April 2010. Available via http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/0304.pdf. Accessed 22 Aug 2017

Luketina KM, Dickie BN (2006) Waikato regional council geothermal policy: on the Home Straight. In: Proceedings of the New Zealand geothermal workshop, The University of Auckland, November 2006

Luketina KM, Olubode F, Phillips Y (2017) Valuing uses of the Waikato and Bay of Plenty geothermal resource. In: Proceedings of the 38th New Zealand geothermal workshop. Rotorua, New Zealand, November 2017

MBIE (2012) Domestic travel survey. Available via http://www.mbie.govt.nz/info-services/sectors-industries/tourism/tourism-research-data/domestic-travel-survey. Accessed 30 June 2017

MBIE (2017) New Zealand energy quarterly, March quarter 2017, ISSN 1178-2714. Available via http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/publications/new-zealand-energy-quarterly. Accessed 22 Aug 2017

Malafeh S, Sharp B (2015) Role of royalties in sustainable geothermal energy development. Energy Policy J 85. Available via https://www-sciencedirect-com.ezproxy.waikato.ac.nz/science/article/pii/S0301421515002414. Accessed 22 Aug 2017

Netcor (2017) Available via http://www.netcoreducation.com/. Accessed 22 Aug 2017

New Zealand Government (1975) Treaty of Waitangi Act 1975. Author, Wellington, New Zealand. Available via http://www.legislation.govt.nz/act/public/1975/0114/latest/DLM435368.html?src=qs. Accessed 22 Aug 2017

New Zealand Government (1991) Resource Management Act 1991; Resource Management (Simplifying and Streamlining) Amendment Act 2009; Resource Management Amendment Act 2013; and Resource Legislation Amendment Act 2017. Author, Wellington, New Zealand. Available via http://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html. Accessed 22 Aug 2017

New Zealand Government (2000) Energy Efficiency and Conservation Act 2000. Author, Wellington, New Zealand. Available via http://www.legislation.govt.nz/act/public/2000/0014/latest/DLM54948.html?src=qs. Accessed 22 Aug 2017

New Zealand Government (2002) Local Government Act 2002. Author, Wellington, New Zealand Available via http://www.legislation.govt.nz/act/public/2002/0084/latest/DLM170873.html. Accessed 22 Aug 2017

New Zealand Government (2011) National policy statement for renewable electricity generation 2011. Author, Wellington, New Zealand. Available via http://www.mfe.govt.nz/publications/rma/nps-renewable-electricity-generation-2011. Accessed 22 Aug 2017

Rule BM, Worth ZJ, and Boyle CA (2009) Comparison of life cycle carbon dioxide emissions and embodied energy in four renewable electricity generation technologies in New Zealand. Environ Sci Technol 43:6406–6413

Siddiki S, Basurto X, Weible CM (2012) Using the institutional grammar tool to understand regulatory compliance: The case of Colorado aquaculture. Regulation & Governance (2012) 6, 12. Available via https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/6738/Siddiki%20et%20al.%202012%20Regulation%20and%20Compl.pdf%3Bsequence=1. Accessed 22 Aug 2017

Stats NZ (2016) International visitor arrivals to New Zealand. Available via http://www.stats.govt.nz/browse_for_stats/industry_sectors/Tourism.aspx. Accessed 3 Mar 2017

Stokes E (2004) Ohaaki: a power station on Maori Land. University of Waikato, Te Matahauaraki Institute Monograph, p 2004

Waikato Regional Council (2011) Waikato regional plan: (reprinted December 2011—incorporating Variations No. 2, No. 5 and No. 7) Hamilton, NZ. Available via http://www.waikatoregion.govt.nz/Council/Policy-and-plans/Rules-and-regulation/Regional-Plan/Waikato-Regional-Plan/ Accessed 22 Aug 2017

Waikato Regional Council (2016) Waikato Regional Policy Statement. Hamilton, NZ. Available via https://www.waikatoregion.govt.nz/assets/PageFiles/6777/2016/WaikatoRegionalPolicyStatement2016.pdf. Accessed 22 Aug 2017

Katherine Luketina is a geothermal scientist with Waikato Regional Council, New Zealand, a position she has held since 1997. She has an M.Sc. in Physics from the University of Auckland and a PGDip Environment Management from Waikato University. She is involved in evaluating geothermal resource consent applications, policy development, environmental and resource monitoring and reporting, and local, national and international liaison. Katherine is on the NZ Geothermal Association's Board of Directors. Because of her involvement in developing the Council's internationally acclaimed geothermal policy, she is frequently called upon to present to international audiences regarding the New Zealand geothermal regulatory environment.

Phoebe Parson is a doctoral candidate at the University of Waikato, New Zealand. Her research interest is in the law and regulation for geothermal resources, including comparative international law. Her research explores the policy and regulatory processes for geothermal resource management in New Zealand with a focus on the use of information and data used to manage geothermal developments. Her research has been supported by the Waikato Regional Council (New Zealand), and by the International Bar Association's Section on Energy, Environmental, Natural Resources and Infrastructure Law. Phoebe studied for her Bachelor of Laws at Te Piringa Faculty of Law, University of Waikato, and continues her current research at the Faculty's Research Centre for Environmental, Resources and Energy Law.

The Philippine Experience in Geothermal Energy Development

Marnel Arnold Ratio, Jillian Aira Gabo-Ratio and Anna Leah Tabios-Hillebrecht

Abstract Situated along the Pacific Ring of Fire, the Philippines has a total installed capacity of 1916 MW geothermal energy, which makes it one of the world's top producers. The Philippine Government aims to increase its renewable energy capacity to an estimated 15,304 MW by 2030 comprising of 1495 MW for geothermal capacity. In order to reach its interim targets for increasing geothermal installed capacity, the government must work closely with the private resource developers to expedite permit related-processes and avoid project delays, thereby supporting timely geothermal exploration and construction activities. With decades of experience in geothermal energy development, the Philippines has learned valuable lessons from its various and unique geothermal energy projects from the lowland accessible Makiling-Banahaw geothermal complex to the socio-culturally and environmentally sensitive Mindanao geothermal complex. The past controversies and successful stakeholder resolutions have shed light on the complicated connection between geothermal energy and stakeholders particularly that of the indigenous cultural communities and indigenous people.

Keywords Philippines · Geothermal energy · Indigenous cultural communities
Social acceptance

M. A. Ratio (✉)
Laboratory of Geothermics, Department of Earth Resources Engineering, Graduate School of Engineering, Kyushu University, 744 Motooka Nishi-ku, Fukuoka 819-0395, Japan

J. A. Gabo-Ratio
Rushurgent Working Group, National Institute of Geological Sciences, University of the Philippines, Diliman, 1101 Quezon City, Philippines

A. L. Tabios-Hillebrecht
Freshfields Bruckhaus Deringer LLP, Maximiliansplatz 13, 80333 Munich, Germany

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_14

1 Introduction

Situated along the Pacific Ring of Fire, the Philippines with its 7100 islands is the second largest archipelagic state in the world after Indonesia. The Philippine archipelago is divided into three island groups: Luzon, Visayas, and Mindanao. The Philippines, located between Taiwan and Borneo, is around 800 km from the Asian mainland. With a population of 100 million (PSA 2015), the country is extraordinarily diverse in terms of geography, ethnicity, ecology, culture, and natural resources. Economic activity is concentrated around the National Capital Region (36.6% of Gross Domestic Product) and two adjacent regions, Southern Tagalog Mainland—(Region 4A) (16.8%) and Central Luzon (9.5%) (PSA 2017a).

Among the fastest growing economies in Southeast Asia, the Philippine economic growth is accompanied by low inflation, improved fiscal performance and strong external balances (ADB 2016). The country's gross domestic product (GDP) grew by an average of 6.9% for 2016 and 6.4% for the first half of 2017. The GDP is now seen to grow by a slightly faster pace as forecasted by Asian Development Outlook 2017 and is projected to strengthen in 2018 (ADB 2017). While the important drivers of the growth have mainly been manufacturing, trade, real estate, renting, and business activities, a rebound in the agricultural sector further boosted the economy (PSA 2017b). Compared to Luzon, the island groups of Visayas and Mindanao both have very high income inequality. Moreover, ideology-based armed conflict is a special challenge to the economic development of Mindanao.

1.1 Geologic Setting

The Philippine island arc is a tectonically active region, which was formed from the accretion and amalgamation of geologic terranes of various origins. Most of the islands comprising the Philippines are situated in the Philippine Mobile Belt, located between the Eurasian Plate and the Philippine Sea Plate. The island arc is sandwiched between two oppositely dipping trench systems (Fig. 1). To the west is the discontinuous east-dipping Manila-Negros-Sulu-Cotabato trench system and to the east is the East Luzon Trough and the west-dipping Philippine Trench (Aurelio 2000; Rangin and Pubellier 1990; Taylor and Hayes 1980). Traversing the length of the archipelago from northwest Luzon to southern Mindanao is the left-lateral Philippine Fault. This complex tectonic setting resulted in numerous active volcanoes, some of which are closely associated with geothermal steam fields.

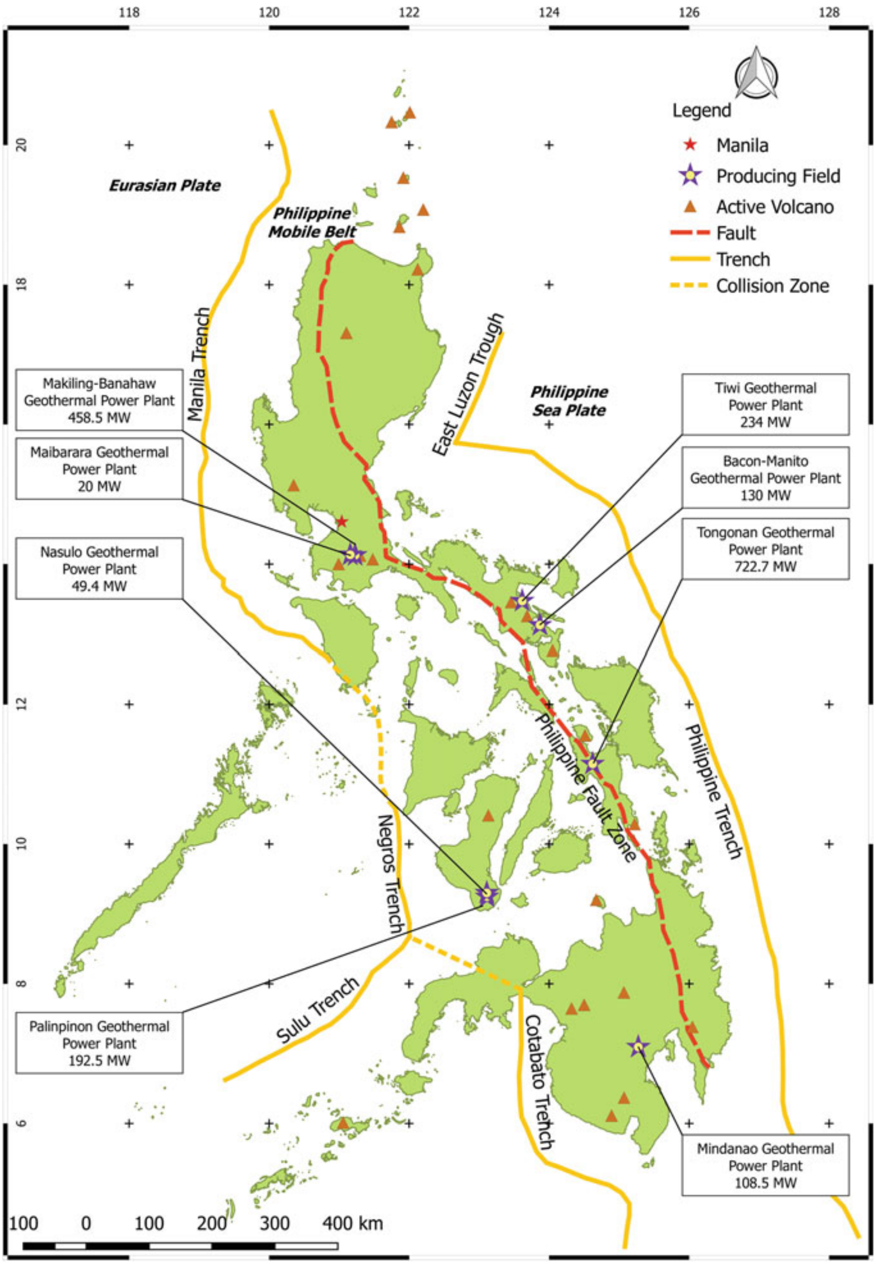


Fig. 1 Philippine geological map and installed geothermal capacity as of 2016. *Data Source* DOE 2017; PHIVOLCS 2008; Tsutsumi and Perez (2013)

1.2 History of Philippine Geothermal Energy Development

The Philippine Commission on Volcanology (COMVOL; presently, Philippine Institute of Volcanology and Seismology) started exploration projects on harnessing geothermal energy for electricity production in 1962. In 1967, Republic Act (RA) No. 5092 or the Geothermal Energy, Natural Gas, and Methane Law was enacted to promote and regulate the exploration, development, exploitation, and utilization of indigenous energy sources. Participation in the activities therein was limited to Filipino citizens and to associations duly incorporated in the Philippines and 60% of whose shares are owned by Filipino citizens.

Due to the worldwide oil crisis in the early 1970s and new legislation on geothermal energy development, exploration and development of geothermal sites all over the Philippines were accelerated to reduce the country's dependence on imported oil (Dolor 2006). In 1970, the National Power Corporation (NPC) entered into an agreement with the Philippine Geothermal Inc. (PGI), a subsidiary of Union Oil Company of California, for determining the feasibility and commercial viability of developing geothermal resources then in Naglabong-1 in Tiwi, Albay. NPC and PGI promptly followed the Tiwi exploration with the development of the Makiling-Banahaw steam field in Batangas and Laguna in 1974. NPC subsequently entered into a bilateral energy cooperation agreement with the New Zealand government for the exploratory drilling contract at the Tongonan steam field in Leyte (1972) and the Palinpinon steam field in Southern Negros (1976). As an institutional response to the oil crisis, the Philippine Government established the Philippine National Oil Company (PNOC), nationalizing therewith oil refining and distribution and created a subsidiary company, the PNOC-Energy Development Corporation (PNOC-EDC) to develop the country's indigenous energy resources in a bid for achieving self-reliance (De Jesus 2000). Further geothermal exploration and developmental projects for electricity production commenced in the different regions of the country, namely the Bacon-Manito steam field in the Bicol Region (1977) and the Mindanao steam fields (1978) (Sabularse 2008; Sussman et al. 1993).

The entry into force of Presidential Decree (PD) No. 1442 or the Geothermal Service Contract Law in 1978 launched the joint undertakings between the Government and private parties (i.e. field developers and contractors). Intended to promote the exploration and development of geothermal resources, PD No. 1442 provides the legal backbone of geothermal activities in the country and authorizes the Government to directly explore for development and utilization of geothermal resources, subject to any relevant and subsisting private rights. Such legal implementation has not gone without creases, however, as particular stakeholders started to raise their concern and dissatisfaction—notably not towards the resource developers—towards the royalty distribution scheme. This dissatisfaction is a particular concern for *barangays* (smallest administrative unit almost similar to a village) in the Makiling-Banahaw Geothermal Complex (Ratio and Fujimitsu 2013). Furthermore, one socio-political barrier among the different levels of the local government units (LGU) is politicking due to overlapping jurisdictions. Should the politicking issue escalate within the different levels of LGU, this causes significant delays in exploration and construction activities for resource developers (Ratio and Fujimitsu 2013). While the legislation governs development activities for the remaining untapped geothermal potential, PD No. 1442 does not provide favourable incentives to attract investment from the private sector (Fronda et al. 2015).

The developmental factors for the accelerated exploration and exploitation of geothermal resources included financial support from international development organizations and technical support for capacity building. Intensive foreign training and capacity building in geologic exploration, drilling and well testing, and steam field operations were provided to PNOC-EDC by geothermal centres in the US, Italy, Iceland, and Japan (De Jesus 2000). Through internally generated funds, foreign financial assistance and government loans from the Overseas Economic Development Fund of Japan, Asian Development Bank, and the World Bank, the Philippine Government launched several geothermal development projects (Alcaraz and Ogena 1997). The issuance of Executive Order 215 in 1987, amending PD No. 40, which established basic policies for the electric power industry, divested NPC of the monopoly to control power generation in the country and subsequently enabled independent power producers to enter into build-operate-transfer (BOT) contracts. In 1990, with the amendment of the BOT Law or RA No. 6957, as amended by RA No. 7718, the private sector was allowed to participate through investment and construction projects, which then expanded geothermal energy development. This legislation accelerated increase in electricity generation without increasing national debt (Vasquez and Javellana 1997).

Geothermal energy development endured a long hiatus from the mid-1980s to the early 2000s. RA No. 9513 or the Renewable Energy Act of 2008 (RE Law) promoted renewable energy and aimed to revitalize the exploration and development of renewable energy resources through foreign capital and the institutionalization of a system of incentives (DOE 2011). With this legislative development came the establishment of the PNOC Renewables Corporation, which is tasked to develop and implement renewable energy projects in the country.

As of 2016, the Philippines has a total installed capacity of 21,423 MW with renewable energy capacity of 6958 MW (32.5%). Among the installed capacity for renewable energy, geothermal energy has a total of 1916 MW (8.9%), second only to hydro energy with a total of 3618 MW (19.9%) (Fig. 2) (DOE 2016a). At present, the Philippines is one of the world's top producers of geothermal energy (World Energy Council 2016).

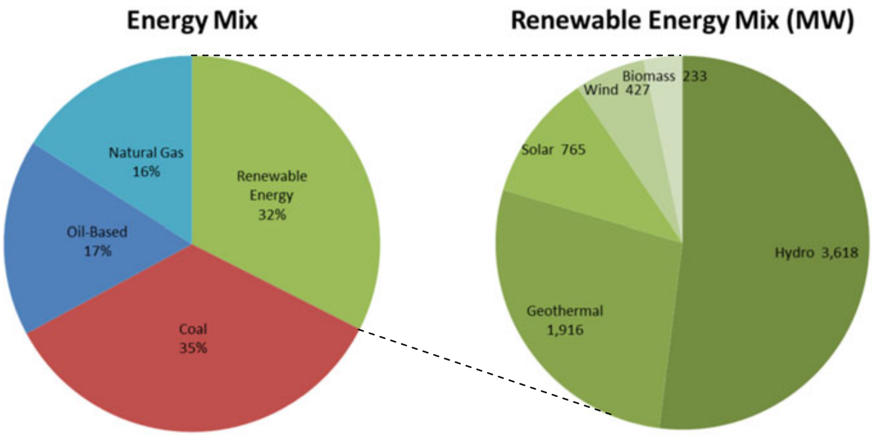


Fig. 2 Philippine energy mix and renewable energy mix. *Data Source* DOE 2016a

1.3 Demand and Uses of Geothermal Energy in the Philippines

While power generation has increased, power supply in the country still remains insufficient to meet the growing demand for electricity, thereby contributing to its high cost (NEDA 2017). The Philippine's geothermal resources are mainly utilized for electricity generation using high-enthalpy geothermal systems. With most of the country's high-enthalpy geothermal resources developed, detailed resource assessment of low-enthalpy geothermal resources is currently being conducted by the DOE for power generation (Halcon et al. 2015).

The direct use of geothermal heat is still limited to space heating and for agricultural processes such as crop drying or refrigeration. The first agro-industrial drying plant at Southern Negros geothermal field was initiated in 1992 and funded through the United Nation Development Programme. With an installed capacity of 1.0 MW, the facility was operated by PNOC-EDC until 1997 and was turned over to the local farmers' association and cooperatives (Alcaraz and Ogena 1997; Aligan 2010; Ulgado and Gular 2005). In the same area, the Palinpinon Geothermal Power Plant uses a combined heat and power plant that uses the 160 °C well to produce electricity while the remaining heat is used in a drying plant that produces *copra* (dried coconut meat) (Ölz and Beerepoot 2010). A pilot study on salt-making was conducted in Tiwi in 1970. Even though it was decommissioned in 1984, this demonstrated the viability of utilizing geothermal heat to process industrial-grade salt which served as a catalyst for the government to consider research on non-electrical applications of geothermal steam and low enthalpy fluids (Datuin and Troncales 1986). In the Bacon-Manito Geothermal Field, the Manito Geothermal Livelihood Project of the government comprised of 1.5 MW pilot power plant and multi-crop drying plant (Karunungan and Requejo 2000; Padua et al. 2000). The multi-crop drying plant uses low enthalpy system to dehydrate agricultural and marine products as an added value to meet higher standard and reduce post-harvest losses (Ulgado and Gular 2005). Although direct use through agro-industrial use and crop drying was proven viable, there were several barriers which hindered its growth and facility maintenance: high capital outlay and lack of financial resources; scaling and major turbine problems; and low market price of market products. While the World Energy Council (2007) have also reported that the Philippines utilizes other direct uses such as bathing, balneology, and swimming in various regions with geothermal sources, these are not likely the main demand for geothermal energy use. Since most of the remaining geothermal prospects in the country are intermediate to low-enthalpy types, these untapped resources can be developed for small-scale direct utilization (Aligan 2010).

