Chapter 1
The Geopolitics of Renewables—An Introduction and Expectations

Daniel Scholten

1.1 Introduction

Renewable energy represents a game changer for interstate energy relations. Its geographic and technical characteristics are fundamentally different from those of coal, oil, and natural gas. Renewable energy sources are abundant and intermittent; renewable energy production lends itself more to decentral generation and involves rare earth materials in clean tech equipment; their distribution, finally, is mostly electric in nature and involves stringent managerial conditions and long-distance losses. These stand in clear contrast to the geographically fixed and finite nature of fossil fuel resources, their general reliance on large centralized production and processing installations, and their ease of storage and transportation as solids, liquids, or gases around the globe. As the characteristics of fossil fuels have shaped contemporary energy-related patterns of cooperation and conflict among countries, the question rises how the transition towards renewables will reshape strategic realities and policy considerations of energy producers, consumers, and transit countries and relations between them. Moreover, who are the likely winners and losers?

Energy geopolitics is generally associated with fossil fuels, especially oil and natural gas. The focus on fossil fuels stems from their dominance in the global energy mix. Coal, oil, and natural gas combined account for 86% of global energy consumption in 2014 (BP 2015). To meet demand, 2014 knew a staggering production of 32.365 billion barrels of oil, 3460.6 billion cubic meters of gas, and 3933.5 million tons oil equivalent of coal (BP 2015). By comparison, nuclear energy (4%), hydropower (7%), and various forms of renewable energy (3%) clearly make up 'the rest' of global energy consumption in 2014 (BP 2015).

D. Scholten (✉)
Faculty of Technology, Policy and Management,
Delft University of Technology, Delft, The Netherlands
e-mail: d.j.scholten@tudelft.nl

D. Scholten (ed.), *The Geopolitics of Renewables*, Lecture Notes in Energy 61,
https://doi.org/10.1007/978-3-319-67855-9_1

Moreover, even though reserves are depleting, global demand is still growing for fossil fuels in general. In short, the importance of coal, oil, and natural gas in global trade can hardly be overstated nor can their key role in fueling industrial processes and modern economies be denied.

The special preoccupation of energy geopolitics with oil and natural gas can be attributed to the specific geographic and technical characteristics of oil and gas systems that have shaped the particular (politicized) nature of contemporary interstate energy relations.[1] Oil and natural gas reserves are finite and geographically concentrated.[2] Energy production and refinement takes place in large, i.e. high capacity, centralized facilities (that are dependent on constant input but produce a stable output) near oil and gas fields or in facilities closer to demand centers; business models are dominated by economies of scale, making national and multinational companies the key players. The physical infrastructure is characterized by many transport modalities (pipelines, tankers, rail, road) and efficient storage options (depots, cylinders), making for an easily manageable whole of physically separable components. Moreover, oil and gas are well-suited for long-distance (global) trade as there is negligible loss of energy content. Current strategic realities and policy considerations are clearly shaped by these characteristics. Energy geopolitics is generally regarded to revolve around depleting and geographically concentrated oil and gas reserves in politically unstable countries in the Middle East and North-Africa (MENA) and Central Asia and Caspian Region (CACR). The unequal geographic distribution creates a clear separation between net-exporters and net-importers, setting up oligopolistic markets where producers such as Russia and the OPEC countries hold considerable market power and try to keep prices up and where consumers follow policies of diversification of source, origin, and route to secure access to (cheap) resources. Naval trade routes and pipeline politics play a crucial role for net-importers such as the US, EU, China, Japan, and India in securing supply from across the globe as do strategic reserves to limit vulnerability to transport bottlenecks and the effects of accidents and cut-offs. The oligopolistic setting is somewhat tempered due to net-exporters' economic dependence on oil and gas rents and net-importers' dominance in global political affairs and their sheer market size. The energy game is furthermore characterized by

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[1]It is safe to state in this regard that since the Industrial Revolution the particular constellation of the geographic location of coal, oil, and natural gas reserves, the nature of energy demand, and infrastructure technologies has formed the specific trade patterns of regional and global energy markets and shaped a complex web of relations among energy producing, consuming, and transit states and a host of non-state actors (Amineh 2007).

[2]Oil and natural gas are considerably more concentrated than coal. About 61,5% of proved oil reserves originate in just five countries ((Venezuela, Saudi Arabia, Canada, Iran, and Iraq) and about 58% of proved natural gas reserves is located in merely four countries (Russia, Iran, Qatar and Turkmenistan) (BP 2016, 6 and 20). While 57% of global coal reserves can be found in three countries (the US, China, and Russia) (BP 2015; 2016), there are far more reserves to last us into the future and a more even distribution beyond these countries.

big (multi)national oil and gas companies that hold key generation and distribution know-how and assets (refineries, storage hubs, harbor facilities, etc.), environmental degradation and harmful emissions due to fossil fuel use, and the concept of peak oil. Until recently, oil companies and net-exporters were planning to exploit ever more unconventional oil and gas deposits in the assurance that prices would slowly rise over time due to growing demand and decreasing stocks. In all, energy relations are viewed as zero-sum and inherently conflict prone.

The increasing use of renewable energy sources slowly but surely erodes the dominance of fossil fuels. Whether due to climate change concerns, stock depletion, or for reasons of diversification away from oil and gas, renewable energy use is growing, generally outpacing fossil fuels (NREL 2008; REN21 2012; Bloomberg 2013) and even our predictions (de Vos and de Jager 2014). Renewables are the fastest growing source with an average ratio of 2.6%/year, followed by nuclear (2.3%/year) and fossil fuels (lower than 2% a year). Moreover, investment is also shifting towards lower-carbon sources of energy (IEA 2016). Nevertheless, due to a general increase in global energy demand, the share of fossil fuels is still expected to cover 78% of world energy consumption in 2040, with renewables and nuclear sharing the remaining 22% (EIA 2016, 9). Essentially, the share of modern renewables in the global energy mix is expected to grow from around 11–13% in 2012 to 15–18% in 2040 (IEA 2013; EIA 2013) with nuclear accounting for the rest. The share of renewables in electricity production is expected to grow faster, from 22% modern renewables in 2012 to 29% in 2040 (EIA 2016, Chap. 5).