1.4 Framework and Policies

1.4.1 Renewable Energy Related Policies

Renewable Energy Act of 2008

The RE Law was promulgated to accelerate the exploration and development of renewable energy resources to achieve energy self-reliance to minimize the country's exposure to price fluctuations in the international market. More concretely, the RE Law facilitates the entry of foreign capital into the country and accordingly provides for incentives. On the community level, this law encourages an equitable distribution of benefits with local stakeholders, in particular the local communities and indigenous groups, with the incentive of 80% share from royalty. The goal of the RE Law is to prioritize the renewable energy sector and to provide for renewable portfolio standards, which would require electricity suppliers to obtain portions of their energy supply for the consumer market from renewable energy resources. In so doing, consumers are provided green sources of energy for their daily use.

The RE Law institutionalized a system of fiscal and non-fiscal incentives. This legislation further outlines the mechanism on the awarding of Geothermal Service Contract and Geothermal Operating Contract between the government through the DOE and the renewable energy resource developer. A contract is awarded through either of the following: Direct Negotiation; Open and Competitive Selection Process; or, via public bidding to a local and/or foreign company deemed legally, technically and financially capable to undertake operation (Fronda et al. 2015). While the feed-in-tariff (FiT) system is an incentive for the renewable energy resource developers, geothermal energy is exempted therefrom. The RE Law also sets out the Philippine Government's share in geothermal energy projects at one and a half percent (1.5%) of the developer's gross income.

Philippine Development Plan 2017–2022

The Philippine Development Plan (PDP) is the government's roadmap to inclusive growth and presents an overarching strategic framework designed to address poverty reduction. Energy security and self-sufficiency will be pursued by increasing energy-generating capacity, encouraging efficient use of energy and implementing various transmission projects. It asserts that the improvement of environmental quality is essential, thereby promoting the use of clean and environmentally friendly alternative fuels and technologies.

Philippine Energy Plan 2016–2030

To implement the PDP, the Department of Energy (DOE) formulated the Philippine Energy Plan (PEP), which is part of the framework of the Energy Reform Agenda that aims to ensure energy security, achieve optimum energy pricing, and develop sustainable energy system. The energy sector contributes to the PDP's goals of promoting inclusive growth and poverty reduction through rural electrification, rapid and sustained economic growth in efficient delivery of services to enhance rural development while maintaining environmental integrity.

National Renewable Energy Program 2011–2030

The National Renewable Energy Program (NREP) outlines the policy framework and sets the strategic building blocks to achieve the goals set forth in the RE Law. This focuses a sustained drive towards energy security and improved access to clean energy by institutionalizing a comprehensive approach to address the challenges and gaps for renewable energy technologies and to outline the action plans necessary to facilitate and encourage greater private sector investments in renewable energy development. As part of its strategies, an integrated and aggressive information campaign will be conducted to increase public awareness and support (IRENA 2017). The NREP targets to increase Philippine renewable energy capacity to an estimated 15,304 MW by 2030 (almost triple its 2010 level) while for geothermal energy, an increase in installed capacity by 75% or 1495 MW. Since 2014, there has only been a total of 69.4 MW additional capacity from the 20 MW Maibarara Geothermal Power Project and 49.4 MW Nasulo Geothermal Power Plant expansion project.

1.4.2 Policies Affecting Geothermal Energy Development

Philippine Environmental Impact Statement System (PEISS)

Signed into law in 1979, PD No. 1151 established the Philippine Environmental Policy to formulate an integrated programme of environmental protection by requiring environmental impact assessments and statements. In its wake, the PD No. 1586 or the Environmental Impact Statement System Law establishes an environmental impact statement system and management related measures in order to attain and maintain a rational and orderly balance between socio-economic growth and environmental protection.

PEISS features the following measures: (1) recognition of other environmental assessment tools; (2) concept of social acceptability as one of the bases for project approval; (3) legal accountability of environmental assessment consultants and project proponents on the reports; (4) provision for the establishment of environmental guarantee funds; (5) provisions for community-based monitoring through the Multipartite Monitoring Team (MMT); and, (6) sanctions and penalties for violations (Tuyor et al. 2007). While the PEISS requires consultations to be conducted at various stages of a project, the social acceptability component forces the project proponents to address public sentiments and ensures the conduct of public consultations over resolution of issues and conflicts which makes social acceptability a major factor in the decision to grant or deny an environmental compliance certificate (ECC). To encourage public participation and to provide a check and balance mechanism in compliance monitoring, the MMT is operationalized as a PEISS mechanism (DOE 2011).

Local Government Code of 1991

The RA No. 8553 or the amended Local Government Code of 1991(LGC) establishes the systems and authorities of provincial, city, municipal and *barangay* governments in the Philippines which aimed to delegate more power, authority, responsibility and resources to the LGU. In relation to geothermal energy development, the LGC requires resource developers to conduct prior and periodic consultations with the LGU prior to any renewable energy exploration activity within the respective area of jurisdiction. This requirement puts forward the interests of the local host communities, as represented by their respective LGUs, so as to ensure that benefits from the development projects are meted out not just to the National Government and its development partners, but also and most certainly to the communities within the area affected by the projects. Regular consultations contribute to the determination of social impacts of the project and also provide a local system of checks, in particular as regards the maintenance by the developers of activities, facilities, and infrastructure for the benefit of the affected community.

National Integrated Protected Areas Systems Act of 1992

The RA No. 7586 or the National Integrated Protected Areas Systems Act of 1992 (NIPAS) establishes and manages biologically important public lands that are habitats of rare and endangered species of plants and animals, biographic zones and related ecosystems, particularly strict nature reserves, natural parks, natural monuments, wildlife sanctuaries, protected landscapes and seas, and resource reserves among others. While the NIPAS specifies that the survey of energy resources in protected areas may be subjected to exploration only for data gathering, further development through exploitation and utilization of energy resources located within NIPAS will only be allowed through passage of law by the congress.

While the NIPAS lists the prohibited activities and its penalties within the protected areas, its enforcement is hampered by overlapping jurisdictions and disputes between the Department of Environment and Natural Resources (DENR) and the Local Government Units (LGU) (La Viña et al. 2010). Conflicting land use between potential geothermal areas with key biodiversity areas, proposed protected areas, ecotourism areas and forestry projects is another developmental issue confronting geothermal energy development (Peñarroyo 2012).

Indigenous Peoples Rights Act of 1997

The RA No. 8371 or the Indigenous Peoples Rights Act of 1997 (IPRA) serves to recognize, to protect and to promote the rights of Indigenous Cultural Communities/Indigenous Peoples (ICC/IP), creating a National Commission on Indigenous Peoples (NCIP). While the IPRA empowers the ICC/IP in relation to ancestral land, this requires renewable energy resource developers to secure prior certification from NCIP that exploration activity does not overlap with ancestral domain and *Free and Prior Informed Consent* of the concerned ICC/IP. Given that exploration activities and development projects often affect indigenous groups, IPRA plays a primordial role in ascertaining that the rights, interests, culture, freedom, and integrity of the indigenous people, who stand to be affected by these developments and exploration projects, are protected in full measure.

Electric Power Industry Reform Act of 2001

Responding to high electricity price rates in the country largely brought about by insufficient local fuel reserves, the Philippine Government enacted RA No. 9136 or the Electric Power Industry Reform Act of 2001 (EPIRA). The EPIRA is intended to ensure affordable and reliable electric power supply by restructuring of the entire power industry, the privatization of state-owned power generation and transmission assets and deregulation of the industry within a more competitive, efficient, and market-based regulatory framework. In practical terms, the EPIRA is a legislative attempt to break the state monopoly in the provision of electric power. While the EPIRA ensures transparent and reasonable prices of electricity and full public accountability, it also promotes the utilization of indigenous and new and renewable energy resources in power generation.

2 Public Engagement Activities and Social Acceptance Assessment in the Philippines

2.1 Definition of Social Acceptability in Policy Frameworks

Social acceptability was formally adopted through the comprehensive Implementing Rules and Regulations of the DAO 1996-37 to enhance public engagement in the environmental impact assessment (EIA). The DAO 1996-37 defines social acceptability as "the result of a process mutually agreed upon by the DENR, key stakeholders, and the proponent to ensure that the valid and relevant concerns of stakeholders, including affected communities, are fully considered and/or resolved in the decision-making process for granting or denying the issuance of an ECC." This operational definition was revised after a decade through the DAO 2003-30 as "acceptability of a project by affected communities based on timely and informed participation in the EIA process particularly with regard to environmental impacts that are of concern to them." As one of the criteria in the review of EIS, social acceptability must be based on informed public participation and a result of meaningful public participation. The DAO 2017-15 has rationalized public participation under the PEISS as required for the entire EIA process from social preparation prior to scoping until project implementation and abandonment. The participation of all key stakeholders is vital to develop the social acceptability of the project (WB 2005).

While the DENR's Environment Management Bureau (DENR-EMB) administers the EIA and is limited to its environmental aspects, it recognizes that the social acceptability and resolution of conflicts are within the LGU's jurisdiction and responsibility. While the DENR-EMB review process will provide guidance to the LGUs on environmental aspects, the LGU should facilitate community participation through public outreach (DENR-EMB 2007). Because of its inherent subjectivity and debated operational definition, social acceptability is one of the most contentious requirements in the PEISS (Tuyor et al. 2007). While social acceptability is a major part of the EIA process for granting or denial of an ECC, very limited publications are available which renders further study about local stakeholder engagement a challenge.

2.2 Present Challenges of Philippine Geothermal Energy

Over the decades of geothermal development, social issues raised against geothermal projects in the Philippines include: (1) lack of consultation; (2) physical and economic dislocation of settlements; (3) lack of benefits; (4) encroachment of ancestral domain; and, (5) privatization of the people's forest patrimony (De Jesus 2005). Since most geothermal sites are located in mountainous areas in ICC/IP ancestral domain, major cultural impacts are encroachment to ancestral lands, desecration of ancestral sites, and hindrance to practice their traditional way of life (i.e. nomadic lifestyle, hunting and gathering, among others). These issues mainly contribute to strong resistance from ICC/IP to accept any development project in their ancestral domain (De Jesus 2016).

Unequal distribution of socio-economic benefits for stakeholders, particularly on the LGU and local communities, can cause dissatisfaction towards resource developers, which can lead to project delay or project expansion disapproval (Ratio and Fujimitsu 2013). For the distribution of royalty among the LGU, while high allocation percentage has been set for the provincial government, royalty allocation at the municipal and *barangay* levels is based on population rather than the area of land utilized.

Compared to non-base load renewable technologies, geothermal projects have very different risk profiles and tailored support policies will be significantly required to accelerate geothermal deployment (IRENA 2014). While the Feed-in-Tariff (FiT) serves as a mechanism to support renewable energy development, without any state subsidy, the end-users face piling charges from electricity producers and distributors such as universal charges, value-added taxes, and system losses in transmission generation (NEDA 2017). Although geothermal energy is excluded from the FiT, high electricity rates for geothermal energy, as compared to solar and wind, generally remain an issue for the public stakeholders.

Technological barriers still pose challenges for commercial development in the Philippines. The utilization of low enthalpy systems and young or acidic geothermal systems is still a promising prospect for geothermal development (DOE 2016b). Despite the passage of the RE Law and the adoption of the NREP, only 7013.9 MW of renewable energy has been installed out of the potential 14,499.8 MW (NEDA 2017). Technological development for intermediate-to low-enthalpy systems can contribute to installed capacity as well as to non-electricity direct utilization.

2.3 Controversies and Resolutions

Tiwi Geothermal Project

The Tiwi geothermal complex is located about 450 km southeast of Manila. While it was the country's first geothermal project for large scale power generation, its initiation was tied to various environmental, health, safety and political concerns because regulatory guidance and social framework were not readily available (Camu 2015). The social acceptability of this geothermal project greatly improved through the promulgation of the RA No. 7638 or the Department of Energy Act of 1992 which provided financial benefits to host communities. In line with the aim of PD No. 1586 to promote public information, a pilot project on geothermal education campaign was launched in 2000 in the local community and public schools with the following objectives: to promote safety practices for local stakeholders; to raise awareness of geothermal operations, benefits and concerns; to echo geothermal learning; and, to enhance proactive communication between the geothermal industry and its host community. The participants were elementary school teachers and representatives from the nearby municipalities who have undergone a perception survey regarding geothermal project operations and geothermal awareness workshops. Despite the acclamation and positive feedback of the education campaigns, it was discontinued due to organization-related shifts, changes in management priorities and budget concerns.

The Tiwi steam field has a total of 158 wells drilled since 1972. Due to typhoon damages, Tiwi geothermal complex' Units 3 and 4 has been decommissioned, thus, decreasing its installed capacity from 344 to 234 MW as of 2016 (Fronda et al. 2015).

Makiling-Banahaw Geothermal Project

Located about 70 km southeast of Manila, the Makiling-Banahaw geothermal complex is hosted by a rapidly industrializing area due to its accessibility and lowland location which poses unique challenges to maintaining safe and stable operations such as encroachment, pilferage and right-of-way issues.

One particular concern for *barangays* in the Makiling-Banahaw Geothermal Complex is the royalty distribution scheme towards the LGU, which is a cause of dissatisfaction (Ratio and Fujimitsu 2013). One socio-political barrier among the different levels of LGU is politicking due to encompassing jurisdictions. If the politicking issue escalates within the different levels of LGU, this causes significant delays in exploration and construction activities for resource developers (Ratio and Fujimitsu 2013). Concerns such as sulfuric odor and noises from well pressure release have been a cause of dissatisfaction among the local residents, which may cause less support for further project expansion (Ratio et al. 2014).

Its steam field developer has been active in engaging its local stakeholders in its operations and projects. They utilize the in-house tool, Community Impact Review (CIR), which integrates community issues (i.e. security, cultural, economic among others) with operations and provides valuable information to facilitate successful project planning, design and implementation conducted by all functional groups involved. With the purpose of integrating assessment of community issues into the project management process, meaningful community engagements provide critical information about key stakeholders which can affect the project phases. To increase stakeholder support and favorability, the CIR tool was complemented by a stakeholder engagement plan which outlines methods and strategies of managing stakeholder expectations (Batac and Dugan 2015).

With the various benefits from the geothermal resource developers and its CIR tool, the local host community has a harmonious relationship with geothermal energy development (Batac and Dugan 2015; Ratio et al. 2014). With a total of 132 steam wells drilled since 1975, the Makiling-Banahaw has an installed capacity of 458.5 MW as of 2016 (DOE 2017).

Mindanao Geothermal Project

Commissioned by PNOC-EDC, the Mindanao Geothermal Project was considered one of the more controversial development projects with concerns focused on the legal, environmental and cultural. The project is located within a national park and an ASEAN heritage area while it was also considered the ancestral home by indigenous cultural communities/indigenous people (ICC/IP) who believed that their god resides in the mountain. The project was charged with violation of Philippine National Park Laws and its international commitment to ASEAN. This has been clarified and resolved by the DENR that it does not prohibit energy development in parks. Moreover, the Department of Foreign Affairs stated that the ASEAN commitment is not in the category of an executive agreement hence the Philippine Government may conduct development activities (Ote and De Jesus 1995).

To create a model of sustainable development, the conditions of the environmental permit of the Mindanao Geothermal Project required to address biodiversity concerns through total inventory of the sites to be opened. Aside from the EIA, Environmental Risk Assessment (ERA) was undertaken to characterize the risks of the geothermal plant from environmental and natural hazards and to formulate guidelines to enhance risk management and response capability of the resource developer and government agencies (Ote and De Jesus 1995).

While the scoping guidelines for the project's EIA were developed with various members of the sectors from tribal groups and NGO under a coalition called Task Force Sandawa (*Apo Sandawa* was considered the name of the great grandparent of the Lumad indigenous group in the Southern Philippines), the EIA was requested by the LGU to be conducted by a third party from the academe due to the controversial nature of the project. In response, the resource developers conducted consultations with legitimate tribal leaders that were facilitated by experts and witnessed by government officials. To settle the agreement, the tribes requested for indemnification for crop damage, prioritization in employment for qualified local residents and installation of environmental measures together with an endorsement of an ancestral domain law, and royalty for the recognition of their rights over the ancestral land (Ote and De Jesus 1995). As part of cultural harmonization with the project, propitiatory rites and ceremony were conducted at Lake Agco of Mt. Apo led by a tribal elder.

Since 1987, a total of 40 wells have been drilled to supply the steam to the 2 power plant units. The 54.24 MW Mindanao I was commissioned in 1996 and the Mindanao II was commissioned in 1999 (Fronda et al. 2015). As of 2016, the Mindanao Geothermal Project has an installed capacity of 108.5 MW (DOE 2017).

2.4 Public Engagements, Information Campaigns and Social Impact Mitigations

As a component of the environmental monitoring regularly conducted by the DOE, the multipartite monitoring team (MMT) is undertaken by multi-stakeholders from the LGU, academe, and local residents with the main objective of applying social and environmental safeguards (DOE 2011). The activities of the MMT include: ensuring project proponent compliance and implementation of the Environmental Management Plan and the environmental compliance certificate (ECC), among others; harmonizing stakeholder relationships and ensuring public participation; preparing and disseminating reports; and, monitoring information, education and communication activities. The installation of MMT provided a mechanism of communication with stakeholders, which greatly reduced operation interruptions due to complaints and cases filed by communities and other interest groups (De Jesus et al. 2013).

The DOE and NGOs are strengthening renewable energy campaigns in the hope of spreading knowledge about renewable energy and increasing public awareness. Environmental groups such as the World Wildlife Fund Philippines and Greenpeace Philippines have been keen in supporting renewable energy development through its campaigns. Geothermal resource developers are also aggressive with their education campaigns aiming to elicit public participation in geothermal development (Ratio and Fujimitsu 2013).

As a strategy in the NREP, the DOE currently conducts assessment studies of all potential geothermal sources while keeping vigilant of their information and education campaigns (IEC). In a project study on Philippine Geothermal Resource Inventory and Assessment, the DOE also solicits the endorsement of inter-agency groups from the national government and LGU. One such example is the Regional Development Council of the Cordillera Autonomous Region for the promotion and development of geothermal energy in Northern Luzon (Herald Express 2017).

In collaboration with the DOE, interest groups like the National Geothermal Association of the Philippines (NGAP) conducts information campaigns in geothermal host communities with the support of geothermal resource developers. The NGAP and the DOE have also been conducting learning sessions with geothermal resource developers about newly implemented government guidelines and regulations such as the Guidelines on Public Participation under the PEISS (DAO 2017-15).

To enhance social acceptability, private geothermal resource developers have adopted protocols and procedures set by then government-owned PNOC-EDC, which now form part of the rules of the regulatory agencies such as DOE and the DENR (De Jesus 2000). These include stakeholder participation; access to meaningful benefits; remuneration, amenities and livelihood for unavoidable resettlements, among others. Private geothermal resource developers also conduct regular socio-economic opinion surveys for monitoring and integrated information campaigns (De Jesus 2005; De Jesus et al. 2013).

International research projects have also conducted research on the fundamental link and trade-offs between geothermal energy and society. Supported by the Japanese Government, an international research project of the Research Institute for Humanity and Nature was aimed at understanding the complexity of the water-energy-food nexus system and creating policy options to reduce trade-offs among resources. On an integrated approach, this project conducted technical monitoring and opinion surveys to investigate the resource use conflicts for water and geothermal energy particularly in the Laguna province and the Makiling-Banahaw geothermal complex.

In conjunction with the Nexus Project, a research project through the International Grant Program of Toyota Foundation has conducted focus group discussions and workshops with the LGU and host community of the

Makiling-Banahaw geothermal complex to probe the means to overcome development barriers and construct policy recommendation on community development with geothermal power introduction. The results of study were presented and workshops were conducted in the target countries. One of the most significant outcomes is the recognition that community development with geothermal resource requires joint fact-finding activities in order to elicit public participation and consensus building.

Other studies from the academe have been conducted in relation to geothermal studies such as socio-economic analysis of environmental impacts, case studies of social acceptability, ERA, among others. As a post-graduate research in the University of the Philippines Diliman, a study on ERA on the Makiling-Banahaw Geothermal Complex was conducted to present a methodology by identifying hazards associated with the project; health risk assessment for chemicals of potential concern; and, evaluate risk reduction and management measures at the geothermal complex. Being generic in nature, the methodology can be applied to other energy projects for the same goals (Echavez 1997).

A post-graduate research in Kyushu University, Japan, conducted a case study of social acceptability in the Makiling-Banahaw Geothermal Complex, which included perception about renewable energy and perceived vulnerability. The results of the study showed that the stakeholders residing in the *barangay* which host geothermal facilities were more accepting of geothermal energy compared to stakeholders residing farther from the geothermal buffer zone. Moreover, trust with geothermal resource developers and communication with the stakeholders can be improved through periodic dialogues and information campaigns to assure stakeholders of stable and safe geothermal operations (Ratio and Fujimitsu 2013).

As a joint undertaking between the University of the Philippines Los Baños and Dalhousie University, a socioeconomic and valuation study was conducted in the Makiling-Banahaw Geothermal Project to provide an objective assessment of the impacts of its operations on the properties, health and crops of the host communities. While the study showed that the geothermal project affected the property value in the area, further studies to validate the effects of the geothermal operation on crops and health was recommended. To ensure harmonization with the stakeholders and prevent future conflict, the major recommendations of the study included: just payments for direct effects of operation; relocation of families within 100 m of the complex; implementation of livelihood and social engineering measures; and, preparing long-term project land use plan (Butardo-Toribio et al. 1995).

Moreover, private geothermal resource developers conduct their own social acceptability surveys. Results from opinion surveys conducted by the resource developers last 2016 in Mindanao Geothermal Project and Southern Negros Geothermal Project reveal that stakeholders have high level of support for the project attributing it to assistance on education, health, livelihood and provision of electricity for the host community and capacity building activities and trainings for the LGU (EDC 2017). During the initiation of Mindanao Geothermal Project, in the absence of any set procedure on social acceptance by the ICC/IP, the resource developers conducted consultations resulting to conflict resolution and a formal agreement on the role of the host communities (De Jesus et al. 2013). The Mt. Labo, Camarines Norte and the Northern Negros Geothermal Projects were among the first in the country to model the complete participative process using various tools such as conduct of scoping meetings, information drives, key informant interviews, focused group discussions, perception surveys, and public dialogues (Pascual 2005).

3 Discussion

The Philippines has a long history of geothermal energy development, which was initiated by the government and later on involved the private sector. Since 2014, out of the country target additional installed capacity of 1495 MW for 2030, only 69.4 MW installed capacity has been added to geothermal energy which is just 5% of the overall total target installed capacity. In order to timely reach target installed capacities for 2030, the government needs to work closely with the private sector to expedite exploration and construction activities while preventing project delays.

With the country's high energy demand and insufficient supply of electricity, the main use of geothermal energy has been for electricity production. The technological development of intermediate- to low-enthalpy geothermal resources can provide additional installed capacity and provision of electricity. The other direct uses in the country, such as agricultural drying and balneology, have been scarcely utilized. The non-electricity use of geothermal energy has been found viable through several projects supported by the government and international organizations. However, there were developmental barriers identified such as lack of private sector participation due to high capital outlay, scaling of pipes and low market value of produced agricultural products. In order to develop the agricultural use of geothermal energy, a form of subsidy, incentive or technical assistance from the government can encourage private investment.

The most significant legislation that supports renewable energy development, including therein the furtherance of geothermal energy production, is the Renewable Energy Law (RE Law), which provides the legal framework for the fast-tracked development of renewable energy resources and strategies to further ensure the effective usage of renewable energy. The RE Law also offers fiscal and non-fiscal incentives to attract private investment.

Nevertheless, the implementation of renewable energy projects necessitate the application not only of the RE Law provisions but also other relevant legislations and policies such as the National Integrated Protected Areas System (NIPAS) Act, and the Indigenous Peoples Rights Act (IPRA). As a significant part of the permitting and approval process, the Philippine Environmental Impact Statement System requires social acceptability as a requirement for the issuance of an Environmental Compliance Certificate (ECC) and the LGU must conduct public engagement and assessment of social acceptance as mandated by the Local Government Code. The environmental aspect of the assessment will be implemented by the Environmental Management Bureau of the DENR, the agency who issues the ECC. In case the geothermal resource is located in an ancestral land of an indigenous cultural community, project proponents are required to secure the *Free and Prior Informed Consent* (FPIC) from the National Commission on Indigenous People as mandated by the Indigenous Peoples Rights Act. Such FPIC is grounded on the indigenous concept of ownership that ancestral domains and its resources serve as the material foundation of the cultural integrity and identity of the indigenous cultural community in these domains. As such, these domains and the rights to the resources therein are protected not just for the benefit of the indigenous cultural communities presently living therein but also for the benefit of the generations to come. Moreover, should the geothermal resource be co-located in national parks or in protected areas so identified by the NIPAS Act, only resource survey for data collection is allowed to preserve the nature and biological importance of such national park or protected area.

Other challenges for geothermal energy development include the designation of national parks and ancestral domains in geothermal areas, which require soliciting social acceptance and public participation, resolving conflicts, and settling agreements with indigenous cultural communities. Involving and integrating the stakeholders in a project's initiation phase as well as transparent communication may guarantee support and build trust. In these procedures, social acceptability is a contentious requirement due to its subjectivity but constitutes a major factor in the decision to grant or deny an ECC (Tuyor et al. 2007). Baseline studies of social acceptability may be conducted on existing and prospective geothermal projects. Further monitoring the same on a periodic basis can shed light on effectively managing stakeholders and further enhancing public participation.

To increase awareness and support for renewable energy, the government and the resource developers have been conducting IECs especially among host communities of geothermal projects and prospect areas. Moreover, interest groups have also been engaging the public through its campaigns to support renewable energy. International research projects have been conducted to understand the fundamental links of renewable energy and society such as studies to understand trade-offs of conflicting resource use and social acceptability.

4 Conclusions

With decades of experience in geothermal energy development, the Philippines have learned valuable lessons from its various and unique geothermal energy projects from the lowland accessible Makiling-Banahaw geothermal complex to the socio-culturally and environmentally sensitive Mindanao geothermal complex. The past controversies and debates and its successful resolutions have shed light to the complicated relationships between geothermal energy and its stakeholders especially the ICC/IP and host communities. This connection can further be understood by periodic monitoring of social acceptability. In-depth policy analysis and policy dialogues on the harmonization of renewable energy-related laws can resolve conflicting policies thus minimizing if not preventing project delays.

Acknowledgements The authors are grateful for the support of the Geothermal Energy Management Division—Renewable Energy Management Bureau—Department of Energy, the National Geothermal Association of the Philippines and the Energy Development Corporation.

References

Alcaraz AP, Ogena MS (1997) Geothermal energy development—a boon to Philippine energy self-reliance efforts. Paper presented at the symposium on energy in connection with the S&T centennial celebration, 23 Oct 1997

Aligan ME (2010) Opportunities for direct use of geothermal resources in the Bicol Region, Philippines. In: Abstracts of the World Geothermal Congress 2010, Bali, 25–29 Apr 2010

Asian Development Bank (2016) Asian development bank and the Philippines: fact sheet. https://www.adb.org/sites/default/files/publication/27790/phi-2016.pdf/. Accessed 14 Oct 2017

Asian Development Bank (2017) Asian development outlook 2017 update—sustaining development through public–private partnership. https://www.adb.org/sites/default/files/publication/365701/ado2017-update.pdf/. Accessed 14 Oct 2017

Aurelio MA (2000) Tectonics of the Philippines revisited. J Geol Soc Philippines 55:119–183

Batac EL, Dugan V (2015) Enabling sustainable geothermal operations through social impact assessment. In: Abstracts of the World Geothermal Congress 2015, Melbourne, 19–25 Apr 2015

Butardo-Toribio MZ, Orno JL, Dakila-Bergonia A et al. (1995) Socioeconomic analysis of the environmental impacts of the operations of Makban geothermal project, Luzon. Dalhousie University, Halifax, Philippines

Camu MM (2015) Geothermal education: a campaign for sustainability. In: Abstracts of the World Geothermal Congress 2015, Melbourne, 19–25 Apr 2015

Echavez JW (1997) Environmental risk assessment study: Mak-Ban geothermal complex. Masters thesis, University of the Philippines Los Banos, Laguna, Philippines, 132 pp

Energy Development Corporation (2017) 2016 Performance report. Energy Development Corporation, Pasig

Datuin RT, Troncales AC (1986) Philippine geothermal resources: general geological setting and development. Geothermics 15(5/6):613–622

De Jesus AC (2000) Philippine geothermal development: a successful renewable energy and a guide for new and renewable options. Paper presented at the World Energy Congress, Japan, 18 Oct 2000

De Jesus AC (2005) Social issues raised and measures adopted in Philippine geothermal projects. In: Abstracts of the World Geothermal Congress 2005, Antalya, 24–29 Apr 2005

De Jesus AC (2016) Environmental benefits and challenges associated with geothermal power generation. In: DiPippo R (ed) Geothermal power generation developments and innovations. Elsevier House, London, pp 477–494

De Jesus AC, Pascual RVJ, Addawe C (2013) Harmonizing energy development corporation's environmental and social initiatives with the Philippine environmental impact statement system. Paper presented at the First National Convention on the Philippine EIAS System, Manila, Philippines. 19–21 June 2013

Department of Energy (2011) National renewable energy program 2011–2030. https://www.doe.gov.ph/national-renewable-energy-program/. Accessed 15 Oct 2017

Department of Energy (2016a) 2016 Philippine power situation report. https://www.doe.gov.ph/sites/default/files/pdf/electric_power/power_situationer/2016_power_situation.pdf/. Accessed 26 Nov 2017

Department of Energy (2016b) Philippine energy plan 2016–2030. https://www.doe.gov.ph/pep/philippine-energy-plan-2016–2030/. Accessed 24 Dec 2017

Department of Energy (2017) List of existing power plants. https://www.doe.gov.ph/list-existing-power-plants/. Accessed 2 Dec 2017

Department of Environment and Natural Resources-Environment Management Bureau (2007) Revised procedural manual for DENR Administrative Order No. 30 Series of 2003 (Implementing Rules and Regulations of Presidential Decree No. 1586, Establishing the Philippine Environmental Impact Statement System). http://eia.emb.gov.ph/wp-content/uploads/2016/06/Revised-Procedural-Manual-DAO-03-30.pdf/. Accessed 18 Nov 2017

Dolor FM (2006) Geothermal projects in National parks in the Philippines: the case of the Mt. Apo geothermal project. Paper presented at the workshop for decision makers on geothermal projects in Central America, San Salvador, 26 Nov–2 Dec 2006

Fronda AD, Marasigan MC, Lazaro VS (2015) Geothermal development in the Philippines: the country update. In: Abstracts of the World Geothermal Congress 2015, Melbourne, 19–25 Apr 2015

Halcon RM, Fronda AD, Del Rosario RA et al. (2015) Detailed resource assessment of selected low-enthalpy geothermal areas in the Philippines. In: Abstracts of the World Geothermal Congress 2015, Melbourne, 19–25 Apr 2015

Herald Express (2017) Conduct of geothermal resource assessment backed. http://baguioheraldexpressonline.com/conduct-of-geothermal-resource-assessment-backed2/. Accessed 14 Oct 2017

International Renewable Energy Agency (2014) Renewable power generation costs in 2014. International Renewable Energy Agency, Abu Dhabi

International Renewable Energy Agency (2017) Accelerating renewable mini-grid deployment: a study on the Philippines. International Renewable Energy Agency, Abu Dhabi

Karunungan V, Requejo R (2000) Update on geothermal development in the Philippines. In: Abstracts of the World Geothermal Congress 2000, Beppu-Morioka, 28 May–10 June 2000

La Viña AGM, Kho JL, Caleda MJ (2010) Legal framework for protected areas: Philippines. International Union for Conservation of Nature, Gland

National Economic and Development Authority (2017) Philippine Development Plan 2017–2022. http://www.neda.gov.ph/2017/07/26/philippine-development-plan-2017-2022/. Accessed 15 Oct 2017

Ölz S, Beerepoot M (2010) Deploying renewables in Southeast Asia: trends and potentials. International Energy Agency, Energy Papers 06

Ote LM, De Jesus AC (1995) Mt. Apo Geothermal Project: a learning experience in sustainable development. In: Abstracts of the World Geothermal Congress, Florence, 18–31 May 1995

Padua D, Gerona P, Fajardo V (2000) Manito Lowlands: the first low-enthalpy field under exploitation in the Philippines. In: Abstracts of the World Geothermal Congress 2000, Beppu-Morioka, 28 May–10 June 2000

Pascual RVJ (2005) Impacts of Philippine environmental regulatory policies on PNOC-EDC's corporate environmental management initiatives. In: Abstracts of the World Geothermal Congress 2005, Antalya, 24–29 Apr 2005

Peñarroyo FS (2012) Geothermal exploration and development after the passage of the Philippines Renewable Energy Act 2008. In: Abstracts of the 4th African rift geothermal conference, Nairobi, 21–23 November 2012

Philippine Institute of Volcanology and Seismology (2008) PHIVOLCS volcano monitoring http://www.phivolcs.dost.gov.ph/index.php?option=com_content&view=article&id=50&Itemid=86/. Accessed 20 Dec 2017

Philippine Statistical Authority (2015) Highlights of the Philippine population 2015 census of population. https://psa.gov.ph/content/highlights-philippine-population-2015-census-population. Accessed 15 Oct 2017

Philippine Statistical Authority (2017a) All regions of the Philippines posted positive economic growth in 2016. https://psa.gov.ph/regional-accounts/grdp. Accessed 14 Oct 2017

Philippine Statistical Authority (2017b) Philippine economy grows by 6.5 percent in the second quarter; 6.4 percent in the first half of 2017. https://psa.gov.ph/nap-press-release. Accessed 14 Oct 2017

Rangin C, Pubellier M (1990) Subduction and accretion of Philippine Sea Plate fragments along the Eurasian margin. Tectonics of Circum-Pacific continental margins 139–164

Ratio MAR, Fujimitsu Y (2013) Challenges of geothermal energy development in the Philippines: from social and political viewpoints. In: Abstracts of the international symposium on earth science and technology 2013, Kyushu University, Fukuoka, 3–4 Dec 2013

Ratio MAR, Fujimitsu Y, Nishijima J et al. (2014) Perceived knowledge and social acceptance of geothermal energy of the local community in Makiling-Banahaw geothermal complex. In: Abstracts of the grand renewable energy 2014—international conference and exhibition, Tokyo. 27 July–1 Aug 2014

Sabularse RC (2008) Geothermal energy in the Philippines. Paper presented at the workshop on geothermal energy: resources and technology for a sustainable development, Trieste, 10–12 December 2008

Sussman D, Javellana SP, Benavidez PJ (1993) Geothermal energy development in the Philippines: an overview. Geothermics 22(5/6):353–367

Taylor B, Hayes DE (1980) The tectonic evolution of the South China Basin. In: Hayes DE (ed) The tectonic and geologic evolution of Southeast Asian Seas and Islands. American Geophysical Union, Washington, DC, pp 89–104

Tsutsumi H, Perez JS (2013) Large-scale active fault map of the Philippine fault based on aerial photograph and interpretation. Active Fault Res 39:29–37

Tuyor JB, Bautista JG, Shah JJ et al. (2007) The Philippine environmental impact statement system: framework, implementation, performance and challenges. Discussion papers, East Asia and Pacific Region. Rural Development, Natural Resources and Environment Sector. World Bank, Washington, DC

Ulgado AF, Gular MTM (2005) Status of direct use of geothermal energy in the Philippines. In: Abstracts of the World Geothermal Congress 2005, Antalya, 24–29 Apr 2005

Vasquez NC, Javellana SP (1997) Present and future geothermal developments in the Philippines. In: Abstracts of new energy and industrial technology development organization international geothermal symposium, Sendai, 11–12 Mar 1997

World Bank (2005) Multistakeholder participation. Handbook for the application of the enhanced environmental performance monitoring and audit system of the Philippine environmental impact assessment system, vol 2. World Bank, Washington, DC

World Energy Council (2007) Survey of energy resources 2007. World Energy Council, London

World Energy Council (2016) World energy resources: geothermal 2016. World Energy Council, London

Marnel Arnold Ratio earned his double masters in the Philippines (Philosophy) and Japan (Earth Resources Engineering). His research interests include environmental ethics, social acceptance and geothermal energy.

Jillian Aira Gabo-Ratio earned her undergraduate and masters (Geology) in the Philippines and Phd (Earth Resources Engineering) in Japan. Gabo-Ratio has published on mineralization and tectonics.

Anna Leah Tabios-Hillebrecht earned her law degrees in the Philippines (JD), Japan (LL.M.), and Germany (Dr. jur.). Tabios-Hillebrecht has published on the *locus standi* of future generations and on the Fukushima Disaster and has been cited as one of the contributing experts on Earth Jurisprudence in the 2016 summary report of the UN General Assembly on Harmony with Nature.

Geothermal Energy in Switzerland: Highlighting the Role of Context

Olivier Ejderyan, Franziska Ruef and Michael Stauffacher

Abstract This chapter presents the latest trends of deep geothermal energy (DGE) in Switzerland. The country played a pioneering role in the development of low-enthalpy DGE. But setbacks in early flagship projects have slowed these efforts. Since then, the development of DGE in Switzerland has been characterised by a plurality of technologies, actors and institutional frameworks. We examine how federalism and direct-democracy has shaped this plural landscape and how it influences current DGE development. The chapter first introduces the institutional and political setting of DGE, as well as the main actors involved. Then, focusing on specific cases, the chapter presents different forms of public engagement that are shaped by the variety of actors involved, as well as the regulatory frameworks and cultural backgrounds. The results underline the importance of taking into account the social context of DGE projects. Furthermore, the results highlight that such a context is dynamic and responsive to the communication and public engagement strategies set up by DGE project operators. In conclusion, using Switzerland as an example, we show that operators must develop functional-dynamic siting, communication and public engagement procedures.

Keywords Switzerland · Social acceptance · Perception · Public engagement

O. Ejderyan (✉) · F. Ruef · M. Stauffacher
Department of Environmental Systems Science, Transdisciplinarity Lab, ETH Zurich, 8092 Zurich, Switzerland
e-mail: Olivier.Ejderyan@usys.ethz.ch

O. Ejderyan · F. Ruef · M. Stauffacher
Swiss Competence Center for Energy Research-Supply of Electricity (SCCER-SoE), ETH Zurich, 8092 Zurich, Switzerland

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_15

1 Introduction

1.1 Country and Institutional Profile

Switzerland is a country in Central Europe that lies between the Alps, the Swiss Plateau and the Jura. It covers an area of 40,000 km^2 with most of the more than eight million inhabitants living on the plateau; in Switzerland, the two major urban centres are Zurich and Geneva. Switzerland has four national languages that have common yet unique regional and socio-political characteristics, namely German, French, Italian and Romansh. It is one of the richest countries in the world and is especially proud of its direct democratic system. Federalism is essential in Switzerland, with a high degree of autonomy at the three hierarchical levels of the municipality, the canton and the federal state (Linder and Vatter 2001). With different legal regulations across the 26 cantons, any national matter needs to overcome a number of administrative barriers and complications to take form.

The direct democratic system provides opportunities to citizens and actors from civil society (e.g., NGOs, professional corporations, etc.) to intervene in the planning and implementation of policies and projects, especially the ones with a local impact (Linder and Lanfranchi 1992; Kübler 1999). Instruments such as national or local referenda and initiatives enable citizens to oppose or propose laws, policies and projects, provided enough signatures are collected. Moreover, several legal and administrative procedures allow identified stakeholders to contest projects. To avoid lengthy legal or political processes with uncertain outcomes, policy makers and project managers are therefore prone to engage with concerned stakeholders and the public in early phases (Kübler 1999). This is especially the case in new and emerging sectors that do not yet have routinized decision-making processes or that are strongly context dependent, such as DGE.

1.2 Overall Power/Heat Demand and Present/Future Supply Mix

As with any other developed country, energy demand in Switzerland increased sharply starting in the 1950s (Pfister 1995) and peaked in the late 1990s. Since then, it has stabilised and, as of lately, even slightly decreased (BFE 2016a). With respect to power production in Switzerland, the biggest share is covered by hydropower (60%) and nuclear (34%). The rest is provided by a set of various resources, including renewable technologies. In contrast to the overall energy demand, the demand for electricity is still increasing (BFE 2016b).

As in other countries, the nuclear accident in Fukushima in 2011 has had a strong impact on the Swiss energy policy. The federal government decided to phase out nuclear power, improve energy efficiency and increase the share of renewable energies, which has been deemed Energy Strategy (ES) 2050. As part of this strategy, Switzerland has produced different scenarios that present various possibilities of how energy supply and demand will develop (Prognos 2012; Densing et al. 2016; Berntsen and Trutnevyte 2017; Braunreiter and Blumer 2018). The scenarios now serve as a guide for future action and are not only used in research, but also regularly referred to in political and broader societal discourses. With the national referendum on 21 May 2017, the Swiss population approved the revision of the Energy Act as part of the ES 2050, including the first set of measures to restructure the Swiss energy system.

Part of the ES 2050 are major investments in research and development activities, especially with the establishment of several Swiss Competence Centers for Energy Research (SCCERs, see: Innosuisse 2018). The authors of the current chapter participate in one of these centres, the SCCER Supply of Electricity (SCCER-SoE 2017), which focuses specifically on deep geothermal energy and hydropower.

1.3 Geothermal Energy in Switzerland

When it comes to geothermal energy, it needs to be noted that Switzerland is the world leader in terms of the density of heat-pump installations (Rybach 2013), which will, however, not be further discussed here. Our focus is on geothermal energy at deeper levels. Although traditional technology focuses on existing sources of hot water (hydro-thermal), the enhanced or engineered systems dig deep into the earth's crust and thus need to stimulate the host rock through the injection of water (petro-thermal) (Hirschberg et al. 2015).

1.3.1 Future Scenarios of DGE

In the scenarios for the ES 2050, an electricity production of 4.4 TWh/year by 2050 (Prognos 2012) from deep geothermal sources is presumed. Still, with slow progress, DGE lags behind the development of other renewables. The exclusive focus on power production was recently expanded by including the use of heat produced from DGE, both for economic (Hirschberg et al. 2015) and environmental (lower CO_2 emissions) (Menberg et al. 2016) reasons. Yet no target has been set in the ES 2050 for heat production from geothermal means.

To further the development of DGE, research projects are focusing on the following topics: processes that are occurring when creating a reservoir several thousands meters underground and the establishment of pilot sites to develop scientific engineering methods. Social scientific research (see Sect. 2) has been included from the beginning, though on a much smaller scale than the largely dominating natural scientific and engineering perspectives.

The Swiss underground is still practically unknown. Policy instruments foresee that industrial pilot projects will be developed. These pilot sites should help uncover more on the underground mechanisms of DGE technologies. Moreover, such subsidised pilot sites are crucial because project developers and electricity producers are hesitant to invest in geothermal projects due to high upfront investment costs and exploration risk. Most large electricity providers have stopped their investments with the sharp drop in electricity prices. With the national referendum in May 2017, the Swiss Federal Office of Energy (SFOE) can now support both the exploration risk and high initial investment costs with specific instruments, for example, with the federal risk guarantee.