This transition towards renewable energy represents a game changer for interstate energy relations. The geographic and technical characteristics of renewable energy systems differ greatly from those of coal, oil, and natural gas systems. Renewable energy sources are abundant and intermittent; renewable energy production lends itself more to decentral generation and involves rare earth materials in clean tech equipment; their distribution, finally, is mostly electric in nature and involves stringent managerial conditions and long-distance losses. As the share of renewables in the global energy mix grows, so too will their characteristics increasingly shape energy geopolitics.

The geographical and technical characteristics of renewable energy systems have given rise to a number of expectations[3] regarding the nature of future interstate energy relations (Scholten and Bosman 2013, 2016). First, a shift from oligopolistic to more competitive markets due to the abundance of renewable energy sources. As most countries possess some form of renewable energy, countries essentially face a make-or-buy decision and are no longer completely dependent on overseas reserves. While political entanglements in the MENA and CACR are likely to become less, access to geographically bound renewables and availability at the right time due to renewables' intermittent nature are set to become new concerns. Second, we may expect an increasingly decentralized nature of energy production by and for a more varied set of local actors, enabling new business models and local

[3]These are discussed in more detail in Sect. 1.4.

empowerment. Third, increasing competition for rare earth materials and clean tech know-how between countries that aspire to be industrial leaders in renewable generation technology is highly likely. Another expectation is the electrification of energy systems, as electricity is the energy carrier of most renewables. The likely implications of this are a regionalization of energy relations because of long-distance losses and a strategic emphasis on continuity of service supply instead of commodity supply due to renewables' abundance and stringent managerial conditions.

Contemporary developments show some indication that we are heading in the direction of these expectations. We can already observe, for example, that net-importers use domestically available renewables as sources of diversification, eroding the market power of oil and gas exporters, who for their part worry about stranded assets. We can also see how countries like the US, Germany, and China compete for industrial leadership in renewable energy generation technologies and that they investigate access to rare earth materials as a potential bottleneck and liability. Another visible development is plans for supergrids like Desertec, the North Sea offshore wind grid, or North-American interconnection. China has even spoken about a global electricity grid in this regard. Their implications for energy relations are unclear, however. Perhaps the best indication stems from Germany's Energiewende, where European interconnection allows intermittent renewables' negative effects (price fluctuations and network congestion) to spill across borders, but also provides the benefits from trade and the possibility to level out regional peak production across the continent. Locally, the system integration of renewable energy production by households, companies, and cooperatives and microgrid options are changing networks and markets from the bottom up. They challenge established operational practices of utilities and business models of big power companies, but also offer countries new possibilities to secure energy supply and develop regions. In all, great powers such as the US, EU, China, Russia, Japan, India, and OPEC countries are clearly strategizing to reap the benefits and mitigate the drawbacks of a transition to renewable energy. New institutions seem necessary to guide potential conflict towards mutually beneficial cooperation.

Despite such developments, much remains uncertain. It is unclear, for example, how developments like great power rivalry between the US and China or the EU and Russia and technical innovations in batteries or ICT will influence the speed and direction of the energy transition and nature of energy systems. Moreover, renewables will be utilized in very different socio-cultural and political-institutional environments. Such, and other, contextual factors might influence interstate energy relations just as much if not more than renewables' characteristics. We would also do well to remember at this point that coal, oil, and natural gas are not disappearing anytime soon; fossil fuels will occupy a larger share in the global energy mix well into this century (EIA 2016). It is even questionable whether renewable sources are sufficient to power the globe at all, given their spatial and material requirements. Hence, despite the fundamental changes that renewables are expected to bring to energy systems, energy geopolitics will be dominated by fossil fuels in the coming decades. It might well be that, for the time being, expectations about the energy transition are going to affect energy geopolitics more than the actual use of renewable energy. The perception of inevitable things to come, like stranded assets or plans for supergrids, may influence country strategy more than any tangible development.

In sum, it is clear that the energy transition is more than a mere change in the energy mix. While renewables offer solutions to fossil fuel related concerns such as import-dependence, climate change, and transport bottlenecks, they create a range of new challenges for interstate energy relations. The question is more how exactly renewable energy systems impact infrastructure topology and operations, business models and energy markets, trade patterns and welfare, and strategic realities and policy considerations of producer, consumer, and transit countries and relations between them. Moreover, which countries are the likely 'winners' and 'losers' of a transition to renewable energy and how can they strategize to reap the benefits and mitigate the drawbacks? What is necessary is a comprehensive study of renewables' impact on interstate energy relations in general and for specific countries and regions in particular, supported by a framework that can help understand the relationship between renewable's characteristics and energy geopolitics.

This volume explores the geopolitics of renewables: the implications for interstate energy relations of a transition towards renewable energy. More specifically, it investigates how the geographic and technical characteristics of renewable energy systems (re)shape strategic realities and policy considerations of producer, consumer, and transit countries and energy-related patterns of cooperation and conflict between them. Focus is on contemporary developments and how they may shape the coming decades. The objective is to establish a comprehensive overview and understanding of the emerging energy game, one that puts the topic on the map and provides practical illustrations of the changes renewables bring to energy geopolitics and specific countries. To this end, a novel analytical framework is introduced that moves from geography and technology to economics and politics and developments are studied on three levels of analysis:

- The emerging global energy game; winners and losers
- Regional and bilateral energy relations of established and rising powers
- Infrastructure developments and governance responses

The Geopolitics of Renewables is the first volume to specifically explore the geopolitical implications of a transition to renewable energy; a novel topic that has gone under the radar for too long. It should certainly not be seen as the definitive work on the subject. Quite the contrary, it represents a first inroad to a new topic, one that scopes a new phenomenon and acts as a teaser for future works. It is intended for both academics and practitioners. To start, readers are provided with the first literature review of the field of geopolitics of renewables and a novel analytical framework that breaks down a complex topic into manageable pieces and structures the discussion. This not only enhances our understanding of the relationship between renewables' characteristics and interstate energy relations, it also makes the study more accessible and tangible to readers, ideal for putting the topic on the map and emphasizing the need to research and debate this topic. Second, the volume offers a comprehensive overview of global, regional, and infrastructure challenges facing countries and regions such as the US, EU, China, India, Russia, and OPEC in the emerging energy game and illustrates these with practical examples. Such an understanding may be able to assist decision makers to oversee the geopolitical implications of a growing use of renewable energy sources, allowing them to make informed decisions on securing an affordable renewable energy supply in the future.