1.3.2 Overview of Hydro and Petro-Thermal Projects in Switzerland

At present, no electrical power is produced from geothermal resources in Switzerland. There were several attempts, most notably in Basel and St. Gallen, to establish a geothermal power plant. Both failed because of a large seismic event in the first case and low availability of water, among other reasons, in the second. We will come back to the cases of Basel and St. Gallen later in this chapter. To date, more than 40 projects of different scales and technologies exist, are planned or have existed on Swiss territory, most being hydro-thermal systems (Fig. 1). Half of the projects are either already actively running and producing heat (12 projects) or are in development with good chances of success in the future (7 projects). The actively producing systems are mostly mid-depth projects with drilling depths varying from between 300 and 2371 m. The most important and largest project is the *Erdwärme* project in Riehen near Basel with a capacity of 5 MWt heat. All other projects are very small in comparison, with a capacity of 1.35 MWt or less. Nevertheless, the success of these relatively small projects is important to show the potential of geothermal energy on different scales and with different resources. Many of the projects in planning and development aim for greater depth, higher temperatures and the production of electricity.

1.3.3 Actors of DGE in Switzerland

The Swiss federal structure and direct democratic system result in a wide range of actors influencing the development of DGE in Switzerland.

The federal government, through the SFOE, sets the framework conditions for energy provision within the country. The ES 2050 supports DGE by offering a federal guarantee covering 60% of exploration costs if a geothermal project (power or heat) is not successful because of insufficient resource potential. Moreover, it introduces a preferential price for electricity produced by geothermal energy. Additionally, the SFOE supports DGE development through the funding of pilot projects or research programmes.

The 26 cantons are responsible for implementing the federal energy law. Sovereignty over the underground lies with the cantons, and as such, they are the authorising bodies for any DGE project. Cantonal legal bases for regulating DGE

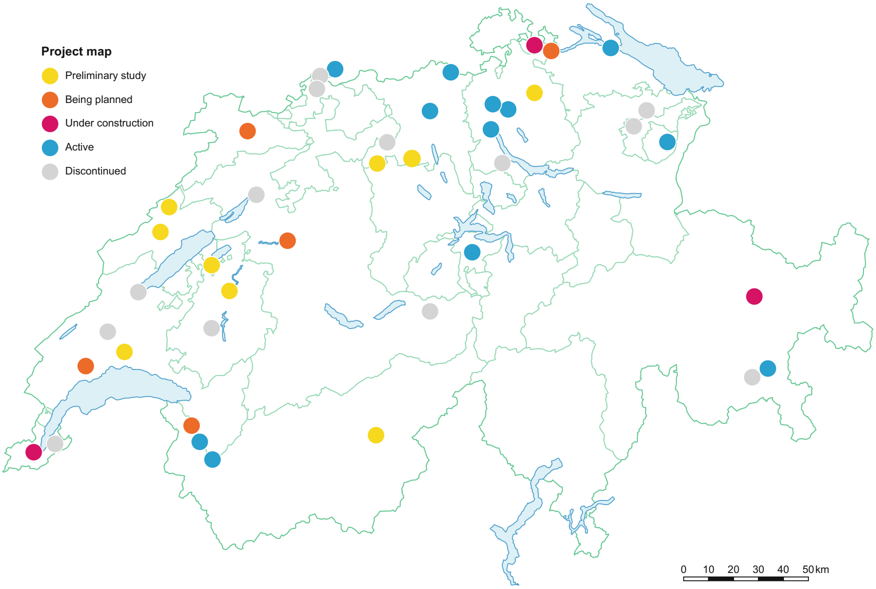


Fig. 1 Geothermal projects in Switzerland and their development status. *Data Source* adapted from Geothermie-Schweiz (2018)

vary strongly across the country, and this diversity in cantonal rule has been identified by legal experts as an important hindering factor for the nationwide development of DGE (Hirschberg et al. 2015).

In some cantons, the responsibility of geothermal energy projects is delegated to the municipalities. Cities that have enough financial capacity might even develop their own projects through their public utilities, as was the case in the city of St. Gallen and in the city of Zurich with the Triemli project, a hydrothermal project that failed because of low water flow.

In Switzerland, DGE operators can be either private or public. One of them is Geo-Energie Suisse, the only operator active at a national level. It is a private company with several Swiss public utilities as major shareholders. Geo-Energie Suisse aims at developing petro-thermal power plants. Public utilities are also important players for the development of geothermal projects. Larger utilities such as *Services industriels genevois* (SIG) in Geneva or *Elektrizitätswerk der Stadt Zürich* (EWZ) in Zurich might carry their own projects. Smaller public utilities might also be active in geothermal energy, often within a consortium or a public–private partnership set up for a specific project. Professionals active in geothermal energy convene in the organisation Geothermie-Schweiz, which promotes and lobbies for DGE.

National environmental NGOs generally have a positive attitude toward DGE. They consider geothermal as an alternative to fossil fuels for heat and as a replacement for nuclear energy and are supportive of national policies to develop DGE.

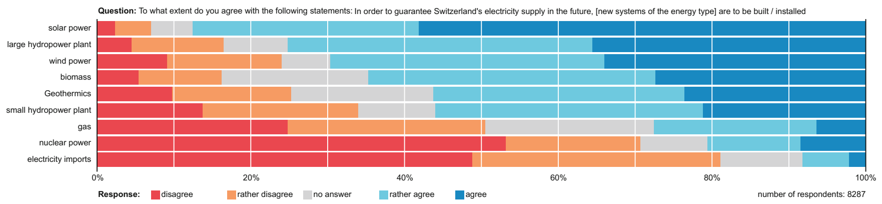


Fig. 2 Results from a national representative survey (N = 8287) in Switzerland. *Data Source* Stadelmann-Steffen and Dermont (2016)

The Swiss population is also an important actor to be considered. Through legal procedures or referenda, citizens can have a direct influence on policies promoting DGE, as well as on single projects. In St. Gallen, for instance, municipal funding for a geothermal plan was approved by a referendum. In the canton of Jura, citizens are calling for a vote to ban DGE. Thus, acceptance from the wider public is a crucial issue.

1.4 Perception of Different Technologies—Geothermal in Comparison

To close this section, we show some results from a recent national representative survey (2016, N = 8287) that compares the acceptance of different energy technologies (see Fig. 2). Overall, geothermal energy seems to be broadly accepted in Switzerland, though its support is markedly less positive than for other more popular renewable technologies, such as solar, wind and biofuels. Still, geothermal is perceived far more positively than nuclear or imports of electricity. More detailed results of this survey illustrate that males are slightly more positive than females toward this technology; the French- and Italian-speaking parts of Switzerland are more positive than the German-speaking part; and the younger generation is slightly more positive than the older ones (Stadelmann-Steffen and Dermont 2016).

2 Overview of Public Engagement and Social Research on DGE in Switzerland

In the remaining sections of the chapter, we will exclusively focus on deep geothermal projects, both hydro- and petro-thermal. Thereby, we will present the projects in Basel, St. Gallen, Haute-Sorne and the integrated programme in the Canton of Geneva. We chose these projects because they are the most discussed and thus largely shape the context of the geothermal picture in Switzerland.

2.1 *Public Engagement in Swiss DGE Projects*

2.1.1 Basel: A First Pioneering Effort with a Negative Outcome

The *Deep Heat Mining* project in Basel was supposed to be the first commercially operating petro-thermal power plant in the world. The project was supposed to develop a plant that would deliver 6 MW of electricity and 17 MW for heat uses. The project was developed by Geothermal Explorers Ltd. and Geopower Basel AG, a sister company of the local public utility IWB. The parliament of the canton of Basel-City approved funding for the project in 2004. Being a pilot project, it also received funding from the SFOE.

The project developers communicated about the project through media releases, exhibitions and guided site tours. They emphasised its pioneering character and highlighted its potential benefits. Although the project received some national media coverage, there were no active information and public engagement campaigns aimed at the local population.

In December 2006, stimulation operation for the reservoir provoked a 3.6 magnitude earthquake, causing strong reactions within the population. Minor damage to buildings was reported. The event triggered controversies about the absence of communication on the project, the quality of the project management and the absence of a prior risk assessment study. The canton of Basel-City filed a lawsuit against the operator for the earthquake. The court did not hold the operator liable for the events. In 2009, the project was definitively terminated.

2.1.2 St. Gallen: Strong Local Support but in the End Still No Success

In 2009, the DGE project of the city of St. Gallen started with a feasibility study. The study was followed by large-scale seismic monitoring in 2010, and in August 2010, the St. Gallen City Parliament approved the project. At the end of November 2010, the population of St. Gallen approved the project budget of CHF 159 million (138 million Euros) in a public vote with 82.9% in favour of the project. Parallel to the planning of the geothermal energy project in St. Gallen, the city also launched a preliminary study on the perceptions, hopes, fears and knowledge of the people in St. Gallen on the subject of geothermal energy (Holenstein 2009). The study was based on 31 semi-structured in-depth interviews with key stakeholders and members of the public. One of its main findings was that open, honest and transparent communication of the risks is essential for the success of such a project. In addition, the study pointed out that no fundamental opposition was to be expected and that the overall perception was dominantly positive, though some concerns related to uncertainties about the exploration risk were raised. These findings were decisive for the future orientation of the communication carried out by the St. Gallen city's project management team.

The installation of seismic monitoring stations by the Swiss Seismological Service (SED) and the preparation of the drilling site took place in 2012, with the first deep-well drilling and subsequent production test being carried out in 2013. Unexpectedly, one drilling encountered gas that had to be blocked by injecting water. Following this event, the first earthquake, with a magnitude of 3.5, was registered in July 2013. This was a setback for the project because it had been emphasised from the outset that the seismic risk of hydro-thermal systems is significantly lower than that of petro-thermal systems and that earthquakes comparable to those caused in Basel by the deliberate stimulation of the host rock were not possible. However, still benefitting from the public's large support, the drilling resumed to the planned depth. Due to insufficient water production rates and an increased earthquake risk, the project was discontinued in 2014 (see Muratore et al. 2016 for a detailed account). It is worth noting that the reaction by the population to seismic events in St. Gallen and Basel, though physically very similar, was quite different: the intensity in St. Gallen was perceived less strongly than that in Basel (Edwards et al. 2015).

2.1.3 Haute-Sorne: A Project that Faces Local Opposition

The only petro-thermal project in an advanced phase of planning in Switzerland as of 2018 is in the rural town of Haute-Sorne in the Canton of Jura in western Switzerland. The project is carried out by Geo-Energie Suisse. The project plans to build a 5 MW geothermal power plant by capturing heat from an artificial reservoir created in a crystalline bedrock at a depth of 5000 m (GES 2017). The project was presented to local authorities and the population in 2013. The cantonal government of Jura, who supports the project, delivered the building authorisation in 2015.

To ensure local support, Geo-Energy Suisse informed the population early on after the company had selected the site of Haute-Sorne. An accompanying group was set up, which was composed of local politicians and representatives of NGOs and businesses. This group acted as a relay between the local population and Geo-Energie Suisse. It informed the developers about local concerns and provided the population with updates about the project's advancement through a newsletter and public events. Geo-Energie Suisse also organised various information events and excursions, inviting local people to visit geothermal plants in neighbouring France and Germany.

Although cantonal and municipal authorities support the project, significant opposition from the local population has delayed its implementation. A group of inhabitants of Haute-Sorne is contesting the planning process and has taken the matter up to the federal court. They argue that the project will bring nuisance such as noise and impact the landscape, but they state it will also create risk for groundwater resources and seismicity. As of June 2018, the federal court has not ruled on this case. In parallel, a group of citizens in the Canton of Jura who are opposed to the project have collected enough signatures to call for a vote on a complete ban of DGE in the canton. The date of the vote has not been settled yet, and as of June 2018, the completion of the project remains uncertain.

2.1.4 Geothermal Energy in Geneva: Step-by-Step to Greater Depths

In 2014, the canton of Geneva and the public utilities (SIG) have jointly launched the geothermal programme GEothermie 2020, which consists of prospection and exploration measures to assess the resources available in the local subsoil. The strategy is to progress gradually and to feed on previous experiences to limit risks. GEothermie 2020 does not define itself as a project; rather, it aims to be a programme that includes different projects that are each optimally adopted to the local territory. Quickly, the programme managers realised that the responsibilities of such a programme go much further than '*simple*' exploration and prospection campaigns; it necessarily needs to include aspects such as an accompaniment of interested stakeholders, collaboration with universities, transnational concertation due to the close border with France and finally the development of a new industry branch (because geothermal is a new activity for public utilities).

The inclusion of the local population in the process is key, and regular updates are provided on the programme's website, as well as through the organisation of public events at each milestone of the programme (see GEothermie 2010 2018). ETH Zurich is studying the participation processes in the frame of a transdisciplinary research project to analyse how these are taken into account in the strategic decision-making process and to draw conclusions for other similar programmes in Switzerland.

2.2 Social Science Research on Acceptance and Public Engagement for DGE in Switzerland

As said above, part of the Swiss ES 2050 is a major investment in research and development activities, along with some social scientific research. Here, we briefly review the main studies and introduce some of their core results in the next section.

Most of the existing works on the social aspects of DGE in Switzerland are found in an edited volume published by the Swiss Foundation for Technology Assessment (TA-SWISS); this publication evaluates the risks and potential benefits of DGE (Hirschberg et al. 2015). The volume includes work on the legal aspects, highlighting the lack of provision for the exploitation of the subsoil in the federal constitution. Therefore, the jurisdiction for DGE remains with the cantons. This explains the very differentiated practices from one canton to the other. The TA-SWISS study also evaluates public acceptance and public opinion on DGE. These were evaluated through various methods, including a literature review, a media analysis, a focus group study and an analysis of social media.

As mentioned above, a large share of funding for research on DGE is concentrated in the SCCER-SoE group. Most social science research on DGE within the SCCER-SoE group has been carried out within the Transdisciplinarity Lab of the Department of Environmental Systems Science (D-USYS, TdLab) at ETH Zurich. Here, the research includes media analyses (Stauffacher et al. 2015), surveys (Knoblauch et al. 2017), case studies (Muratore et al. 2016) and conceptual work (Trutnevyte and Wiemer 2017; Trutnevyte and Ejderyan 2017).

These studies generally stress the importance of involving the stakeholders and the public early on and continuously during process through adapted procedures, which can range from information campaigns, in cases where strong support to the project is expressed, to more active engagement forms, such as workshops or focus groups when direct exchange is needed to address local concerns.

3 Results and Discussion

In this section, we present and discuss the results from the selected studies—which were carried out by the authors of this chapter—introduced in the previous section. We include results from two media analyses conducted on German and French language newspapers. Furthermore, we introduce two case studies: the hydro-thermal project of St. Gallen and the petro-thermal project in Haute-Sorne. These studies offer insights into the role of local actors carrying out the project and how their personality and status influence acceptance.

3.1 Media Analyses

The media analyses focus on the way DGE is framed in national and regional print media. In a media analysis, framing refers to the way an information is presented by media, including the storyline, aspects that are emphasised or vocabulary used. The way media frames information influences the way this information is processed by the audience (Scheufele 2014). Analysing the way DGE is framed in the media can help to anticipate public debates on DGE.

3.1.1 German Language Newspapers[1]

Articles from the two core daily newspapers *Neue Zürcher Zeitung* (NZZ) and *Tages-Anzeiger* (TA), which have broad coverage in the German-speaking part of

[1]A more extended version of this study is available as a published research paper, see Stauffacher et al. (2015).

Switzerland, were analysed. The time frame for the analysis was from 1997 to 2013.

The first analysis focused on the frequency of articles mentioning geothermal energy (see Fig. 3). The results show that the geothermal debate in the Swiss newspapers is largely driven by events with news value. More precisely, seismic events related to the new projects in Basel and St. Gallen; the public vote on the Triemli geothermal project in Zurich; and global events, such as the Fukushima accident, play key roles as the catalysts of journalists' attention. Regarding DGE in Switzerland, the seismic events in Basel and St. Gallen triggered a significant increase in media attention; particularly, the adverse reactions in Basel led to an increase of negative arguments. Thus, geothermal energy is broadly discussed in the media, which in principle informs societal discourse.

Arguments that share a specific perspective on the issue of DGE were aggregated into the following frames: energy transition, risks, technology and costs. In each frame, we also differentiated between an argument opposing DGE and one supporting it. The framing strategies of the different actor groups can be characterised as follows: industry actors mainly frame DGE as an opportunity for the upcoming energy transition in Switzerland. Scientists clearly favour the risks frame in the debate. However, the media has scarcely reported about existing risk mitigation mechanisms to inform readers about increased seismicity, as well as the proposals to stop drilling and/or the ingestion of water. For both aspects (risk mitigation and energy transition), scientists could play a valuable role by providing relevant information for future energy policy decisions. In contrast, politicians in general scarcely support a specific frame; instead, they use different frames while talking about DGE, probably in accordance with their respective political standpoints. Public authorities do not emphasise a particular frame either; their

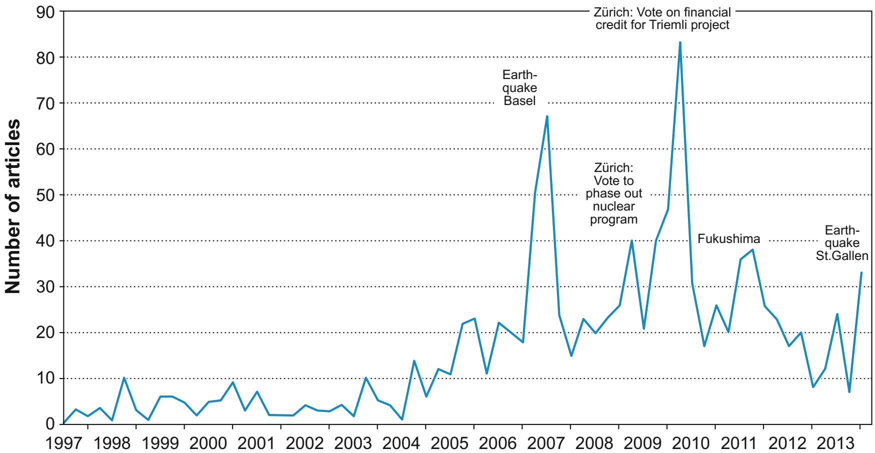


Fig. 3 Frequency of newspaper articles containing the keywords 'Geothermie' (geothermal) or 'Erdwärme' (terrestrial heat) in TA and NZZ over time (N = 1091 articles). *Data source* adapted from Stauffacher et al. (2015)

arguments are more or less proportional to those of the politicians. Policy makers and public authorities strongly argue for geothermal energy as an opportunity for energy transition, but they also refer to the uncertainties and risks around geothermal projects.

3.1.2 French Language Newspapers[2]

The media analysis for the French-speaking part of Switzerland was conducted on a filtered sample of 131 articles from the following newspapers: *Le Temps*, *La Tribune de Genève* (TDG) and *Le Quotidien jurassien* (LQJ). An inductive qualitative content analysis revealed that six main frames are used in the French-speaking press (technology, risks, governance, energy transition, knowledge and costs). These frames are consistent with the four frames identified in the study on the Swiss-German media. This clearly indicates that there is a public discourse on DGE at the national level, and as such, it might influence policy making at the federal level. However, the media analysis also revealed the prevalence of a governance frame that is specific to the French-speaking press.[3] Under this frame, DGE is discussed as an issue in need of governance. The main topics that are addressed under the governance frame are the following: the most suitable legal-institutional framework needed to govern DGE at different administrative levels (often referred to as lacking), the importance of public engagement (often discussed in terms of sufficient/insufficient information and participation) and whether DGE is legitimated by popular support (often based on statements asserting or questioning the level of support). The governance frame is most prevalent in LQJ, which is the local newspaper of the canton of Jura, and this is explained by regular reporting on the Geo-Energie Suisse project in Haute-Sorne, which is a local issue for this newspaper.

A closer look at the risk frame in the French-speaking press reveals that the most discussed type of risk is by far seismic risk (208 statements in 67 articles). It is followed by exploration risk (33 statements in 25 articles) and environmental risk, which groups the risk of pollution of groundwater or soil and the potential impact on health/well-being (29 statements in 22 articles).

An important finding is that the media is framing seismic risk as a polarised issue (Fig. 4). A first category of statements underlines seismic risk, mentioning that it can cause damage, impact property value, be unpredictable or cause fear. Therefore, seismic activity can affect the acceptance of a project. This is further supported by mentions that induced earthquakes related to DGE can damage buildings. In the media, such statements are predominantly attributed to the population. In

[2] A longer version of this study is in preparation for submission.

[3] Statements classified in the 'knowledge' frame in the study on French-speaking news articles correspond to a subcategory of statements classified under the 'technology' frame in the analysis of German-speaking media.

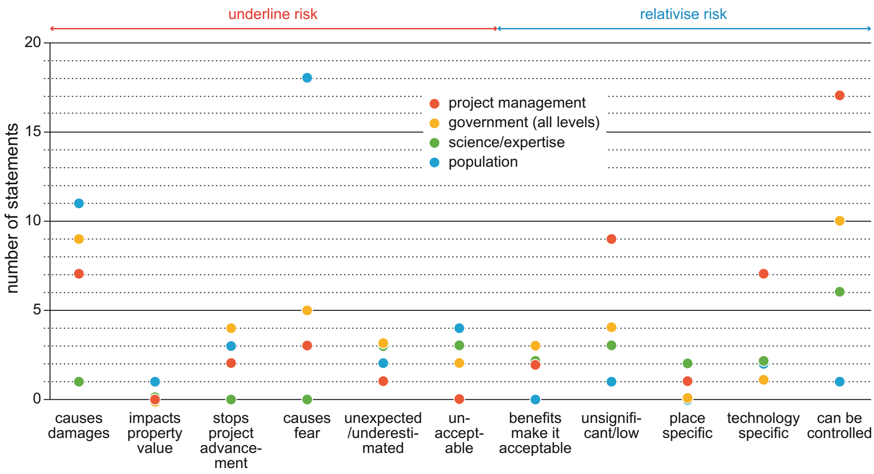


Fig. 4 Statements on seismic risk within the risk frame of DGE in the French-speaking newspapers of Switzerland

opposition to these views, there are statements that are relativizing seismic risk; they do so either by presenting seismic risk as something negligible (low magnitude, not causing harm, etc.) or asserting some control over seismic risk (through traffic light systems, forecasting, etc.). A further way is to present risk as something that must be accepted if put into relationship with possible benefits. Finally, there are occurrences suggesting that risk is relative to a specific place. The statements that relativize risk are predominantly associated with project managers, political authorities, scientists and experts. An issue here is that such a polarisation crystallises images of an ‘irrational public’ against images of promoters who only seek to address public concerns about risk by increased technological control. This indicates an issue that must be addressed in public engagement procedures to avoid misunderstandings that could lead to conflict.

3.2 *Case Studies*

3.2.1 St. Gallen[4]

Conducted in 2015, the St. Gallen case study is based on an analysis of all written documents created by the project developers for communication to the public. It puts a special emphasis on how the risks and benefits were communicated. In

[4]A longer version of this study is available in German, see Muratore et al. (2016).

addition, to assess public perception about the project communication, focus group discussions were carried out.

The document analysis shows that the communication of risks and benefits in the beginning was quite balanced. Seismic risk was an important topic from the beginning on; however, it became the most emphasised topic after the earthquake happened. When the project stopped, the communication of risks and benefits was balanced again. The exploration risk was a frequent topic, and especially, written communication focused on the details linked to these risks.

The benefits mentioned most often in all focus groups were the potential energy independence that the project would have brought on one side and deep geothermal as a renewable energy source on the other. Participants of the focus groups discussed whether deep geothermal would be a way to phase out nuclear power. Furthermore, they debated whether the gas that had caused the earthquake should be considered an opportunity and used or whether this would contradict the aim of the project to increase the share of renewables. The most significant values emerging out of these discussions were the pioneer image and pride. People appeared to attach immense importance to being one of the first places to explore this technology and pave the way for projects elsewhere in Switzerland.

Regarding risks, uncertainty regarding the underground came up in all focus groups. However, this was just seen as a reality to be considered in these types of projects. Participants related this uncertainty to the financial risk inherent to such projects. Seismic risk was mentioned but not perceived as an important threat. Participants in the focus groups agreed that the project was terminated too early. According to them, this bore the risk that the St. Gallen example might lead to a pessimistic view of renewable technologies overall. In general, the people felt well informed about the risks. Some had the feeling that probabilities about the success rate were not communicated accurately, but they attributed this perception to the broad media attention and the generally positive support for the project.

Overall, the perception of the communication was positive. Participants considered the communication as being open, honest, transparent and understandable. All focus groups agreed that the city councillor in charge of relaying messages had a positive impact on the communication. He was considered to be a key to the success because he showed personal affiliation and dedication to the project.

Important lessons regarding the communication of the risks and benefits that can be learned from the St. Gallen project are first the importance of transparent communication and readily accessible information to the citizens from the very beginning. Second, when the risks of the project were communicated, there was always an emphasis on the measures in place to deal with them. Although a charismatic champion carrying the project is not always available, the key role the city councillor seemed to have illustrated the importance of this role and of, third, getting strong local stakeholders on board. Likewise, the public felt there was clear engagement with the project developers.

3.2.2 Haute-Sorne

The case study on the project in Haute-Sorne is based on a content analysis of project-related written sources, interviews with the operator, the cantonal authorities and local stakeholders, as well as observations from an information event for the local population. Research on this case is ongoing.

The reconstruction of the planning process highlighted that besides geological conditions, institutional willingness to host a geothermal project was a key factor for the siting of the Haute-Sorne project.

However, local opposition to the project developed. Inhabitants from Haute-Sorne opposed the project out of fear of induced seismicity and environmental consequences. In reaction, the operator provided a guarantee that would cover potential damages caused by the project. He furthermore agreed to organise further information events. Most of these opponents retracted, except for six citizens who took the project to the federal court. Adding to this, a committee of concerned citizens from the canton of Jura launched an initiative that called for a vote to forbid DGE within the canton.

The results indicate a shared impression that the population of Haute-Sorne was not adequately informed. Several interviewees expressed this view, even though the promoters set up several information events and sent newsletters informing citizens about the activities of the accompanying group and the advancement of the project. A possible explanation for this could be the timing of the information. Information was sent during an early phase of the project before the project had attracted public scrutiny and was covered in the media. Because deep geothermal energy is still a relatively unknown form of energy in Switzerland, it is possible that a significant share of the recipients ignored this early information.

Another shared impression among the interviewees is that the project lacked political legitimacy. Although it received support from parties across the political spectrum and was carried by a cantonal councillor, this view was widely shared among the interviewees, as well as participants in the observed information event. Two elements might explain this. First, the cantonal authorisation procedure was regarded by some actors as bypassing the local political debate. Residents from Haute-Sorne could oppose the project. But this was an administrative procedure based on individual oppositions with decisions taken at the cantonal level. This impression of the absence of room for political debate was shared by supporters of the project. Some supporters even stressed that although they hoped that the initiative would not pass the vote, they nevertheless considered it to be a necessary step for ensuring the project's legitimacy. A second element that appears from the document analysis is that even if the government backed the project, it predominantly framed the project as a local economic development project, stressing potential benefits in terms of employment and tax revenues. As such, the project was not anchored in a visionary narrative like in the case of St. Gallen.

4 Conclusions: Toward a Dynamic Understanding of Social Context

DGE in Switzerland is part of the new national energy strategy and supported strongly by national agencies and numerous research projects. However, its development is slow, and two well-known projects in Basel and St. Gallen had to be stopped because of seismicity and low water availability. A third project of a comparable size is planned in Haute-Sorne, where it is being blocked by local opposition. Yet prospects are still promising because with the national referendum in 2017, the SFOE can financially support new pilot projects, and research and development is still being encouraged at a large scale. In addition, the shift from the production of electricity to also include the production of heat certainly helps to illustrate the benefits of DGE for decarbonising the energy supply.

One of the core lessons learned from the previous projects is the importance of close interaction with different stakeholders and the broader public from the very beginning of a project. This means that public participation becomes more and more important. In addition, much more attention is paid to risk mitigation and an appropriate risk governance system. Still, intense social scientific research is necessary to provide further guidance on the concrete implementation of future projects.

Social science research on DGE in Switzerland highlights the importance of the social context when planning a project. The varied institutional settings, the multiplicity of actors involved because of the federal structure of the country and its multilingualism highlight how different social characteristics influence the way local populations respond to DGE projects. Therefore, Switzerland offers a good example of how 'context matters' for the siting of contested energy infrastructure (Rosa and Short 2004).

Guidelines for planning DGE projects have already underlined the importance of taking into account the social context (Majer et al. 2013) as part of the *siting* process for geothermal plants. Such an approach considers the context before a decision has been made to implement a DGE project and supposes that the context is static. However, research in social science and the humanities has shown that a social context is dynamic and ongoingly updated by the actors involved in it as they receive new information (Van Dijk 2008). Stakeholders and members of the broader public *interpret* each of the messages and actions of the developers of geothermal projects. They adapt their position and attitudes toward geothermal energy based on these interpretations, which are strongly dependent on their socio-economic, cultural, linguistic and geographic (rural/urban) backgrounds.

The case studies of St. Gallen and Haute-Sorne show the importance of conceiving the context in such a dynamic and responsive way. Although positive or negative pre-conditions determining the siting might exist in specific locations, the way project developers frame a project, the legitimacy of the local actors championing it and the forms in which promoters engage with the local public can considerably influence these conditions. Even when promoters deploy efforts to communicate and engage with the public, these efforts might be interpreted differently. In Haute-Sorne, some residents claim that the information meetings held by the promoters of the project in presence of governmental officials during the authorisation phase did not provide legitimacy. Instead, they would have preferred having the same discussions at a municipal council session where they would have a greater possibility of influencing the decision.

Such a dynamic understanding of the social context implies that it is necessary to also take a dynamic view to communication and public engagement (Krütli et al. 2010): social aspects must be taken into account throughout the project, and communication and engagement must be continuously adapted. Risk governance frameworks for DGE projects have already integrated an approach that leaves room for deliberative phases all throughout the planning process (Trutnevyte and Wiemer 2017).

This deliberative approach can open up discussions during the planning of DGE projects to aspects that might seem beyond the responsibility of project developers. Thus, project developers and policy makers need to integrate geothermal energy as 'one part of the solution' in larger discussions about energy transition. In Switzerland, the GEothermie 2020 programme that was launched in Geneva adopts such an approach. Further social science research on it will offer insights into how to integrate geothermal energy into local energy transition strategies. The transdisciplinary project of the ETH TdLab with the authorities in the Canton of Geneva offers a role model for other projects.

Acknowledgements The authors thank Evelina Trutnevyte for comments on an earlier version of this chapter, as well as Corinne Moser, Nora Muggli and the students of the transdisciplinary case study 2015 who participated in parts of the research presented in this chapter.

Parts of this text have been adapted from annual reports for the Swiss Federal Office of Energy, which was written within SCCER and CCES/CCEM Geotherm-2 and from the TA Swiss Study.

Funding: Geotherm2 project, co-financed by the Competence Centers Environment and Sustainability (CCES) and Energy and Mobility (CCEM) of the ETH Domain; the Swiss Foundation for Technology Assessment (TA-SWISS); the Swiss Competence Center for Energy Research-Supply of Electricity (SCCER-SoE); the Energy Turnaround National Research Program (NRP70) of the Swiss National Science Foundation; Canton of Geneva and Services industriels de Genève (SIG); European Union's Horizon 2020 research and innovation programme DESTRESS (grant agreement No 691728).

References

Berntsen PB, Trutnevyte E (2017) Ensuring diversity of national energy scenarios: bottom-up energy system model with modeling to generate alternatives. Energy 126:886–898. https://doi.org/10.1016/j.energy.2017.03.043

BFE Bundesamt für Energie (2016a) Schweizerische Gesamtenergiestatistik 2015. http://www.bfe.admin.ch/themen/00526/00541/00542/00631/index.html?lang=de&dossier_id=00763. Accessed 26 Feb 2018

BFE Bundesamt für Energie (2016b) Schweizerische Elektrizitätsstatistik 2015. http://www.bfe.admin.ch/themen/00526/00541/00542/00630/index.html?lang=de&dossier_id=00765. Accessed 26 Feb 2018

Braunreiter L, Blumer YB (2018) Of sailors and divers: how researchers use energy scenarios. Energy Res Soc Sci 40:118–126. https://doi.org/10.1016/j.erss.2017.12.003

Densing M, Panos E, Hirschberg S (2016) Meta-analysis of energy scenario studies: example of electricity scenarios for Switzerland. Energy 109:998–1015. https://doi.org/10.1016/j.energy.2016.05.020

Edwards B, Kraft T, Cauzzi C et al. (2015) Seismic monitoring and analysis of deep geothermal projects in St Gallen and Basel, Switzerland. Geophys J Int 201:1022–1039. https://doi.org/10.1093/gji/ggv059

Géo-Énergie Suisse (GES) (2017) Projet pilote de géothermie profonde dans la commune de Haute-Sorne (JU). http://www.geo-energie.ch/fr/projekte/hautesorne.php. Accessed 26 Feb 2018

Geothermie-Schweiz (2018) Geothermie-Schweiz Homepage. http://geothermie-schweiz.ch/. Accessed 3 Feb 2018

GEothermie 2020 (2018) GEothermie 2020. Développer et accompagner la géothermie à Genève. http://www.geothermie2020.ch/. Accessed 3 Feb 2018

Hirschberg S, Wiemer S, Burgherr P (eds) (2015) Energy from the earth deep geothermal as a resource for the future? vdf Hochschulverlag, Zurich

Holenstein M (2009) Erdwärmeprojekt St. Gallen: Wahrnehmung und Erwartungen der Bevölkerung und von Interessenvertretern. St. Gallen

Innosuisse (2018) Energy for the future. https://www.innosuisse.ch/inno/en/home/themenorientierte-programme/foerderprogramm-energie.html. Accessed 31 Jan 2018

Knoblauch TAK, Stauffacher M, Trutnevyte E (2017) Communicating low-probability high-consequence risk, uncertainty and expert confidence: induced seismicity of deep geothermal energy and shale gas. Risk Anal. https://doi.org/10.1111/risa.12872

Krütli P, Stauffacher M, Flüeler T et al (2010) Functional-dynamic public participation in technological decision-making: site selection processes of nuclear waste repositories. J Risk Res 13:861–875. https://doi.org/10.1080/13669871003703252

Kübler D (1999) Beyond nimbyism: urban conflict resolution in swiss drug policies. In: Khan U (ed) Participation beyond the ballot box: European case studies in state-citizen political dialogue. UCL Press, London, pp 43–64

Linder W, Lanfranchi P (1992) Mitwirkungsverfahren und -modelle: Vorschläge für eine Mitwirkungspolitik des Bundes nach Art. 4 RPG. Bundesamt für Raumplanung, Bern

Linder W, Vatter A (2001) Institutions and outcomes of Swiss federalism: the role of the cantons in Swiss politics. West Eur Polit 24:95–122. https://doi.org/10.1080/01402380108425435

Majer E, Nelson J, Robertson-Tait A et al. (2013) Best practices for addressing induced seismicity associated with enhanced geothermal systems (EGS). Report Number: LBNL-6532E. Lawrence Berkeley National Laboratory, Berkeley CA. https://pubarchive.lbl.gov/islandora/object/ir%3A159101. Accessed 27 Jan 2018

Menberg K, Pfister S, Blum P et al. (2016) A matter of meters: state of the art in the life cycle assessment of enhanced geothermal systems. Energy Environ Sci 9:2720–2743. https://doi.org/10.1039/C6EE01043A

Muratore S, Müller S, Kulla H et al. (2016) Tiefengeothermie: das Projekt St. Gallen. USYS TdLab Transdisziplinäre Fallstudie 2015, Zürich

Pfister C (1995) Das 1950er Syndrom: Der Weg in die Konsumgesellschaft. Paul Haupt, Bern

Prognos AG (2012) Die Energieperspektiven für die Schweiz bis 2050. Energienachfrage und Elektrizitätsangebot in der Schweiz 2000–2050

Rosa EA, Short JF Jr (2004) The importance of context in siting controversies: the case of high-level nuclear waste disposal in the US. In: Boholm Å, Löfstedt R (eds) Facility siting: risk, power and identity in land use planning. Earthscan Publications Ltd, London, pp 1–20

Rybach L (2013) New developments in geothermal heat pumps—with a view to the Swiss success story. J Geotherm Res Soc Japan 35:35–40. https://doi.org/10.11367/grsj.35.35

SCCER-SoE (2017) SCCER-SoE portrait. http://www.sccer-soe.ch/en/aboutus/portrait/. Accessed 3 Feb 2018

Scheufele DA (2014) Science communication as political communication. Proc Natl Acad Sci 111:13585–13592. https://doi.org/10.1073/pnas.1317516111

Stadelmann-Steffen I, Dermont C (2016) Energie-Enquete. Erste Einblicke. In: Inst. für Polit. Univ. Bern. https://ipwenergy.shinyapps.io/preferences/. Accessed 22 Jan 2018

Stauffacher M, Muggli N, Scolobig A et al. (2015) Framing deep geothermal energy in mass media: the case of Switzerland. Technol Forecast Soc Change 98:60–70. https://doi.org/10.1016/j.techfore.2015.05.018

Trutnevyte E, Ejderyan O (2017) Managing geoenergy-induced seismicity with society. J Risk Res 1–8. https://doi.org/10.1080/13669877.2017.1304979

Trutnevyte E, Wiemer S (2017) Tailor-made risk governance for induced seismicity of geothermal energy projects: an application to Switzerland. Geothermics 65:295–312. https://doi.org/10.1016/j.geothermics.2016.10.006

Van Dijk TA (2008) Discourse and context: a sociocognitive approach. Cambridge University Press, Cambridge

Olivier Ejderyan a Ph.D. in Geography from the University of Zurich, is a researcher at the Transdisciplinarity Lab of the Department of Environmental Systems Science at ETH Zurich. He has worked at the University of Chiba (Japan), the National School for Water and Environmental Engineering of Strasbourg (France) and the University of Fribourg (Switzerland). His research interests include participatory decision making, socio-technical controversies and the analysis of techno-scientific discourses on sustainability. His current work focuses on the politics of deep geothermal energy.

Franziska Ruef a M.Sc. in Human Geography, is a doctoral student at the Transdisciplinarity Lab of the Department of Environmental Systems Science at ETH Zurich. Her Ph.D. is part of the project Territorialising Geothermal Energy in Geneva, a transdisciplinary collaboration with the Genevan geothermal energy programme GEothermie 2020. Its goal is to analyse the processes that underpin the inscription of geothermal energy in the Genevan territory to develop tools for informed, honest and democratic public engagement.

Michael Stauffacher a Ph.D. in sociology and professor at ETH Zurich, is the co-director of the Transdisciplinarity Lab of the Department of Environmental Systems Science. He has taught and researched for more than 20 years at ETH Zurich, was a guest researcher at the Potsdam Institute for Climate Impact Research (PIK) and at Lancaster University (UK) and had teaching appointments at Stellenbosch University (SA) and Leuphana University Luneburg. He serves as President of the 'Swiss Academic Society for Environmental Research' and is a member of the Board of Directors of the 'Swiss Academy of Humanities and Social Sciences—SAGW'.

Turkey—Pitching Forward to Energy Independency

Melek Akca Prill

Abstract Turkey is a growing country in economical and demographical sense with an increasing energy demand over the years. In order to meet its rising energy hunger, the country is highly dependent on fossil energy imports, which increases the existing greenhouse gas emissions to a higher level. Although having a rich amount of renewable energy sources, current energy policies of the country are jeopardizing the development and gradual utilization of renewable energies. Among its huge hydro- and wind power potential, Turkey is one of the richest countries across the globe in terms of geothermal energy. Despite government efforts towards the use of geothermal sources in a broader scale, still only a small amount of it is used for the electricity generation and other direct-use applications. This chapter aims to address that, the government supports and incentives are not solely enough to promote exploitation of geothermal energy countrywide; also the geothermal technology and areas of application should gain the social acceptance. Therefore, especially the local people, who reside nearby the geothermal sources, should be informed about the equal distribution of positive impacts, economical benefits and potential adverse effects of the geothermal power plants.

Keywords Turkey · Energy dependency · Renewable sources
Public awareness · Public engagement

1 Introduction

Turkey, with its geographical position between the fossil energy-rich (producer) regions (Middle-East and Caspian Sea) and fossil energy-scarce (consumer) countries (Europe), plays a pivotal and emerging role as an energy hub. The country

M. A. Prill (✉)
Fraunhofer Institute for Systems and Innovation Research ISI,
Breslauer Strasse 48, 76139 Karlsruhe, Germany
e-mail: melekakca@yahoo.com

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes
in Energy 67, https://doi.org/10.1007/978-3-319-78286-7_16

itself is deficient in domestic conventional energy sources (except charcoal), but hosts many existing and planned international crude oil and gas pipeline projects, which the country is highly dependent on in financial and energy terms. The two main challenges in Turkey's energy situation are on the one hand, that the country is strongly dependent on hydrocarbon imports (especially natural gas). The rising energy imports put a big burden on country's volatile economy. On the other hand, its energy demand has been rapidly increasing since the last decades, due to economic development by industrialization and urbanisation.

Based on the January 2017 data of the Turkish Statistical Institute, the population of Turkey reached around 79 million people at the end of 2016, with an annual population growth rate of 13.5 in thousands (TUIK 2017). The young population at the age group of 15–24 was around 13 million, constituting the 16.3% of total population (TUIK 2017). Turkey is still "the youngest nation in Europe" with 8.3% of the population 65 years old and over, according to the data of the Anatolian Agency (AA 2017). It is projected that the population of Turkey will be over 80 million in 2023. The population will increase slowly to the year 2050 and it will reach to its highest value with more than 90 million people in this year. After 2050, the population will start to decline and expected to be under 90 million in 2075 (TUIK 2013).

With its 769,604 km^2 surface area, Turkey is one of the largest countries in Europe. Eastern Thrace in the Marmara region, geographically part of Southeastern Europe constitutes 3% territory of the country, whereas 97% lies in the Anatolian (Asian) region. These two continents are divided by Bosphorus (*Boğaziçi*) and Dardanelles (*Çanakkale*) Straits. Both straits have a strategic importance for Turkey as well as for supplier and consumer countries, as the merchant vessels and oil tankers pass through these passages. Nevertheless, due to the heavy traffic on these chokepoints, the inhabitants are under serious environmental risks. A potential maritime catastrophe would ruin the entire environmental area and cause fatal injuries to thousands of people. In order to diminish maritime traffic on the Bosphorus and Dardanelles Straits and to prevent maritime accidents, the transportation of crude oil, coming mostly from the Caspian Basin, should be replaced by the oil pipelines passing through the country (for example Baku-Tbilisi-Ceyhan Crude Oil Pipeline, operating since 2006).