The remainder of this chapter presents a literature review that maps the new field of the geopolitics of renewables, combining insights from international relations, (energy) geopolitics, and energy security on the one hand and renewable energy technology, energy economics, energy transitions, and energy policy on the other to clarify key concepts and their relation (Sect. 1.2). It then constructs an analytical framework that revolves around the relationship between the geographic and technical characteristics of renewable energy systems as the independent variable and interstate energy relations as the dependent variable (Sect. 1.3). Section 1.4 presents expectations with regard to the geopolitics of renewables. Section 1.5, finally, details the structure of the volume. Please note that in these endeavors this chapter builds directly upon an earlier paper and article by Scholten and Bosman (2013, 2016).

1.2 A Field in the Making

The geopolitics of renewables has only recently become a matter of academic investigation. International Relations scholars have almost exclusively focused on oil and gas when studying energy geopolitics or security whereas renewable energy experts have targeted the development and market diffusion of new technologies. As a result, while the strategic consequences of the depleting and geographically concentrated oil and natural gas reserves are well-documented, there exists a great deal of uncertainty regarding the international political implications of renewable energy systems. In other words, despite the abundant literature on energy security and energy geopolitics on the one hand and renewable energy technologies and transitions to sustainability on the other, the study of how the geographic and technical characteristics of renewable energy systems shape interstate energy relations is still in its infancy. As a consequence, a common framework with which to explore the issue is lacking and existing studies offer only fragmented, partial insights. Nevertheless, due to sufficient source material, the necessary concepts and ideas to progress are present and we are able to identify the most likely implications of renewables for interstate energy relations.

According to the International Energy Agency (IEA) “[r]enewable energy is energy that is derived from natural processes that are replenished constantly [in a natural way and includes such sources as] solar, wind, biomass, geothermal, hydropower, ocean resources [tidal and wave], and biofuels, electricity and hydrogen derived from those renewable resources” (IEA 2004, 12). Renewable energy sources hence stand in direct contrast to exhaustive fossil fuel sources such as coal, oil, and natural gas, whose deposits are essentially finite. The introduction of renewables in the energy mix is more than a mere shift in sources; it entails accompanying changes in infrastructure[4] operations, energy markets, and sector regulation as well. A renewable energy system, then, should not only refer to the actual sources, but also the infrastructure technologies such as generation and distribution assets, storage means, and control facilities necessary to bring them to market. Deudney (1989) already referred to the close relationship between the accessibility of energy sources and technological possibilities of extracting and capturing energy as the 'geotechnical ensemble'. We only add the infrastructure component. Such notions are also more in line with the modern perception of energy infrastructures as complex adaptive socio-technical systems (Ewertsson and Ingelstam 2004; Hughes 1983; Kroes et al. 2006; Kaijser 2005; Nelson 1994; Geels 2004; Weijnen and Bouwmans 2006; Scholten 2013; Scholten and Künneke 2016).[5]

The literature on renewables is dominated on the one hand by engineering studies on their technical potential, their capacity to power the future, and scenarios on their role in future energy systems (see e.g. Resch et al. 2008; Ellabban et al. 2014; Boyle 2004; de Vries et al. 2007; Moriarty and Honnery 2016; Fortes et al. 2015; IEA 2013, 2015, 2016; Ecofys 2008). Economists and social scientists, on the other hand, focus on the transition process, the challenges associated with renewables' market and system integration, the economic modeling of their diffusion, and the policy instruments that may be used to promote them (see e.g. Verbong and Geels 2007; Verbong and Loorbach 2013; Grin et al. 2010; Abrell and Rausch 2016; Bouffard and Kirschen 2008; Schleicher-Tappeser 2012; Duan et al. 2014; Meade and Islam 2015; Haas et al. 2004; Menanteau et al. 2003). This focus on renewable energy technologies and transitions to sustainability goes at the expense of international, geographic, or geopolitical aspects. Only occasionally is renewables' spatial dimension discussed (Bridge et al. 2013; Stoeglehner et al. 2011) or is global energy governance addressed (Van de Graaf 2013; Lesage et al. 2010). Nevertheless, we may draw upon these works to understand how renewables affect system operations (e.g. generation and distribution assets, storage, managerial requirements) and energy markets (e.g. prices, business models, investment

[4]We define infrastructures as "the framework of interdependent networks and systems comprising identifiable industries, institutions (including people and procedures), and distribution capabilities that provide a reliable flow of products and services […]" (Rinaldi et al. 2001, 13, citing the US Critical Infrastructure Assurance Office (CIAO)).

[5]Central to this view is that infrastructures are "erected and structured around a certain technical core of physical artifacts [that are] embedded in, sustained by, and interact[ing] with comprehensive socio-historical contexts" (Ewertsson and Ingelstam 2004, 293). The obvious peculiarity of this perspective is that it does not follow an exclusively technical topology of infrastructures but considers the interaction of the integrated physical and social/ organizational networks a crucial element in determining system performance. Focus is on how technologies, actors, and rules mutually influence and continuously reconstitute each other in a co-evolving manner characterized by lock-in and path-dependency. In this light, energy infrastructure performance - commonly measured in terms of availability, affordability, and acceptability (EC 2001)—is the result of interaction between techno-operational characteristics, energy market dynamics, and institutional arrangements.

decisions, regulations). Most importantly, they remind us to focus on renewable energy systems, not just the sources, when thinking about the energy transition.