According to latest numbers of World Atlas, Turkey is the world's 25th and Europe's 7th largest economy, with a share of 1.02% global GDP (World Atlas 2018). The major industries in Turkey are based on agricultural products such as pomegranates, hazelnuts, quinces, watermelons, tea, tomatoes, eggplants, tobacco, apples, wheat and rye. As being the 28th largest world exporter, cars, vehicle parts, raw iron bars, delivery trucks, jewelry, apparel, foodstuffs and textiles constitute country's main export products (World Atlas 2018). Furthermore, construction and tourism sectors create the main income resources for the government.

As an upper-middle-income country, the country's fragile economy is struggling with political volatilities. Especially due to the insufficient government incentives in the field of renewable energy policy, Turkey's dependence on hydrocarbon has increased rapidly, which consequently put even more burden on economy and increases its current account deficit. Although having scarce fossil energy sources, the country has an abundant potential of all kind of renewable energies, including hydro- and wind power, solar, geothermal and biomass, to meet its energy hunger. The increasing use of renewable energy sources in the energy mix will decrease Turkey's energy dependency on hydrocarbon imports and render possible to accomplish sustainable development goals.

By the end of 2016, Turkey's electricity production ranked as 273.4 billion kWh. 184,889 GWh of total energy production is obtained from coal-fired thermal power plants, 67,268 GWh from hydroelectric power plants and 21,230 GWh from other renewable energy sources. Since 2009 there is a significant increase in electricity production based on renewables. Considering the distribution of resources in domestic electricity production, coal constitutes the biggest share with 67.8%, followed by hydropower with 24.6% and other renewables (geothermal, wind, solar) with 7.8% (Table 1).

The electricity consumption ranked as 278.3 billion kWh. In the last decade, Turkey's energy consumption has increased by 41.1%, while the energy production solely achieved a 27.6% increase. Thus, the growth in energy generation is still significantly behind the energy consumption. In order to meet its energy deficit, the country imports approximately 70% of its total primary energy needs from energy supply countries, particularly natural gas from Russia, which plays the pivotal role for the energy generation. It is estimated that the total electricity consumption of Turkey will be 530,000 GWh by the year of 2023. To meet this high level of consumption, the country is planning to establish an electric power generation capacity of 100,000 MW. According to this plan, 30% production will come from natural gas, 35% from coal, 30% from renewable sources and ultimately 5% from nuclear energy.

Since Turkey has no nuclear power plant, renewable energies comprise the third pillar in power generation with mainly hydroelectric power plants. By the end of 2016, total installed electricity capacity had increased to 78.5 GW from 31.8 GW in 2002. Hydropower contributed 34% of this installed capacity, followed by natural gas with 28.3%, coal with 22.1%, combustible fuels (e.g. waste) with 6.2%, wind power 7.3%, solar 1.1% and geothermal 1%.

2 Geothermal Energy in Turkey

2.1 Turkey's Geothermal Energy Potential

Turkey has a vast amount of renewable energy sources. Besides having a long shoreline and extensive mountains with rich hydropower and wind power potential, the country ranks as one of the richest countries in geothermal energy across the globe. Based on the 2016 data of the *World Energy Council*, Turkey ranks as the 3rd country, after China and the USA, in terms of geothermal energy generation with 1.28 Mtoe per annum (World Energy Council 2016a). In the same year,

Table 1 The distribution of primary energy sources for the electricity production in Turkey

Primary energy source		2014		2015		2016	
		Electricity production (GWh)	Share in total production (%)	Electricity production (GWh)	Share in total production (%)	Electricity production (GWh)	Share in total production (%)
Coal	Hard coal, import coal, asphaltite	39,647	15.7	44,830	17.1	53,778	19.7
	Brown coal (lignite)	36,615	14.5	31,336	12	38,460	14.1
Liquid fuels	Fuel-oil	1663	0.7	980	0.4	1103	0.4
	Diesel	482	0.2	1244	0.5	1548	0.6
Natural gas + LNG		120,576	47.9	99,219	37.9	87,820	32.1
Biomass + waste		1433	0.6	1758	0.7	2179	0.8
Hydro		40,645	16.1	67,146	25.6	67,268	24.6
Wind		8520	3.4	11,652	4.5	15,492	5.7
Geothermal		2364	0.8	3424	1.2	4767	1.6
Solar		17.4	0.1	194	0.1	972	0.4
Total		251,962	100	261,783	100	273,387	100

Data Source MENR (2017)

Turkey accounted for half of the new global capacity additions, followed by the United States, Mexico, Kenya, Japan and Germany (World Energy Council 2016b). According to the latest numbers of the Energy Atlas in November 2017, Turkey's installed geothermal power generation capacity has reached over 1 GW and become the 4th country globally with its installed power capacity, followed by New Zealand with 980 MW and Italy with 944 MW (Enerji Atlasi 2017).

Nonetheless, the country uses only about 4% of its geothermal energy potential efficiently and the electricity generation still remain in low levels. Up until now, around 600 geothermal prospects and more than 250 geothermal fields with 170 of which with a temperature range of 40–242 °C were discovered in Turkey; 95% of which are low to medium enthalpy fields and most of them suitable for direct-use applications (Parlaktuna et al. 2013).

Turkey is located on the seismically and tectonically active Mediterranean Earthquake Belt (Parlaktuna et al. 2013). The tectonically active nature of Turkey results from the Alpine-Himalayan Mountain Belt that began developing by the closing/shrinking of the Tethys Ocean in the Late Mesozoic Era (Serpen et al. 2010). High-mountain chains were shaped along the northern and southern belt of Anatolia, while some pre-Cambrian-Paleozoic metamorphic shields (i.e. the Menderes and Central Anatolian Massifs) remained at the Central Anatolian Belt (Serpen et al. 2009). As it can be seen in the Fig. 1, the westward movement of the Anatolian Sub-plate through the northward push of the Afro-Arabian Plate, particularly in Southeastern Anatolia, resulted in extensional crustal stresses in Eastern and Central Anatolia. These forces led to the development of vast volcanic fields between the Miocene and the recent periods (Serpenet al. 2010).

The southern section of the Western Anatolian is closer to the subduction zone and therefore the heat generated by friction is easily transferred to shallower depths.

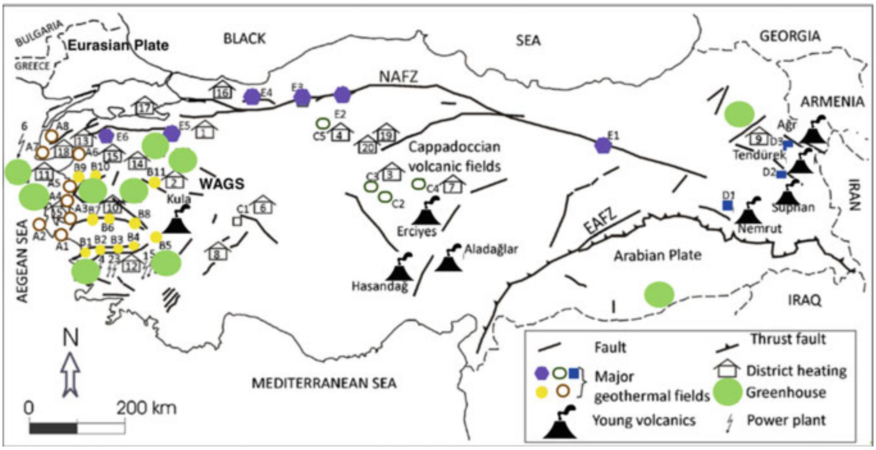


Fig. 1 Map of major geothermal fields and neotectonic plates (NAFZ: North Anatolian Transform Fault, EAFZ: East Anatolian Transform Fault, WAGS: Western Anatolian Graben System). *Modified from* Serpen et al. (2009)

In the northern section, the depth to the subduction slab is larger, so that the heat transfer decreases from the deeper sections to the surface (Simsek 2002). The most important discovered geothermal fields, locate in the Aegean region in Büyük Menderes Graben, are as follows: Manisa-Alasehir-Köseali (287 °C), Manisa-Salihli-Caferbey (249 °C), Denizli-Kizildere (242 °C), Aydin-Germencik-Ömerbeyli (239 °C), Manisa-Alasehir-Kurudere (214 °C), Aydin-Yilmazköy (192 °C), Aydin-Pamukören (188 °C), Manisa-Alasehir-Kavaklidere (188 °C), Manisa-Salihli-Göbekli (182 °C) and Kütahya-Saphane (181 °C).

2.2 Laws and the Regulatory Framework

Since 2005, the geothermal applications and electricity generation from geothermal sources are regulated under the *Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy* (Law No 5346, adopted in 2005) and the *Law on Geothermal Resources and Natural Mineral Waters* (Law No 5686, adopted in 2007) along with the *Geothermal and Mineral Resources Law Implementation Regulation No 26727*.

The Law No 5346 aims to widespread the use of renewable sources in a sustainable, economical and reliable manner, increase the diversification of resources and decrease the amount of CO_2 emissions. Along with the Law on Amendments on the Law No 5346, the new Law No 6094 entered into force in in 2010, in which the electricity generation prices as incentives for the diverse renewable energy sources were determined. As observed in the Table 2, geothermal energy suppliers can sell their electricity at a higher price of 10.5 USD cents, higher than hydro- and wind energy suppliers, but lower than biomass (including landfill gas) and solar power.

The laws and the associated regulation give solutions to the problems concerning legislative matters and obligations of the exploration and production concession rights, as well as the technical responsibility, control, and protection of the

Table 2 Price of electricity in Turkey from renewable energy sources after the provision of the Law in 2010 and numbered 6094

Type of production facility based on renewable energy resources	Prices applicable (USD cent/kWh)
a. Hydroelectric production facility	7.3
b. Wind power based production facility	7.3
c. Geothermal power based production facility	10.5
d. Biomass based production facility (including landfill gas)	13.3
e. Solar power based production facility	13.3

Data Source Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy, Resmi Gazete (Official Gazette), 2005 geothermal areas (Parlaktuna et al. 2013). In pursuit of the Article 4 of the Law No 5686, ownership of geothermal sources belongs to the State rather than private property-owners, where the resources are located. In the case of any planned activity in the geothermal field, Turkish citizens or legal entities are obliged to apply for a license (Kartal 2013). Notwithstanding this, there is still no specific law on geothermal energy that regulates the utilization of geothermal sources of the country in their full potential. Moreover, the existing legislation needs to be developed in compliance with European Community directives.

Despite the strong presence of the State in geothermal and other energy fields, since the amendment of Law No 5686, companies, which are distributing or producing geothermal resources, are provided with some kind of specific incentives. Under Article 26 of the Regulation No 26727, these companies are regarded as an industrial enterprise and can be granted with a geothermal resource distribution or production certificate. These companies are able to apply for some particular incentives, such as reduced electricity tariffs (Kartal 2013).

In Turkey the share of private entities in the power generation has increased from 32% in 2002 to 75% by the end of 2015. As well, predominantly the private companies are operating the geothermal power plants. Since the public sector in Turkey has diminished its share in the power generation sector, the performance of the privatised power plants increased from 45 to 80% between the same time period.

2.3 Geothermal Power Generation in Turkey

Turkish Ministry of Energy and Natural Resources aims in its "Vision 2023" goals to increase the share of renewable energy resources in total energy mix to 30% by the year 2023. In particular, the geothermal power installed capacity is to reach 1000 MW. As a consequence of expanding new research and drilling activities in Turkey, there is a substantial increase both in geothermal applications and in electricity generation from geothermal sources. The country has already achieved 82% of the targeted geothermal installed capacity. Nevertheless, the future prospects show that the growth in Turkey's energy demand will be between 6 and 8% by adding 50,000 MW to the grid by the year 2020. Hence, the electricity generation from geothermal sources will only be able to meet a small amount of Turkey's energy demand, due to its smallest share in renewable sources. In this regard, it would be a much more feasible option to consider geothermal energy rather as a local energy source than a countrywide energy supply.

The electricity generation from geothermal sources needs high temperatures, such as 150 °C and over (Canka Kilic 2016). The most important geothermal fields for the power generation can be observed in Table 3.

There are three significant geothermal fields with the high capacity of power generation: Manisa-Alasehir, Denizli-Kizildere (1, 2, 3) and Aydin-Germencik geothermal fields.

Table 3 Geothermal fields with highest electricity generation in Turkey

Field	City	Installed capacity (MWe)	Operation capacity (MWe)
Kizildere	Denizli-Sarayköy	15	15
		80	80
		6.85	6.85
Ömerbeyli	Aydin-Germencik	47.4	47.4
		162.3	22.5
			22.5
			22.5
Hidirbeyli	Aydin-Germencik	20	20
Bozköy		24	24
		24	24
		24	24
Pamukören	Aydin-Kuyucak	61.72	45.02
Gümüsköy	Aydin-Germencik	13.2	13.2
Alasehir	Manisa-Alasehir	24	24
Salavatli	Aydin-Sultanhisar	8	8
		9.5	9.5
		34	34
Tuzla	Canakkale-Ayvacik	7.5	7.5
Gerali	Denizli-Sarayköy	23	
Total			452.41

Data Source Canka Kilic (2016)

Alasehir field, with 287 °C, has the hottest geothermal water wells in Turkey. The drilling activities in Manisa-Alasehir geothermal well have gained speed especially since 2011.

The Kizildere geothermal field was the first field, discovered by the MTA in 1968, and utilized for the electricity production in 1984 with an installed capacity of 20.4 MW (Parlaktuna et al. 2013). The field is associated with the major fault along the northern boundary of the Büyük Menderes Graben (Karamenderesi 2013). Until now, a total of 20 deep wells varying in depth from 370 to 1241 m have been drilled, while the temperatures range from 170 to 212 °C (Varinca 2011). The most significant characteristic of the field is the high amount of non-condensable gases with a carbon dioxide content of 96–99%, hydrogen sulfide content of 100–200 ppm and ammonia content of 72 ppm (Varinca 2011). The plant, before its privatization, was associated with among other issues, surface water contamination.

Kizildere-I Geothermal Power Plant was run by EÜAS on behalf of the government for 24 years. In 2008, the field was privatized and transferred to Zorlu Enerji Company for 30 years (Kindap et al. 2010). The company acquired the 17.4 MWe capacity of Kizildere-I geothermal power plant, and expanded the plant in 2013 with the 80 MWe capacity of Kizildere-II geothermal power plant. In 2017 the construction of Kizildere-III geothermal power project has accomplished in the same field, which currently generates 99 MWe.

In 1986, a liquid carbon dioxide and dry ice production process with a capacity of 40,000 tons per year was added to the field. The processing capacity increased to 120,000 tons per year in 1999. Besides electricity and dry ice production, the field has been used for greenhouse heating and space heating (Varinca 2011). The Kizildere geothermal fluid is also used for bleaching process in the textile industry as well as in drying and washing of textile products. The area is known for its thermal springs and balneology centers with health and spa facilities, which offer therapeutic mud bath and thermal bath, which particularly attracts tourists to the region.

After its extraction from Kizildere geothermal wells and its utilization, hot water flows into the Büyük Menderes Stream, which engenders deoxygenation and this threatens the aquatic ecosystem and disturbs the ecologic balance. In order to prevent the increase of the concentration of boron in Büyük Menderes Stream and diminish the negative environmental impacts of these water flows, reinjection wells should be built.

Aydin-Germencik geothermal field is the second economically significant geothermal field for generating electricity. The field was discovered by the MTA and is located in the west of Büyük Menderes Graben about 40 km from the Aegean Sea. By now the MTA drilled ten wells for exploration with depths varying between 285 and 2.398 m. The temperatures of the first and second aquifers were between 203–217 and 216–232 °C. The hot water can be used by industry, in electricity generation, district heating, and in touristic as well as balneology centers (Varinca 2011).

In addition to power generation, geothermal energy is used in various sectors as direct-use applications, such as district heating and partially for individual space heating, domestic hot water supply and greenhouse heating.

2.4 Direct-Use Applications of Geothermal Energy: District Heating, Greenhouse Heating, Hot Water and Balneology

The direct-use applications of geothermal energy are widely utilized in Turkey especially in the Aegean region where the surface temperatures range between 25 and 150 °C. The application areas, which mainly centre upon industry and buildings, are listed as follows: heating and/or cooling homes, businesses, spaces and greenhouses, health care and treatment applications, thermal tourism applications (hot springs, spas, balneological uses of geothermal water, etc.), fish farming (heating water), aquaculture productions, farming (crops, fruit, vegetable raising and drying), mushroom production, etc. (Canka Kilic 2016). Other fields of geothermal applications, where the temperature vary between 100 and 250 °C, are process heat supply, drying, chemical and mineral productions (carbon dioxide, fertilizer, lithium, heavy water, hydrogen, and mineral water, etc.) and geothermal heat pump applications (in buildings), refrigeration in industry (Canka Kilic and Kilic 2013).

Contrary to the world trend in geothermal energy, utilization of heat pump applications—due to its high capital costs—and other enhanced geothermal systems have not achieved a remarkable progress in Turkey. Only greenhouse heating systems have become in Turkey very popular in the recent years. The district heating projects have not yet gained the same acceleration as greenhouse applications, mainly due to the following reasons (Serpen et al. 2010):

- Up until now, there is no available geothermal resource has been discovered close to the provinces.
- The competition between geothermal and natural gas industry is inconsiderably low.
- Some of the geothermal district heating systems do not have sufficient heat supply.
- The heating costs are relatively high.

According to the data from the International Geothermal Association, Turkey's total thermal installed capacity is 2.0 GW and the direct use of geothermal energy sources is 10.247 GWh per year (International Geothermal Agency 2014). The direct use applications from geothermal energy include district heating, greenhouse heating, and thermal tourism facilities (JEOMER 2012). 58% of the proven capacity (2.7 GWth) is utilized for geothermal heating, which includes residence heating (805 MWth), greenhouse heating (612 MWth), thermal facilities heating (380 MWth), balneology (870 MWth) and heat pump applications (38 MWth) (Parlaktuna et al. 2013). Space heating is the main type of direct utilization of geothermal energy in Turkey. There are in total 17 provinces (mainly in western and central Anatolia) in Turkey, using geothermal fluid in residential heating. The first geothermal district heating system was established in Gönen in 1987 (Parlaktuna et al. 2013). As it is illustrated in the Table 4, Balcova field in Izmir with 243 MWt has the largest residential heating capacity.

In particular, there are two significant geothermal district heating fields in Turkey with their high capacity of heating and adoption of new technologies. First one is the Balçova-Narlıdere district heating system. This heating field is an exception among other district heating systems in Turkey, due to the adoption of newest technologies and low operational costs. According to 2013 data, the system could reach more than 35,000 residences equivalence heating. The second one is the Afyon district heating system, which attracts attention with its innovative geothermal projects. Afyon has achieved to become the first self-sufficient city in Turkey to meet its own energy needs only through its domestic sources, namely geothermal heating. 15,000 residences, 50 hotels and hundreds of greenhouses are heated through the underground geothermal heating. As natural gas and coal are not

Table 4 Important geothermal district heating systems for households in Turkey

Field	Number of heated residencies	Temperature (°C)	Capacity (MWt)	Company
Balcova-Narlidere	35,000	140	243	Governorship and municipality
Afyon	10,000	95	127.5	Predominantly municipality
Sandikli	11,000	75	119	Predominantly municipality
Simav	12,000	125	92	Municipality
Diyadin	570	70	62	Predominantly governorship
Salihli	7500	94	57	Municipality
Edremit	5500	60	39	Municipality and private
Kozakli	3000	90	34	Predominantly municipality
Kizilcahamam	2500	70	28	Predominantly municipality
Sindirgi	300	98	24	Municipality and private
Kirsehir	1900	57	20	Predominantly municipality
Gönen	3400	80	19	Predominantly municipality
Sarayköy	2500	95	19	Predominantly municipality and private
Dikili	2000	125	19	Municipality
Sorgun	1500	80	19	Municipality
Bigadic	1500	96	7	Municipality
Bergama	450	70	3	Municipality

Data Source Türkiye Jeotermal Dernegi (2017)

utilized for the energy generation, the city is able to save 210 million TL (around € 45 million) each year, which will be invested for the new geothermal discoveries.

Afyon geothermal energy investments draw attention with the innovations exemplified in the world. The city is specialised in the fields of geothermal and solar energy. In addition to having Turkey's largest thermal heating facility, around 15 thousand residences are warming up by the geothermal district heating system 60% cheaper than other traditional heating systems (e.g. natural gas) This is equivalent to 300,000 tons of coal per year. In 2013, the city allocated US$75 million to alternative and renewable projects and accomplished 12 inventions that were tagged with patent and utility model. With recent investments, about 1.5

million m^2 of indoor space has been heated by natural water coming from underground. This includes 50 hotels as well as residences. In addition, the heating of the greenhouse areas is also done with thermal systems (Gecer 2014).

Besides district heating systems for residences, Turkey also has more than 350 thermal resorts, heated by low temperature geothermal water, which offer balneology and thermal tourism applications. Afyon-Orucoglu Thermal Resort facilities have been heated since 1992 with geothermal water at 48 °C temperature. In addition, the Bolu-Karacasu Thermal Facility has been partially heated to 44 °C since 2001, Rize-Ayder Cure Center at 55 °C, Hatay-Kumlu Thermal Facility at 37 °C with bottom heating, Sivas-Hot Cermic Hot Springs at 46 °C and Samsun-Havza Thermal Facilities are heated by geothermal water at 54 °C temperature. In Haymana, the mosque is heated with 45 °C geothermal water (Türkiye Jeotermal Dernegi 2017).

Heating greenhouses through geothermal energy has been in vogue especially in recent years. Major greenhouse areas are located in Western Anatolia. The greenhouse heating capacity in Turkey reached to almost 3 million m^2 greenhouse heating (612 MWth) in 2015. As a result of market saturation, the greenhouse investments slowed down in the last 3 years. Greenhouses are heated 1500–2000 h per year, and their main productions are tomatoes and Californian peppers (Serpen et al. 2010). The major export markets are Russia (60%) and Europe (20%). 10% of the yield is sold countrywide. The major greenhouse applications are located in Dikili-Bergama, in Aegean region, with 1,000,000 m^2 and in Sanliurfa-Karaali in Southeastern Anatolia, with 474,000 m^2.

Geothermal resources with average and excess enthalpy in Turkey have high carbon dioxide content. This carbon dioxide gas is used to accelerate the growth of greenhouse production as well. Greenhouses consume 4,000 tons carbon dioxide per year per hectare. Therefore, it is essential to transmit 1000–2000 parts per million of carbon dioxide into greenhouse atmosphere. Consequently, the carbon dioxide gas obtained from geothermal resources is utilized for greenhouses (Serpen et al. 2010).

3 Geothermal Energy and Society

The main institution responsible for establishing the energy policy and energy strategies of Turkey is the Turkish Ministry of Energy and Natural resources (MENR). Within MENR, the General Directorate of Energy Affairs is responsible for the coordination of electricity reforms (IEA 2016). Additionally, there are other non-ministerial organizations responsible for various aspects of energy policy:

- Energy Market Regulatory Authority (EPDK): Responsible for the Energy policy- and/or regulations
- Turkish Atomic Energy Authority (government entity) (TAEK): Responsible for the regulatory and supervisory activities in the nuclear field.

- TÜBITAK Marmara Research Center (government entity): Having an energy institute, responsible for the energy efficiency issues
- Turkish Standards Institute (TSE), International Electrotechnical Commission (IEC): Responsible for the determination of the energy standards
- Energy Systems and Environmental Research Institute/TÜBITAK Marmara Research Center: Responsible for the Research and Development
- Clean Energy Foundation, Turkish Wind Energy Association, International Solar Energy Society-Turkish Section, Geothermal Energy Association: Responsible for the renewable energy regulations.

The responsible authority in Turkey for the development of geothermal energy is the General Directorate of Mineral Research and Exploration (MTA). First geothermal exploration and investigation activities started in 1962. Up until now, 230 geothermal fields have been discovered by the MTA. 9 of them are suitable for electricity generation, and the others are suitable for heating and thermal tourism. Sixteen of these latter?, which are located in the western Turkey, are also suitable for electrical power generation, but needs to be developed. The total proven geothermal capacity of the wells conducted by the MTA is 5000 MW. Together with the drilling activities operated by the private sector, approximately 14,000 MW proven capacity has been reached (MTA 2017).

Based on the 2016 data of the Turkish MENR, the geothermal capacity of Turkey is 31,500 MW. 79% of the areas with a potential are situated in Western/Aegean region, 8.5% in Central Anatolia, 7.5% in the Marmara, 4.5 in Eastern Anatolia and 0.5% in other regions. 94% of these geothermal sources are low and medium heat, suitable for direct applications (heating, thermal tourism, the output of minerals) (MENR 2016), while 6% medium-to-high enthalpy fields are convenient for indirect applications, such as electricity generation, which are located in the Aegean region of the country. Based on the official data of the Turkish MENR, the development in geothermal energy application and electricity generation can be listed as follows (MENR 2016):

- The number of geothermal fields suitable for electricity production increased from 16 in 2002 to 25 in 2016.
- The number of greenhouses, heated from geothermal energy, increased from 500 m^2 in 2002 to 3931 m^2 in 2016, with a rise of 686%.
- District heating from geothermal energy reached from 30,000 residence equivalent in 2002 to 114,567 residence equivalent in 2016, with a rise of 281%.
- Geothermal heat capacity reached from 3000 to 14,000 MW by the end of 2015, with a rise of 366%.
- Electricity production from geothermal energy reached from 15 MWe in 2002 to 820 MWe in 2016, with a rise of 5366%.

In spite of significant progress that the Turkish government has been showing with regards to widespread utilization of renewable energies, the social dimensions are not attracted much attention in government's policy programmes. The social acceptance and favorable public perception of the renewable energies are important to increase the gradual use of renewable energies among the country. In this regard, the lack of certainties on the authorities, government bodies, organizations, stakeholders and citizens should be eliminated to accelerate the rapid development in clean energy sources.

3.1 Public Perception and Awareness of Renewable Energy Sources

Although having enormous potential of sources for the renewable energy production, the gradual development of the use of renewable sources remain weak. One reason can be addressed to the government's energy policy, which still gives precedence to the full-utilization of indigenous resources (like charcoal) and establishing three nuclear energy power plants. Other reason can be associated with the low awareness and consciousness of renewable energy application among the society. The level of awareness may differentiate in various geographical regions, generation, educational and career level (Yousefi-Sahzabi et al. 2017).

In order to understand the relationship between the awareness of renewable energy applications and the factor of educational level, Tortop, from the Zonguldak Karaelmas University, interviewed with 127 students, who have been attending in different high schools in Isparta, Turkey. The results of his study show that the awareness of high school students regarding the renewable energy applications is very low. They have serious misinterpretations regarding these applications. Most of them would not prefer to make a career in the renewable energy field and are not aware of the presence of "Research and Application Centre for Renewable Energy Resources" at the Isparta Süleyman Demirel University, which locates in the city they reside (Tortop 2012).

In another study Token, Köktürk and Birol Akkurt from the Dokuz Eylül University, Izmir, conducted a research about the contribution of increasing buildings and systems that use renewable energy sources to creation of a public awareness regarding renewable sources. Within this study, they suggested to establish a "Renewable Energy Museum", in where the technologies can be introduced to the society (especially children and youth), which, ultimately, may change the view towards renewable energy sources and promotes more conscious and common utilization of these clean energy sources (Tokuc et al. 2009).

Due to the limited research surveys on the public perception of Turkish society on renewable energy sources, understanding the issue of awareness and consciousness in a countrywide scale is difficult. If the level of education and professional background play a major role in the public awareness, it is expected that the residents of big metropolitan cities such as Istanbul, Ankara and Izmir show higher level of awareness to clean energy technologies than the residents living in urban areas.

3.2 Social Acceptance of Geothermal Energy

The utilization of geothermal sources is an environmental friendlier energy option and has much more diverse application areas than the other renewable sources. Moreover, it does not depend on climate conditions. Nevertheless, just like the other renewable energy production areas, the geothermal facilities are also not free from negative environmental impacts. The wastes produced by geothermal systems include toxic metals. Geothermal plants may also smell and produce noise pollution during construction, drilling wells and the escape of high-pressure steam during testing. Therefore the local residents living nearby of a geothermal plant should be informed by the project owners about the benefits and potential adverse effects.

The main economic benefit of a geothermal plant can be the creation short- and long-term employment opportunities for the local residents. Furthermore, the plant owners may purchase some necessary materials and equipment from the local sources. Another benefit of a geothermal power plant can be providing district heating systems to the close residents or farms. The agricultural crop production can be benefited through the heating system.

Cetiner et al. conducted a case study with 3 high school and 101 university students to determine the social acceptance and perception of geothermal energy in the Big Peninsula, Canakkale, Turkey. The results of the research show that geothermal energy sources in the Big Peninsula have significant potential for different areas of uses, but the knowledge regarding the environmental effects is insufficient. Furthermore, although geothermal systems have a wide-scale public acceptance as an energy resource (73.1%), there is roughly the same level of acceptance (71.2%) that they are used for treatment purposes. Moreover, there is a high awareness (78.9%) of technological choices like hot dry rocks that are not used in Turkey (Cetiner et al. 2016).

4 Conclusions

Turkey locates in one of the most convenient areas in the world, where obtainment of high temperature and low cost geothermal energy is possible. Despite its abundant potential, the systematic exploration of the geothermal resources in entire grabens and belts is not done yet. Furthermore, in order to reach higher temperature of geothermal source, deep drilling activities are needed, which is expensive in a considerable manner. Therefore, the drilling activities in the geothermal areas still remain insufficient in number. Heating costs put a heavy burden on the Turkish economy. District heating through the geothermal energy in Turkey is the cheapest way compared to gas-fired combi boiler (which is mostly preferred for residential heating) conventional or central heating systems and has therefore gained wide acceptance among consumers. In addition to the heating purposes, the use of geothermal energy for the cooling applications should also be encouraged by the Turkish authorities.

According to Turkey Geothermal Association, there are important problems, which have to be eliminated in order to accelerate the sustainable development of geothermal applications. These are:

- There is no available data system that contains information obtained from drilled wells. It is useful to set up such an information system.
- Turkish Petroleum (officially responsible company for the crude oil drilling activities in Turkey) has an information system, which contains the temperature of the wells, water and geothermal value-oriented formation. It is therefore necessary that the Turkey Petroleum share this data also with the geothermal sector.
- There is little incentive for the electricity generation from geothermal resource and no incentive for geothermal heating. There are only incentives given by the Ministry of Agriculture for investments for the geothermal greenhouses, which is around 600,000 TL (around USD 155,000). This incentive was very beneficial for the development of the geothermal greenhouses. Such an incentive form should also be implemented to the geothermal district heating systems.
- In accordance with Law No 5686, MTA is currently responsible for the geological exploration of the geothermal areas, geophysics, geophysical surveys, geological survey related geothermal risk and investigation of the mining risks. These practices should be further deepened and continued.

The partnership of the private sector with the municipalities regarding the construction of geothermal central heating systems should be encouraged with the enactment of necessary legal infrastructures and legal arrangements.

To the contrary of the slight contribution of electricity generation from geothermal sources, geothermal district-use heating potential in Turkey is considerably high. According to the estimations, if the geothermal heating solely in Turkey is used, 5 million residences (30% of the total residences) will be heated and as a result, emission of 48 million ton per annum carbon dioxide to the atmosphere can be inhibited. Thereby, there will be significant reductions in the amount of imported oil, natural gas and coal for the heating purposes.

It is foreseen that the utilization of geothermal energy will become prevalent in Turkey over the next decade. The specific incentives and feed-in-tariff by the government are expected to encourage investments in geothermal energy. Geothermal power may help Turkey to move towards a more decentralized form of electricity generation, where the installed plant meets the necessities of local customers, avoids transmission losses and increases flexibility in system use. Thereby the diversification of power generation plants will be ensured which in turn increases competition in electricity generation.

Turkish government plans to raise the share of renewable energy sources in electricity production to at least 30% by 2023. The calculations show that geothermal power and biomass-based energy production will achieve the 2023 targets, while solar energy installations remain still insufficient in number. Wind- and hydropower with their high potential and adequate number of proposed facilities will contribute to the total electricity generation in considerable amount. Nevertheless some environmental and social aspects should be considered before the construction of new plants. Moreover, Turkey still needs to establish a more coherent energy and climate policy and implement support mechanisms, which particularly address each type of renewable energy resource in Turkey.

Besides the necessity of government support and incentives, the public acceptance regarding the geothermal energy technologies and application areas play also a very significant role to develop the gradual utilization of geothermal resources. Therefore, especially the local residents living nearby a geothermal power plant should be informed about the economical benefits (such as short- and long-term employment opportunities, establishment of a district heating system for the residencies), agricultural benefits (cultivating vegetables and fruits, greenhouse heating) as well as possible burdens (such as noise pollution, smell, etc.). Furthermore, the project owners should take the necessary precautions in order to minimize the adverse effects for the inhabitants.

References

Anadolu Ajansi (Anatolian Agency) (2017) Turkey has the youngest population of Europe. Available via http://aa.com.tr/en/info/infographic/7252. Accessed 24 Feb 2018

Atlasi E (2017) Geothermal power plant by country. Available at http://en.enerjiatlasi.com/geothermal-power-plant-by-country.html. Last visited on 10 Feb 2018

Canka Kilic F (2016) Geothermal energy in Turkey. J Energy Environ 0:1–17. https://doi.org/10.1177/0958305X15627544

Canka Kilic F, Kilic MK (2013) Geothermal energy and Turkey. Turkish Union Chambers Mech Eng Arch (TMMOB) 54:45–46

Cetiner ZS, Ertekin C, Gülay B (2016) Initial assessment of public perception and acceptance of geothermal energy applications in Canakkale, NW Turkey. J Energy Procedia 97:194–201

EBRD (2017) Zorlu—Kizildere III GPP extension. In: European bank for reconstruction and development. Available via http://www.ebrd.com/work-with-us/projects/psd/zorlu-kizildere-iii-gpp-extension.html. Accessed Last 11 Feb 2018

Erdogdu E (2009) A snapshot of geothermal energy potential and utilization in Turkey. J Renew Sustain Energ Rev 13(9):2535–43. Available via http://linkinghub.elsevier.com/retrieve/pii/S1364032109001051. Accessed 10 Mar 2018

Gecer S (2014) Enerji Bagimsizliginda En Basarili Il: Afyonkarahisar. In alternatifenerji.com. Available via http://www.alternatifenerji.com/afyon-enerji-bagimsizliginda-en-basarili-il/. Accessed 30 Jan 2018

International Energy Agency-IEA (2016) Energy policies of IEA countries Turkey review. Paris, France. Available via https://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesTurkey.pdf. Accessed 05 Jan 2018

International Geothermal Agency (2014) Turkey-direct uses. Available via http://www.geothermal-energy.org/geothermal_energy/direct_uses/turkey.html. Accessed 20 Feb 2018

Jeotermal Enerji Arastirma ve Uygulama Merkezi (JEOMER) (Geothermal Energy Research and Application Center) (2012) Geothermal energy in Turkey, Izmir, Turkey. Available via http://geocen.iyte.edu.tr/en/turkiyede-jeotermal-enerji/. Accessed 25 Dec 2017

Karamenderesi I (2013) Characteristics of geothermal reservoirs in Turkey. Izmir, Turkey. IGA Academic Report 0102–2013

Kartal N (2013) Geothermal energy in Turkey. Singular & Singular Law Office. Available via http://www.mondaq.com/turkey/x/224560/Renewables/Geothermal+Energy+In+Turkey. Accessed 10 Mar 2018

Kindap A, Kaya T, Tut Haklıdır FS, Bükülmez AA (2010) Privatization of Kizildere geothermal power plant and new approaches for field and plant. In: World Geothermal Congress, Bali, Indonesia, pp 1–4. Available via http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/0708.pdf. Accessed 05 Jan 2018

Maden Tetkik ve Arama Genel Müdürlügü—MTA (General Directorate of Mineral Research and Exploration) (2017) Türkiye Jeotermal Enerji Potansiyeli ve Arama Calismalari. Available via http://www.mta.gov.tr/v3.0/arastirmalar/jeotermal-enerji-arastirmalari. Accessed 05 Jan 2018

Parlaktuna M, Mertoglu O, Simsek S, Paksoy H, Basarir N (2013) Geothermal country update report of Turkey (2010–2013). In: European Geothermal Congress 2013, Pisa, Italy, pp 1–9. Available via http://www.geothermal-energy.org/pdf/IGAstandard/EGC/2013/EGC2013_CUR-32.pdf. Accessed 05 Jan 2018

Resmi Gazete (Official Gazette) (2012) *Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına Iliskin Kanun* (Law on Amendments on the Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy). Available via http://www.mevzuat.gov.tr/MevzuatMetin/1.5.5346-20120704.pdf. Accessed 18 Feb 2018

Serpen U, Aksoy N, Öngür T (2010) Present status of geothermal energy in Turkey. In: Thirty-fifth workshop on geothermal reservoir engineering, Stanford, California. Available via https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2010/serpen.pdf. Accessed 15 Jan 2018

Serpen U, Aksoy N, Öngör T, Korkmaz D (2009) Geothermal energy in Turkey: 2008 update. J Elsevier 1–3. Available via http://isiarticles.com/bundles/Article/pre/pdf/57944.pdf. Accessed 10 Mar 2018

Simsek S (2002) Origin and characteristics of geothermal energy resource of the wider aegean region. In: The International workshop on possibilities of geothermal energy development in the Aegean Islands region (proceed.), vol 1, Milos Island, Greece, pp 1–8

T.C. Enerji ve Tabii Kaynaklar Bakanligi (MENR—Turkish Ministry of Energy and Natural Resources) (2017) Dünya ve Türkiye Enerji ve Tabii Kaynaklar Görünümü. Available via http://www.enerji.gov.tr/Resources/Sites/1/Pages/Sayi_15/mobile/index.html#p=1. Accessed 07 Jan 2018

T.C. Enerji ve Tabii Kaynaklar Bakanligi (MENR—Turkish Ministry of Energy and Natural Resources) (2016) Geothermal. Available via http://www.enerji.gov.tr/en-US/Pages/Geothermal. Accessed 21 Jan 2018

Tokuc A, Köktürk G, Birol Akkurt H (2009) ISEM Rising social consciousness in the field of renewable energy; Izmir Sustainable Energy Museum. In: SET2009–8th international conference on sustainable energy technologies, Aachen, Germany, pp 1–6

Tortop HS (2012) Awareness and misconceptions of high school students about renewable energy resources and applications: Turkey case. J Energ Educ Sci Technol B Soc Educ Stud 4 (3):1829–1840

Turkish Statistical Institute-TUIK (2017) Press release, no: 24638. Available via http://www.turkstat.gov.tr/PreHaberBultenleri.do?id=24638. Accessed 02 Jan 2018

Turkish Statistical Institute-TUIK (2013) Population projections, 2013–2075. Available via http://www.turkstat.gov.tr/PreHaberBultenleri.do?id=15844. Accessed 12 Dec 2017

Türkiye Jeotermal Dernegi (Turkey Geothermal Association) (2017) Türkiye'de Jeotermal-Mevcut Durum. Available via http://www.jeotermaldernegi.org.tr/sayfalar-Turkiye-39-de-Jeotermal. Accessed 05 Jan 2018

Ulcay S, Kurt O, Akcora CM, Ozturk M (2012) Environmental monitoring in the Kaklik Cave, Denizli, Turkey. J Nat Sci 4(3):159–65. Available via http://file.scirp.org/Html/2-8301615_18065.htm. Accessed 18 Feb 2018

Varinca KB (eds) (2011) The current status of geothermal energy use in Turkey. In: 1st international 100% renewable energy conference and exhibition (IRENEC 2011), Eurosolar

Istanbul, Turkey, pp 333–338. Available via http://de.scribd.com/doc/77263118/The-Current-Status-of-Geothermal-Energy-Use-in-Turkey Accessed 28 Feb 2018
Workman D (2017) Turkey's top 10 exports. In: World's Top Exports-WTEx. Available via http://www.worldstopexports.com/turkeys-top-10-exports/. Accessed 02 Jan 2018
World Atlas (2018) The economy of Turkey. Available via https://www.worldatlas.com/articles/the-economy-of-turkey.html. Accessed 25 Feb 2018
World Energy Council (2016a) Top geothermal producing countries. Available via https://www.worldenergy.org/data/resources/resource/geothermal/ Accessed 10 Feb 2018
World Energy Council (2016b) World energy resources-geothermal 2016. Available via https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Geothermal_2016.pdf. Accessed 13 Feb 2018
Yousefi-Sahzabi A, Unlu-Yucesoy E, Sasaki K, Yuosefi H, Widiatmojo A, Sugai Y (2017) Turkish challenges for low carbon society: current status, government policies and social acceptance. J Renew Sustain Energy Rev 68:596–608

Melek Akca Prill born and raised in Turkey, is a political scientist. She holds a bachelor degree in Economics and a master degree in European Studies. Currently, she finalized her doctoral studies about the contribution of renewable energy sources to diminish Turkey's energy dependency. Her research interests are focused in environmental-friendly energy technologies and responsible research and innovation (RRI). Since 2016 she has been working as a research associate at the Fraunhofer Institute for System and Innovation Research ISI, Karlsruhe, Germany. Furthermore, she is involved in several European projects in the field of RRI, such as SMART-map (projectsmartmap.eu), NewHoRRIzon (newhorrizon.eu) and e-sides (e-sides.eu).

Conclusions

Agnes Allansdottir Adele Manzella and Anna Pellizzone

Keywords: International comparison · Governance · Social aspects
Policy making

Synopsis of the Book

The somewhat modest aim of this chapter is to try to bring together all the contributions to this book in a short synopsis and in particular to provide a sensible overview of the rich material offered by the country case profiles from around the globe. The ultimate aim of this book was not simply to promote geothermal energy as a preferential resource for energy production, but to contribute to the design of new research and policies towards an inclusive, responsible and participatory energy transition. As the mission of energy experts is to pave the way for a sustainable and accessible energy provision while taking into account social and environmental issues, geothermal energy is one of the technologies that could greatly contribute to a carbon-free future.