Geopolitics refers to "politics, especially international relations, as influenced by geographical factors", usually through politicians that act upon geographic considerations (Oxford online dictionary 2012). The notion of geopolitics, belonging to both Political Geography and International Relations harbors many different interpretations. To Criekemans (2011, 4), for example, geopolitics "investigates the interaction between [political actors] and their surrounding territoriality in its three dimensions: physical-geographical, human-geographical and spatial." A different classification can be made between the more classical or orthodox geopolitics and that of critical geopolitics (Mahan 1890; Ratzel 1897; Mackinder 1904; Haushofer 1934; Spykman 1944; Kissinger 1994; Brzezinski 1997; Amineh 2003; Agnew 1998; O'Tuathail and Dalby 1998). The former relates mostly to the 'rivalry between great powers in its geographic dimension' (akin to the realist school of International Relations). In this struggle for power, land and resources are imperative for the survival of the nation. Famous examples in this light are the 'scramble for Africa', Mackinder's heartland notion, Germany's quest for Lebensraum, or US containment policy during the Cold War. The latter perceives "Geographic arrangements [as] social constructions that are changeable over time depending on political, economic and technological changes" (Amineh 2003, 24) (akin to liberal and critical theories in International Relations). Next to the traditional focus on hierarchies of power and the access to natural resources, explanatory factors are also found in the global economy (control of trade, production, and finance), political discourse, and the legitimacy of power. Foregoing a lengthy discussion on what geopolitics is, referring rather to Amineh (2003) and Criekemans (2007) for a thorough reading, we follow the simple definition of the Oxford dictionary in this volume, though we narrow it down to interstate *energy* relations.

Most works on energy geopolitics stem from the discipline of International Relations. Considering the economic and strategic importance of energy for the wealth and power of states, international relations scholars have always had a great interest in energy security.[6] A multitude of studies reveal ample examples of how

[6]The concept of energy security is notably hard to define, but its core dimensions are relatively clear (Winzer 2012; Sovacool and Mukherjee 2011; Chester 2010; Kruyt et al. 2009). At its narrowest, energy security is generally synonymous with security of supply at affordable prices. See for example the World Energy Council (2008, 1): energy security may be defined as "an uninterruptible supply of energy, in terms of quantities required to meet demand at affordable prices." Such a definition relates to dimensions such as geological availability, political accessibility, economic affordability, and infrastructure resilience (or reliability and robustness). Typical concerns relate to the finite and geographically concentrated nature of oil and gas reserves, policies of diversification of source, origin, and route, price volatility due to political instability in producer countries, and a variety of technical, human, and natural risks to infrastructure. Avoiding dependence and vulnerability are key (Percebois 2003; Gnansounou 2008). Focus is on energy supply continuity (Winzer 2012), encompassing continuity of commodity supply, continuity of service supply, and the political-economic impact of discontinuity. At its broadest, the term also includes dimensions such as environmental sustainability, social acceptability, technology

the topology of oil and gas reserves and accompanying infrastructures affect political decision making in both consumer and producer countries and the nature of interstate energy relations between them (Amineh 2007; Amineh and Guang 2010, 2012; Dannreuther 2010; Correlje and van der Linde 2006; Umbach 2010; Klare 2008; Friedman 2006; Andrews-Speed 2008; Eisen 2011). A famous example is the EU's efforts to secure energy supply in the wake of the Ukrainian crises in 2005–2006 and the pipeline politics that followed it or the more recent Energy Union. Another would be the new great game in Central Asia and the Caucasus or the Indian Ocean (Royal Symposium 2015). Most other works focus on the dealings of major oil companies and the politicized history of oil (Yergin 1991, 2011; Parra 2010) and the resource curse and political economy of energy in producer countries (Auty 1993; Akiner 2004; Humphreys et al. 2007). Considering this attention, it is all the more remarkable that present-day geopolitical and international relations literature has "only barely scratched the surface with regard to exploring the potential geopolitical effects of the transition towards more renewable energy sources" (Criekemans 2011, 4). Only a handful works in this area exist, which are treated below. Indeed, stranded oil and gas assets (Ansar et al. 2013; OECD 2015), the implications of shale gas and tight oil (Ladislaw et al. 2014; Pascual 2015), or the impact of climate change and climate policy on (energy) security and politics (Nuttall and Manz 2008; Chevalier and Geoffron 2013; Overland 2015; Salzman 2016; Streck and Terhalle 2013; Rothkopf 2009) have received considerably more attention from the field. Most of the time, renewables feature in oil and gas dominated (country) energy security accounts as means of diversification and climate change abatement (see e.g. Ölz et al. 2007; Verrastro et al. 2010). Such accounts, however, frequently neglect to give proper attention to energy security challenges specifically raised by renewables or, more fundamentally, how renewables' characteristics change the nature of energy geopolitics from the ground up. Put differently, they do not take the disruptive potential of renewables to redefine energy systems and markets as a point of departure and tend to see the energy transition as a mere shift in the energy mix towards renewables. Nevertheless, the literature harbors a rich set of operationalized notions with which to discuss renewable's impact on interstate energy relations: energy security, dependence and vulnerability,[7] stability of energy prices in global markets, trade patterns, and possibilities for

development, and regulatory stability (Sovacool and Mukherjee 2011). Typical concerns are local pollution and climate change, public acceptance and equity, sufficient investments in R&D and networks, and policy (making) transparency and commitment respectively. The policy framework with which energy security should be assured is controversial. While some decision makers trust in market instruments for optimising the energy supply mix, others urge for more government intervention arguing that markets fail to ensure adequate and sustained levels of energy security (Constantini et al. 2007; Egenhofer and Legge 2001).

[7]Dependence refers to "the share of national energy consumption which is produced domestically vis-à-vis energy imports" (Gnansounou 2008, 3735). It is closely related to the concept of risk. "The vulnerability of a system is the degree to which that system is unable to cope with selected adverse events." Vulnerability expresses the consequences of energy supply interruptions (Gnansounou 2008, 3735).

diversification (source, origin, or route), etc. These notions seem just as relevant for renewables as they are for fossil fuels when it comes to analyzing geopolitical implications.