This edited volume was divided into two broad sections or blocks of chapters. The four chapter in the first section presented differing perspectives on geothermal energy and society. Manzella (Chapter "General Introduction to Geothermal Energy", this volume) presented the current state of the art in the sciences and technologies applied in the harnessing of geothermal energy, for both heating & cooling and electricity production. Dumas (Chapter "Policy and Regulatory Aspects of Geothermal Energy: A European Perspective", this volume) outlined the current regulatory framework in this field, how such a framework has evolved and what the future prospects are, with a particular emphasis on Europe. Contini and his colleagues (Chapter "Business Strategies in Geothermal Energy Market: A

A. Allansdottir
Fondazione Toscana Life Sciences, via Fiorentina 1, 53100 Siena, Italy

A. Manzella · A. Pellizzone
National Research Council, Institute of Geosciences and Earth Resources,
Via Moruzzi 1, 56124, Pisa, Italy

A. Manzella et al. (eds.), *Geothermal Energy and Society*, Lecture Notes
in Energy 67, https://doi.org/10.1007/978-3-319-78286-7

Citizens-Based Perspective", this volume), presented an overview of the business models available to energy companies in this sector and how they interact with society, with a particular emphasis on the concept of Corporate Social Responsibility in the case of both heating & cooling by shallow Ground Source Heat Pumps (GSHP) and electricity production. Allansdottir and her colleagues (Chapter "Geothermal Energy and Public Engagement", this volume) discussed conceptual and methodological frameworks that can guide and inform research and activities related to geothermal energy and society. Pellizzone and her colleagues (Chapter "Drawing the Picture: Public Engagement Experiences as Tools Towards an Emerging Framework", this volume) provide a bridge between the two sections, from the different perspectives presented in the first block and to the eleven country profiles and cases studies presented in the second block.

The collection of eleven country profiles in the second part of this book has taken the reader on a journey across different parts of the globe in order to explore how the diverse societies actually configure in developments and processes of innovation that harness the natural geothermal resources of the respective countries. Two chapters come from Oceania: Australia and New Zealand, two from Asia: the Philippines and Japan, one from North America: Quebec in Canada, and six from European countries in a wide sense: France, Greece, Iceland, Italy, Switzerland and Turkey. The country profiles were all written for this edited volume and adhered to a minimal agreed common structure and most report upon a series of social scientific case studies or activities that have been conducted in the respective countries. The authors come from a wide range of disciplinary backgrounds and this diversity is reflected in their contributions. Some of the country profiles tilt towards a more sophisticated technical presentation of developments in the geothermal sector in their countries, some tilt towards the perspectives of social sciences and innovation studies and some strike a balance between those two points of view on geothermal energy and society. As editors, we provided editorial assistance to ensure that all key aspects were covered in each country profile and the case studies presented therein. Beyond those guidelines, all the authors had considerable freedom in constructing their respective chapters. This, we believe, is one of the key strength of this book as it really does give a voice to a multitude of perspectives on innovation and development in the geothermal sector. The result is a multifaceted, unique and truly interdisciplinary contribution to the literature in the geothermal sector. The material that has been prepared and presented in the second section is both extremely rich and nuanced and, by definition or necessity, more descriptive than analytic.

These eleven chapters reflect both the historical and cultural peculiarities of the countries presented and the perspectives of the authors in terms of their disciplinary background and involvement in the sociotechnical systems in which the geothermal energy sector evolves. These country profiles, with the concrete case studies embedded within them, therefore constitute "Thick Descriptions" in the sense articulated by Geertz (1973). We are very much aware of the potential pitfalls of having assembled yet another loosely connected set of case studies (Stilgoe et al. 2013). Hence, in this concluding chapter we do attempt to tease out a brief synopsis on the basis of these accounts and do try to compare and contrast the themes that emerge from this collection of experiences. The aim is to offer at least some inspiration for future research and reflections upon the relationship between geothermal energy and society. Further elaboration of the material presented in these country profiles might for example draw upon available tools and techniques for analysis of multiple cases such as comparative qualitative analysis of case studies (Hansen and Allansdottir 2011).

To a varying degree, the descriptions presented by the country profiles touch upon three distinct societal levels as articulated by the Multi-Level Perspective on sociotechnical systems and innovation processes (Geels and Schot 2004). First, on a *macro level* in the sense of the broadest context of cultural, historical, economic and political patterns or in other words, outlining the political and economic history of the use of geothermal resources and the whole energy framework, in a given country. Second, on a *meso level*, or the socio technical regime in the sense of networks of actors and practices that form around particular technology developments, in other words various sets of stakeholders involved in particular developments and related communication processes. And finally, on a *micro level* that entails the perspectives and outlooks of individuals and groups (see also Allansdottir and her colleagues, Chapter "Geothermal Energy and Public Engagement", this volume; Devine-Wright et al. 2017). Our point of departure in this brief synopsis, and overview of the preceding chapters, is the distinction put forward by Manzella (Chapter "General Introduction to Geothermal Energy", this volume), that was further taken up and elaborated upon by the authors of other chapters, that is the distinction between heating & cooling and electricity production technologies. While the former use geothermal fluids in a wide temperature range, electricity production technologies require fluids at high temperature, usually obtained from deep resources. Although the heterogeneity of rock types, heat source and in general of geological processes impedes a direct proportionality, the higher the fluid temperature the more complex is the production and management of geothermal fluids due to increasing mineral and gas fluid content and drilling depth.

What Drives the Harnessing of Geothermal Resources?

Geothermal resources are older than human societies and from Palaeolithic times onwards these resources have been utilised by local communities most notably for bathing, washing, preparation of food - important already in the times of the Roman empire as well as in the Japanese tradition of *onsen*, just to take two examples. At the outset of the 20th century, technological solutions had been developed that enabled the harnessing of the power of geothermal resources to produce electricity to meet increasing demands (as described in Manzella, Chapter "General Introduction to Geothermal Energy", and Pellizzone et al. Chapter "Geothermal Resources in Italy: Tracing a Path Towards Public Engagement", all in this volume). In the thirties, during times of a profound economic crisis, geothermal resources were harnessed to provide affordable heating and comfort to local communities and towns (as in Manzella, Chapter "General Introduction to Geothermal Energy", and Jónsson et al. Chapter "Taming the Elements—The Use of Geothermal Energy in Iceland", all in this volume). For the most part, these developments were supported by society as a whole. The next major wave of developments occurred during the oil crisis in the seventies, when the need to find alternatives to fossil fuels encouraged the technological development of renewable energies (see for example Chavot at al. Chapter "Geothermal Energy in France. A Resource Fairly Accepted for Heating but Controversial for High-Energy Power Plants", Jónsson et al. Chapter "Taming the Elements—The Use of Geothermal Energy in Iceland", Ratio et al. Chapter "The Philippine Experience in Geothermal Energy Development" all in this volume). The concerns related to nuclear energy technologies after the Fukushima disaster have recently increased the interest for renewable and sustainable energies and, among them, geothermal (see for example Carr-Cornish et al. Chapter "An Application of Social Science to Inform the Stakeholder Engagement of an Emerging Geothermal Industry in Australia", Chavot et al. Chapter "Geothermal Energy in France. A Resource Fairly Accepted for Heating but Controversial for High-Energy Power Plants", Yasukawa Chapter "Issues Around Geothermal Energy and Society in Japan", Ejderyan et al. Chapter "Geothermal Energy in Switzerland: Highlighting the Role of Context", all in this volume).

The latest wave in technological developments that enable the harnessing of geothermal resources rests upon the capacity to extract the heat of the earth from resources that have hitherto been unmanageable in order to produce electricity and heat to meet growing demands for energy. In recent years, as concerns over climate change have grown and debates over environmental protection and respect for the only planet we have got have become mainstream, this new frontier of harnessing deep geothermal resources has greatly gained in prominence as an important contribution to energy production that facilitates the transitions to a sustainable low carbon future (see also the Preface to this volume).

Heating & Cooling and Electricity Production Technologies

The obvious first reflection that follows from making a distinction between heating & cooling and electricity production technologies is that the history of the former type of application goes back centuries, at least in many of the countries profiled in this book such as France, Iceland, Italy and Japan or for that matter in more recent times, Switzerland has become one of the world leaders in terms of the density of geothermal heat pump installation. In other countries profiled in this book, the heating & cooling applications are not yet considered economically competitive but applications are emerging such as greenhouse heating for agricultural use in Turkey.

If harnessing geothermal resources for a variety of heating & cooling purposes is for the most part rather well accepted, although there are inevitable disputes over particular developments as clearly emerges from reading the country profiles, it is also because in most cases there is a direct benefit to the users and the technologies applied in developments are increasingly familiar to the local communities involved. When it comes to the harnessing of deep geothermal resources, in particular for electricity production, the picture changes in some radical ways. Note that the typology of the natural resource, in this case the heat inside the earth, is of the same category; what changes is the approach and the technologies used for harnessing, and the physical condition (abundance, temperature, pressure) and chemical composition of the fluids exchanging and transporting the heat to the surface. It is this difference that allows us to characterise harnessing of deep geothermal as an emerging field of science and technology. Further, even if the use of geothermal resources has always been an integral part of communities and societies where such resources are abundant, the harnessing of deep geothermal resources for heating & cooling and electricity production is generally unfamiliar to societies and the general public (as is evident in most of the country profiles presented in this book). In many countries there is considerable perplexity over the use of geothermal energy in contrast with other more familiar renewable energy resources, such as wind and solar (Pellizzone et al. Chapter "Geothermal Resources in Italy: Tracing a Path Towards Public Engagement" of this volume).

The sources of perplexity might vary. Societies might be insufficiently informed about geothermal technologies as such and the risks and the benefits involved. That holds for Canada in general and Quebec in particular (Malo et al. Chapter "Public Perception Regarding Deep Geothermal Energy and Social Acceptability in the Province of Québec, Canada", this volume) and for Italy (Pellizzone et al. Chapter "Geothermal Resources in Italy: Tracing a Path Towards Public Engagement" of this volume). There is clearly important work ahead on this front and we will come back to that later in this chapter. Another possible source of perplexity derives from unfortunate experiences. The French chapter presents two such stories, the abandoned pilot projects for deep geothermal for the production of electricity in the French overseas territories in Guadeloupe in the Atlantic Ocean, in the West Indies and Réunion in the Indian Ocean and as well the difficulties faced by the pilot project at Soultz-sous-Forêts in the Rhine Basin in mainland France (Chavot at al. Chapter "Geothermal Energy in France. A Resource Fairly Accepted for Heating but Controversial for High-Energy Power Plants", this volume). Another example from the collection of country profiles would be the controversy over geothermal power plants on the Greek Island of Milos in the seventies (Karytsas et al. Chapter "Social Aspects of Geothermal Energy in Greece", this volume) that still reverberates in the debate over geothermal energy in the country. However, negative results not always preclude the interest of public in deep geothermal resource development (e.g. the St. Gallen experience of Switzerland, described in Ejderyan et al. Chapter "Geothermal Energy in Switzerland: Highlighting the Role of Context", this volume). A further possible source of perplexity over the use of geothermal energy, in particular for producing electricity, is the question of how the energy that would be generated would eventually be used (Jónsson et al. Chapter "Taming the Elements—The Use of Geothermal Energy in Iceland", this volume).

That brings us to the crucial issue of *energy demand* that varies greatly across the countries profiled in this book, from countries where internal electricity production more than meets demand, such as Iceland, to countries where even large geothermal production may cover only a minor part of the large energy demand, as Italy, to countries, as Turkey, where a surge in demand for electricity, in particular from clean renewable sources such as geothermal given the countries commitment to the transition towards a low carbon sustainable future, provides further pressure toward harnessing of geothermal resources. The relationship between levels of energy demand and impetus for development and innovation in this sector is an argument that warrants further considerations.

Ownership and Management of Geothermal Resources

The laws and the regulations that govern the ownership, harnessing, the trade and management of geothermal resources clearly vary greatly between the countries profiled in this book and a comprehensive overview of this field is far beyond the much more modest scope of this chapter.

Some countries, for example Switzerland and Greece, do not really have complete or adequate normative frameworks on geothermal resources in place (Ejderyan et al. Chapter "Geothermal Energy in Switzerland: Highlighting the Role of Context", Karytsas et al. Chapter "Social Aspects of Geothermal Energy in Greece" in this volume for further details). The processes granting authorisation and licensing for development and use of geothermal resources is managed at different administrative levels around the world. For example, in France, where geothermal resources are governed by the national laws regulating mining in general (Chavot at al. Chapter "Geothermal Energy in France. A Resource Fairly Accepted for Heating but Controversial for High-Energy Power Plants", this volume), tensions between local and national levels of decision making can result in situations of conflict for local democracy. In Japan (Yasukawa Chapter "Issues Around Geothermal Energy and Society in Japan" this volume), where for historical reasons geothermal resources fall under the so-called Hot Spring Law and are regulated at local level instead of regional or national level, the interests of owners of *"onsen inn"* (spa) businesses have clashed with developments in other fields of geothermal harnessing. Further, New Zealand has a unique regulatory regime to sustainably manage its geothermal resources, also for historical reasons valuing the close inextricably ties between the first nation Maori people and geothermal resources (Luketina and Parson, Chapter "New Zealand's Public Participation in Geothermal Resource Development", this volume). The close ties between culture, history and nature also figures prominently in the chapter from the Philippines (Ratio et al. Chapter "The Philippine Experience in Geothermal Energy Development", this volume). This is why it is probably no coincidence that New Zealand and

Philippines have two of the most complete and advanced regulatory framework as regard to public engagement and public consultation for geothermal development.

These are just examples and further characterisation of national, regional or municipal laws and regulations governing the use of geothermal resources and how these different regulatory frameworks relate to the debates over developments and innovation in the geothermal sector is an interesting line of analysis to pursue. The chapters on regulatory framework (Dumas Chapter "Policy and Regulatory Aspects of Geothermal Energy: A European Perspective", this volume) and on business models and corporate social responsibility (Contini et al. Chapter "Business Strategies in Geothermal Energy Market: A Citizens-Based Perspective", this volume) contain interesting guidelines to follow for further exploration of the material presented in the country profiles.

Geothermal Energy and Societal Engagement

All the country profiles report upon an astonishing variety of activities, reflections and social scientific research that has been carried out in the countries presented. The very richness of the material raises many pertinent research questions that for the sake of brevity cannot be properly addressed in this very brief synopsis and we hope that this can pave the way for interesting international comparative research projects for the future.

Amongst many interesting research questions for the future is the pertinent question of *who initiates and funds social scientific research on geothermal energy and society?* In some countries, for example Australia (Carr-Cornish et al. Chapter "An Application of Social Science to Inform the Stakeholder Engagement of an Emerging Geothermal Industry in Australia", this volume) public authorities decided to invest in social scientific research when exploring the feasibility of further developments and innovation in the geothermal energy sector. Methodological approaches and research techniques applied included surveys, interviews and focus groups and most of this research has already been published internationally. In other countries, for example Turkey (Prill Chapter "Turkey—Pitching Forward to Energy Independency", this volume), public authorities have not as yet showed much interest in funding social scientific studies on geothermal energy and society although the author does report upon some interesting studies. Another example is Iceland where grass roots movements questioning further exploitation of geothermal resources for electricity production have become vocal in recent years but social scientific studies on public views and citizens' engagement are still scarce (Jónsson et al. Chapter "Taming the Elements—The Use of Geothermal Energy in Iceland", this volume). The country profiles for Italy, France and Québec in Canada report upon multi-methodological approaches that were applied in a series of publicly funded case studies within the framework of scientific and engineering research on geothermal resources (Pellizzone et al. Chapter "Geothermal Resources in Italy: Tracing a Path Towards Public Engagement", Chavot at al. Chapter "Geothermal Energy in France. A Resource Fairly Accepted for Heating but Controversial for High-Energy Power Plants", Malo et al. Chapter "Public Perception Regarding Deep Geothermal Energy and Social Acceptability in the Province of Québec, Canada", all in this volume). Most of this research has already been published internationally.

The profile of Switzerland, where direct democracy is firmly institutionalised on all levels of administration, presents a range of activities, public consultation and social scientific research regarding geothermal energy (Ejderyan et al. Chapter "Geothermal Energy in Switzerland: Highlighting the Role of Context", this volume). That raises another interesting question: *how forms of citizens' participation and public engagement are institutionalised in different countries and how does that impact national, and eventually international debates on innovation in the geothermal sector?* Although there is not much space here to further elaborate on these, as well as other questions stemming from reading through the profiles, the chapter by Allansdottir and her colleagues, Chapter "Geothermal Energy and Public Engagement", this volume can provide some guidance on further analysis.

Policy Implications

As in all cases of analysis of the relationship between technological development and society, the technologies themselves or as such are rarely objected to. What often drives societal concerns are societal perplexities over the use, governance and management of those technologies and the same holds for the range of technologies that harvest geothermal energy resources. This book might not have provided definite answers to a myriad of questions about the relationship between geothermal energy and society, or more broadly the relationship between societies and the transition towards a sustainable low carbon energy future, but we do hope to have raised some interesting and pertinent questions for further research and reflections in this field. The chapters in the second section had a national focus and often reported upon highly localised issues, conflicts and case studies and as such they hold immense value as first steps. However, as work in this field evolves and develops, the moment has come to start thinking on a more global scale in terms of polycentric systems for coping with global environmental change (Ostrom 2010) and the transition to a low carbon energy future for all and the pursue of the "common good".

There are several policy implications that derive from all the efforts that have gone into making this book happen. The first regards *interdisciplinarity and a societal dialogue* about innovation in the geothermal sector. As this book in itself shows, various actors and stakeholders can come together to pursue a common aim and further the knowledge by learning from other experiences. The final goal of mutual learning is to strike a balance between many conflicting perspectives and points of view on a sector that is often controversial. As social aspects of the energy transition are becoming a field of interest for different actors (i.e. researchers from different disciplines, policy makers, public engagement practitioners, industries and civil society organizations) new “spaces” for an interdisciplinary discussion on energy technologies and energy transition are needed at both local and international level. As public views towards energy technology are often place-related and as the impacts of energy production, distribution and use act at the global level, both global and local dimensions need to be considered when it comes to energy research and the design of new policy developments.

The second policy implication regards *processes of communication*. Research, reported in this book and elsewhere, indicates that the potential of geothermal energy is simply much less familiar to the general public than other renewable. Further to that, there is considerable uncertainty over geothermal technology and therefore public communication campaigns are necessary. An important distinction has to be made between public communication, preferably designed and conducted by independent experts on the one hand, and the communication processes instigated and provided by private companies on the other hand. The latter tend to be more organised and have more resources while public communication in this field needs to be strengthen. Research shows that scientist in universities and public research centres are highly trusted in these matters and are regarded as the preferred source of information in comparison to companies’ experts, decision makers and journalists. In terms of policy actions, it would be extremely valuable to give support to scientists and researchers in order to make available accurate, accessible and organised information for the public and local communities. This implies that science and communication curricula should seek a common ground, and professional and economic resources of research organizations working in the geothermal sector should be strengthened. At the moment of writing this chapter, some interesting initiatives are emerging, for example The Geothermal Resources Portfolio Optimization and Reporting Tool of the US Department of Energy (Young and Levine 2018) that could serve as a source of inspiration for future activities.

Finally, and in order to smooth the path of the energy transition, *public engagement activities are of increasing importance and such activities should be strengthened and reinforced through adequate levels of public funding*. Forms of dialogue that facilitate taking into account the views of local communities and the general public, need to be further consolidated and developed. Public engagement in the energy field is not only a matter of social acceptance, but it is about co-creating the future together with citizens and society as a whole. Meaningful engagement activities in the geothermal field have to be considered part of the innovation process and public views and values needs to be included from the very beginning of the geothermal innovation process itself. The final goal is to embed social needs, perplexities and expectations within arena of responsible energy choices, fostering the participation of a scientifically literate society, enhancing diversity, stimulating collective intelligence, furthering mutual understanding and mutual learning among different stakeholders in research design and results. An interesting recent development that points in this direction includes the novel concept of Geoethics that deals with the ethical, social and cultural implications of geoscientific research, including geothermal energy (Meller et al. 2017). Taken together, these considerations suggest that new organizational arrangements would be highly beneficial for all. Such arrangement might for example include a continuously updated "open access" observatory of new energy technologies and society, including geothermal energy and that inevitably requires public funding.

We hope that this book has made a contribution to the design of future collaborative research on geothermal energy and society, as a successful transition towards a low carbon future for all hinges upon the support of all diverse layers of society and social groups.

References

Devine-Wright P, Batel S, Aas O, Sovacool B, LaBelle MC, Ruud A (2017) A conceptual framework for understanding the social acceptance of energy infrastructure: insight from energy storage. Energy Policy 107:27–31

Geels FW, Schot J (2007) Typology of sociotechnical transition pathways. Res Policy 36:399–417

Geertz C (1973) Thick description: toward an interpretive theory of culture. In: The interpretation of cultures: selected essays. Basic Books, New York, pp 193–230.

Hansen J, Allansdottir A (2011) Assessing the impacts of citizen participation in science governance: exploring new roads in comparative analysis. Sci Public Policy 38:609–617

Meller C, Schill E, Bremer J, Kolditz O, Bleicher A, Benighaus C, Chavot P, Gross M, Pellizzone A, Renn O, Schilling F, Kohl T (2017) Acceptability of geothermal installations: a geoethical concept for GeoLaB. Geothermics 73:133–145

Ostrom E (2010) Polycentric systems for coping with collective action and global environmental change. Glob Environ Change 20:550–557

Stilgoe J, Owen R, Macnaghten P (2013) Developing a framework for responsible innovation. Res Policy 42:1568–1580

Young KR, Levine A (2018) Using GeoRePORT to report socio-economic potential for geothermal development. Geothermics 74:163–171