Specifying the parts, i.e. renewables and geopolitics, does not automatically describe what the whole, i.e. the geopolitics of renewables, is all about. The novelty of the topic also does not help in this regard; there exists no readily available description of the field, what its focus is or should be and what is included or excluded. At this moment, the field merely combines all kinds of insights from the source material above to make due, but lacks a consistent and clearly defined research trajectory. This leaves it to us to define what we mean by it. Doing so, and following our earlier definition of renewable energy and geopolitics, this volume takes the perspective that the study or field of the geopolitics of renewables is at its very essence about how the geographic and technical characteristics of renewable energy systems shape interstate energy relations, i.e. the strategic realities and policy considerations of producer, consumer, and transit countries and energy-related patterns of cooperation and conflict between them. We consider investigating this core relationship key for understanding contemporary developments and estimating the impact of renewables on interstate energy relations in the coming decades.

Five additional remarks on this perspective are in order at this point. First, there is an analytical distinction between implications for interstate energy relations stemming specifically from renewables' geographic and technical characteristics and those stemming from the transition to renewables in general. For example, while the abundance of renewable sources would qualify for a geopolitical analysis as it represents a clear geotechnical feature, possibilities for industrial leadership in clean tech or the effects of renewables on oil demand are not. This creates a dilemma for this volume. On the one hand, we do not want to miss out on important implications of a transition to renewables, i.e. sacrifice practical relevance. On the other hand, academic rigor dictates a clear focus on the geographic and technical characteristics if we want to do justice to the term *geo*politics. To get the best of both worlds, this volume shows all relevant implications of a transition to renewable energy, but acknowledges the analytical difference and has special interest in the core relationship. In other words, while it follows the strict interpretation of 'geopolitics of renewables', it does a concession to the more general usage of the term. Second, the geopolitics of renewables is heavily intertwined with the geopolitics of fossil fuels. While we may analytically separate the geopolitics of renewables from those of fossil fuels,[8] the fact that both fossil fuels and renewable energy will coexist in the energy mix for the foreseeable future implies that any

[8]In principle, one could investigate the geopolitics of renewables as isolated from that of fossil fuels. In the past, energy geopolitics has been synonymous with that of fossil fuels and was studied as isolated from renewables. In the far future, energy geopolitics may be synonymous with the geopolitics of renewables, due to lack of use of fossil fuels. It is only now, in the meantime, that the geopolitics of renewables is essentially about how the increasing use of renewables affects the current, fossil fuel dominated, energy game.

(practically relevant) understanding of the geopolitics of renewables is in essence about how the energy transition affects fossil fuel dominated interstate energy relations. Third, the focus on interstate energy relations does by no means imply that non-state actors are irrelevant. Considering the importance of multinational oil and gas companies in the exploration, production, transportation, and retail of energy thus far, they cannot and should not be excluded. Moreover, renewable energy opens possibilities for new business models and empowers new actors. Fourth, the focus on interstate energy relations does not automatically exclude a necessity to investigate national political implications of renewables. Quite the contrary, domestic opportunities for more centralized and decentralized renewable energy options and powerful industrial and consumer lobbies are a key factor in determining energy foreign policy of countries. Finally, the obvious drawback of this perspective is that it excludes the opposite, i.e. studying how interstate energy relations influence the development of renewable energy. The course and speed of the transition or the specific technologies developed are not immune to other developments in global politics in general and energy politics in particular. For example, Fischhendler et al. (2016) noted how renewable energy projects are used as political tools between the Israeli and Palestinians.

First attempts to bring the worlds of geopolitics and renewables together are steadily emerging. Criekemans (2011), for example, noting the different locations for efficient generation of renewable energy vis-à-vis the location of fossil fuel reserves today, speculates about the effects on the position of major powers and their ability to utilize the transition to renewables to move up the global hierarchy. Following up, Scholten and Bosman (2013, 2016) explored the general principles or determinants that shape the nature of interstate renewable energy relations, i.e. the play of the game between producer, transit, and consumer countries and the strategic realities these countries face, in a thought experiment where the world would source its energy needs 100% from renewables. In similar attempts, Johansson (2013) explores the energy security implications of renewable energy while Casertano (2012) points to new challenges as a result of renewable and climate policies. Others investigated the effect of the energy transition in one country on its energy security and neighbouring countries, e.g. Germany's Energiewende (Bosman 2012; Bruninx et al. 2013; Strunz and Gawel 2016), the role of renewables in foreign policy (Dreyer 2013), the geo-economic implications for EU energy policy of a shifting topology of generation and infrastructure capacity as a result of renewables (Scholten et al. 2014) or the impact of EU internal decarbonisation policies (climate and energy) on its external relations with energy partners such as Norway, Russia, the Caspian region, and to a lesser extent the MENA region (Sweijs et al. 2014; Dupont and Oberthür 2015). Again others note more broadly the impact of the clean energy transition on international oil companies and oil producing countries (Haug 2011; van de Graaf and Verbruggen 2015), see possibilities for mutually beneficial energy cooperation among countries (Gullberg 2013; Gullberg et al. 2014), or have studied the risks and rewards of renewable energy (Smith Stegen 2014). Specific attention has also been paid to the conflict potential of rare earth materials in international energy dependencies (Buijs and Sievers 2011; de Ridder 2013) and security threats to renewable energy infrastructure from sabotage by terrorists (Smith Stegen et al. 2012). More recently, Stang (2016) and Huebner (no date, likely 2016) see the political weight of renewables growing in an energy geopolitical setting that is increasingly stuck between fossil fuels and renewables. They find clear winners in those countries with high energy consumption and few own resources like India, China, Mexico, Brazil, and Europe and clear losers in the form of leading oil and gas exporters whose leverage decreases as energy types and suppliers diversify and the need for long-distance transport of fuels diminishes due to decentral generation and smart grids. Hache (2016) and Paltsev (2016), in contrast, point to new dependencies replacing the old and to how the transition to renewables increases complexity of energy geopolitics due to a more heterogeneous set of technologies and actors involved, which makes predicting winner and losers highly uncertain. Most recently, the need to scope the topic and provide options for further analysis stood central in a paper resulting from a high-level workshop on the geopolitics of renewable energy in Berlin, Germany (O'Sullivan et al. 2017).

In all, while these early studies provide good examples of how renewables affect interstate energy relations, they present a fragmented picture of the issue at best.[9] As a consequence, there exist quite some ideas where renewables' geographic and technical characteristics lead us, but a framework with which to systematically approach and investigate the geopolitics of renewables is lacking. The dependent and independent variables in these studies are different, the operationalization of core concepts differs, and more often than not is an explicit investigation into the core relationship between the geographic and technical dimension of renewable energy systems and its geopolitical implications absent. As a result, there is no comprehensive overview and understanding of the geopolitics of renewables. Nevertheless, we possess the necessary concepts and ideas to frame the issue thanks to abundant source material on renewable energy systems and international (energy) relations. In turn, Sect. 1.3 develops a framework of analysis to study the relationship between the geographic and technical characteristics of renewable energy systems and interstate energy relations, while Sect. 1.4 provides a look at renewables' likely implications for energy geopolitics.

1.3 A Framework of Analysis

The study of the geopolitics of renewables is at its very essence about how the geographic and technical characteristics of renewable energy systems (independent variable) shape interstate energy relations (dependent variable). To systematically

[9] We currently have hardly any academic research on how the geographic abundance of renewable sources will affect energy system topology and cross-border energy flows, or how decentralized generation and the generally electric nature of renewable energy transportation will pose new challenges to energy trade and security.

approach and investigate the topic, we proceed by operationalizing the core concepts under study, building upon the literature review in Sect. 1.2, and discussing how their relationship can be established in a complex, dynamic setting where many contextual factors impact it. The aim is to break down a complex topic into distinguishable and manageable pieces and in this way structure a discussion on the subject. This aids the understanding of the relationship between renewables and energy geopolitics and makes it more accessible to readers. In doing so, a framework of analysis is created. Afterwards, we reflect on the use of the framework in this volume and identify various levels of analysis on which the core relationship is investigated. For the exact methods and data gathering we refer to the various chapters.

In our endeavour, the independent variable comprises the geographic and technical characteristics of renewable energy systems. This relates to sources, generation, and distribution.[10] For sources, it is of interest to look at their geographic location, their stability/variability, and their overall potential in meeting demand. Examples are efficient locations for solar farms or the intermittency of wind. Generation relates to site location, the technology used and its central-decentral nature, and material requirements. Examples are possibilities for local generation vs. large facilities or the availability of rare materials. Distribution can be operationalized as network technology and topology, operating systems, and storage means. The nature of transportation (as solid, liquid, gas, electric) and the managerial requirements to bring renewable energy to consumers like grid reinforcements and smart control systems feature here. Some of these geographic and technical characteristics are more fixed than others. The prime locations of renewable energy production such as the location and intensity of solar radiation, wind speeds, waves, geothermal hotspots, etc. are weather and geology dependent and highly unlikely to change over the course of centuries (assuming that climate change will not alter this). Distribution networks, in contrast, are actually more flexible despite their fixed appearance: electricity wires, transformer stations, storage facilities, interconnectors, and managerial control may relocate based on political decisions, costly as it may be. In the end, it is of course especially interesting how these characteristics differ from those of fossil fuel based systems and how this changes infrastructure topology and operations.

The dependent variable comprises interstate energy relations. This relates to the strategic realities and policy considerations of producer, consumer, and transit countries and energy-related patterns of cooperation and conflict between them. Strategic realities can be assessed by looking at countries' energy security

[10]The consumption of energy is left out intentionally. While the location of demand, the type of appliances, and the nature of energy use are relevant for energy geopolitics, our focus is here explicitly on renewable energy system characteristics. Investigating the implications of changes in energy demand for interstate energy relations, for example a demand shift from the global North to the global South, would in fact entail an entirely separate research effort.

situation[11]—its various dimensions,[12] components, and indicators[13] (Sovacool and Mukherjee 2011; Winzer 2012; Chester 2010; Kruyt et al. 2009)—and the means available to carry out particular strategies, i.e. a country's political and economic capabilities in relation to those of other countries. How does the energy transition affect the secure supply of energy at affordable prices? What new dependencies and vulnerabilities arise? What leverage can be used to pursue energy targets? Policy considerations can be analyzed by looking at country interests (policy goals such as availability and affordability), available policy options, and possible strategies to pursue these options. What policy responses are available to safeguard energy security? How can countries strategize to reap the benefits and mitigate the drawbacks? We assume in this regard that consumer countries are concerned about security of supply and desire stable and affordable energy prices, that producers want to maximize energy revenues to fuel their economy and desire security of demand, and that transit countries are interested in retaining their position in the infrastructure in order to extract a fair rate for their services and to create some political leverage for themselves. Energy-related patterns of cooperation and conflict can be studied by looking at historical accounts of energy relations between countries and the changes that renewable energy have brought to these relations. Specific interest may go to different forms of cooperation (long-term or short-term, via markets or bilateral) and conflict (diplomatic, legal-institutional, political and economic pressure and sanctions, military intervention). Do renewables lead to more or less conflictuous interstate energy relations, i.e. more or less geopolitical tensions, and what can be done, through policy or institutions, to remedy tensions and steer towards cooperation? The question is not only what do we see, however, but also in how far observations are a consequence of the geographic and technical characteristics of renewable energy systems.

The relationship between the dependent and independent variables may not be immediately apparent. First, it can prove a big step from geography to politics, making it hard to connect the dots. Second, numerous contextual and case-specific factors also shape interstate energy relations next to the geographic and technical characteristics of renewable energy systems, blurring what geopolitical implications are caused by renewables and which are not.

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[11]Typical things to investigate, among many others, would be national capacities for (renewable) energy generation, import dependence, access to rare materials, know-how of key technologies, manufacturing capability, infrastructure and storage options, decision rights on cross-border flows, etc.

[12]We distinguished between geological availability, political accessibility, economic affordability, infrastructure resilience, environmental sustainability, social accessibility, technology development, and regulatory stability as dimensions in this light.

[13]Sovacool and Mukherjee (2011), for example, distinguish between 5 energy security dimensions, divided into 20 components, and a staggering 320 simple and 52 complex indicators. Winzer (2012), in contrast, identifies various sourcesof risk (human, technical, natural), four clusters of impact measurement (continuity of commodity supply, service supply, the economy and environmental impacts), and six severity filters to distinguish levels of impact, i.e. continuity interruption.

To address the former, it can be beneficial to investigate the influence of renewables' characteristics on business models, energy markets, trade patterns, and welfare effects as an intermediary step. As we saw earlier, both the market integration of renewables as well as the strongly interwoven nature of energy markets and strategic dependencies of countries are well described in the literature. The economic 'detour' may therefore be convenient for linking geography and politics and in this way enhance our understanding of renewables' impact on the energy game. As an additional benefit, breaking the relationship up by adding an intermediary component provides additional insights and further structures our reasoning. To investigate the economic implications of the technical and geographical characteristics of renewable energy systems, we may borrow from works on business models, micro and macro-economics, and international economics.

First, we may study what new business models like decentral generation or flexibility trading look like in terms of value proposition, creation, and capture, or in somewhat different terms where the innovation lies, how companies or other actors are organized, and how revenue is generated.

Second, we may analyze how characteristics of renewable energy systems affect the relevant market and market structure. The relevant market refers to product characteristics, time constraints (storage possibilities), and market scope (geographic size and consumer groups). For example, renewable sources vary in terms of intermittency and markets may be local, national, regional/continental, or global. The notion of technical system boundaries strongly relates to the relevant market as they enable and constrain market functioning. For example, the ramp-up/down time of nuclear power plants as compared to combined cycle natural gas turbines impacts their position in the merit order and their functioning in energy markets.[14] Market structure refers to the number of producers and consumers (many, few, single), barriers to entry/exit, and the nature of the good (homogenous or heterogeneous, substitutability). Though not usually included, price stability may also be included here as an important market feature considering the intermittent nature of some renewables. The key logic here is a rather familiar one: do we face a buyer's or seller's market? Like with any market, the presence of many producers, consumers, and transit possibilities, results in a competitive market, and the energy source or carrier may be considered a commodity; the more monopolistic features on the consumer or producer end or bottlenecks in transport, the more the energy source or carrier becomes politicized, is considered a strategic good, and may be expected to lead to geopolitical tensions.

Third, it is of interest to investigate changes in trade patterns by looking at historical and new trade flows, shifts in import and export ratios, interconnectivity

[14]Different energy production technologies imply various capex and opex trade-offs. There is hence no uniform cost-curve to describe the economics of power plants. Network capacity is another factor that seriously impacts how much energy may be 'traded' between producers and consumers at a given point in time. Combined with demand patterns, these operational considerations have already given rise to a variety of energy markets: day ahead spot markets, long-term bilateral contracts, balancing markets, etc.

between countries, and trade creation and diversion. What new trade relations are emerging between countries and which old ones are terminated in the transition to renewable energy?

Finally, it is beneficial to look at the overall welfare implications of renewables, in terms of GDP (per capita) growth, allocative efficiency, and distribution of costs and benefits. Allocative efficiency relates here to average costs and energy prices, profit margins, and sufficient investments and innovation. The distribution of costs and benefits relates to equity considerations (which societal groups benefit from renewables and which do not), where economic activity and employment are located, and where and how national revenues are generated and on what they are spent.

To address the latter, we need to establish whether a specific change in interstate energy relations is caused by the geographic and technical characteristics of renewable energy systems or by contextual and case-specific factors. Numerous technological, operational, economic, environmental, social, and political developments can affect how renewables' impact on interstate energy relations takes form. For example, climate change and local pollution, innovations in electricity generation and storage, economic growth and globalization, historical interstate relations and great power rivalry, public support and increasing urbanization, financial markets, and national institutional arrangements all influence the way in which renewables affect energy markets and politics. Indeed, energy is but one of many aspects of international relations. These contextual ramifications within which our core relationship is embedded have to be taken into account when making approximations of renewables' geopolitical impact. Hence, whilst investigating how the geographic and technological characteristics of renewable energy systems affect interstate energy relations we need to keep a close eye on how contextual factors influence this reasoning. Only if we are able to separate the context from the geotechnical drivers, can we establish an understanding of contemporary geopolitics of renewables and their likely future implications.

Combining these considerations, we arrive at a framework of analysis that rests on four steps (see Fig. 1.1). The first step charts the implications for infrastructure topology and operations of the geographic and technical characteristics of renewable energy systems. The second investigates how renewables reshape business models, energy markets, trade patterns, and welfare effects within and among countries. The third step studies the strategic realities producer, consumer, and transit countries face in the emerging energy game, the policy responses available to safeguard their energy security, and their effect on established patterns of energy-related cooperation and conflict. Finally, the last step links the previous steps together and reflects on the relationship under study in light of broader contextual developments.

The objective of this volume is to provide a comprehensive overview *and* understanding of the geopolitics of renewables. To do justice to this dual purpose, the introductory and concluding chapters provide a more analytical contribution whereas Chaps. 2–11 focus on contemporary developments and how they may shape the coming decades. This introductory chapter puts emphasis on the (different) geographic and technical characteristics of renewables and the expectations they raise for interstate energy relations (see next section). The independent variable

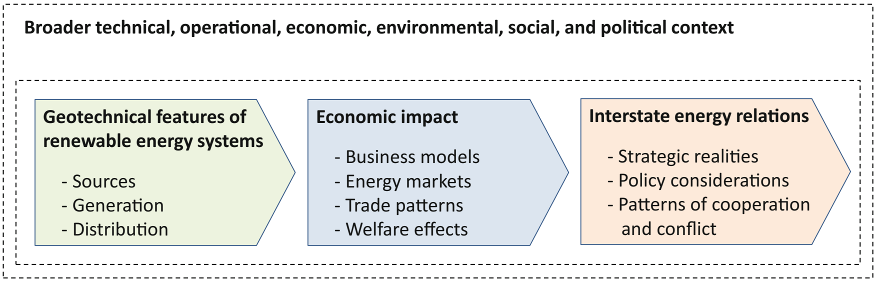

Fig. 1.1 Framework of analysis—the core relationship and its context

hence leads the narrative. Chapters 2–11 showcase the various ways in which the transition towards renewable energy is reshaping energy systems, markets, and politics. The narrative focuses on providing an overview of current developments, country experiences and intentions, and their strategic implications regarding the dependent variable. The concluding chapter summarizes the empirical chapters and reflects on the relationship under study, essentially linking the independent and dependent variable. This highlights what we can already observe from our expectations for energy geopolitics. In this set-up, the analytical framework is used to structure our expectations about and understanding of the geopolitics of renewables in the introduction and conclusion respectively. It is *not* intended for rigid application throughout the empirical chapters of the volume. Rather, it serves as a source of operationalization of the core relationship's main concepts and as inspiration for structuring thinking about the geopolitics of renewables.

To achieve a *comprehensive* overview, we need to do justice to the diverse ways in which renewables affect interstate energy relations. To this end, the core relationship is investigated on three levels of analysis: a) the emerging global energy game, winners and losers; b) regional and bilateral energy relations of established and rising powers; and c) infrastructure developments and governance responses. The global level focuses on the key developments that frame the emerging energy game among great powers from a geopolitical perspective. It offers insights into how the energy transition acts like a force of 'creative destruction' that creates new winners and losers in global energy markets and that blurs the distinction between net-importing and net-exporting countries. The second part offers a country specific perspective by zooming in on how the US, Germany, China, and India[15] approach,

[15]We limit ourselves purposefully to this selection of countries. While there are more big players in global energy, e.g. Japan, Russia, Brazil, Saudi-Arabia, etc., the purpose of the volume is to showcase the most important changes that renewables bring to energy geopolitics, not to be exhaustive in terms of country scope. We did, however, want to include a distinction between established and rising powers in the energy sector to link the countries to the processes of creative destruction at the global level; how can countries utilize the transition to renewable energy to move up in the global hierarchy or to cement their position? Moreover, as Chap. 4 already focuses on

experience, and handle the energy transition. It highlights what these countries perceive to be their main issues, the opportunities and challenges for these countries' regional and bilateral energy relations, and the strategies they may employ to reap the benefits and mitigate the drawbacks of the energy transition. The infrastructure level discusses how national energy policy is pressured from below and above by decentral generation and microgrids on the one hand and plans for centralized facilities and supergrids on the other. Domestic capacity for more centralized and decentralized renewable energy systems, the simultaneous development of microgrids and supergrids, and the rise of new local and supranational actors harbor the potential to revolutionize energy systems and markets, challenge or support vested interests, and require novel institutional responses. Combined, these three levels capture to the different arenas through which renewables influence interstate energy relations: global energy markets, direct country relations, and infrastructure developments. They also provide a clear separation between more structural changes that affect global energy markets from the country specific strategizing regarding their energy relations within that setting, where countries' range of possibilities is also influenced by changes in physical infrastructure.[16]

It is important to note that our treatment of the geopolitics of renewables is partly about what we already observe and partly about looking forward. Discussions of contemporary developments obviously differ from those that elaborate on the likely geopolitical implications of renewables in the coming decades. The former focus on factual, historical accounts of the core relationship under study within its wider context, with measurable indicators supporting claims of causality. Investigations of the likely future political implications of renewables, in contrast, utilize a number of assumptions and scenarios to support the argumentation of where trends and developments are heading. The analytical framework suits both purposes. It can be used to structure the analysis and assessment of past and contemporary developments (see concluding chapter) and can be translated into a forward-looking exercise as in the next section.

1.4 Expectations

The geographic and technical characteristics of renewable energy systems are different from those of fossil fuels. Looking at renewables' abundant and intermittent sources, their possibilities for decentral generation and reliance on rare earth

current net-exporters, preference was given to net-importers for part II. This way we avoid unnecessary duplication whilst showing divergences in country approaches to renewable energy.

[16]This is actually similar to the way Geels (2004) writes about the landscape and niche level influencing the regime undergoing a transition. The structural global level creates the larger market setting within which countries trade and the infrastructure level captures those developments that reframe the way energy can be physically moved between countries. This leaves the countries' bilateral- regional relations as the level where policy makers strategize to secure affordable energy given certain global market and infrastructural developments.

materials, and their generally electric nature of transportation, we may infer the likely implications for interstate energy relations. Four sets of expectations stand out in this regard.

The first set of expectations relates to a shift from oligopolistic to more competitive markets. Fossil fuels (coal, oil, and gas) are finite and depleting resources whose reserves are geographically concentrated. Some countries possess them while others do not. Consequently, we see an oligopolistic market where a relatively few well-endowed net-exporters dominate global energy markets and where consumers struggle to get access to these resources and/or try to diversify away from them via source, origin, or route, or hedge using strategic reserves. This game is often perceived as inherently zero-sum. Renewable energy, in contrast, is abundant and relatively evenly spread across the globe. Every country has access to at least some form of renewable energy, be it solar, wind, biomass, hydro, oceanic, or geothermal. This creates the possibility for more countries to produce a larger share of their energy needs domestically, to the extent domestic capacity allows, and to diversify their portfolio. This lowers consumers' import-dependence, to the point that they might become new producers, giving rise to the view that they are the 'winners' of a transition to renewables.[17] Nevertheless, some countries are better endowed to become efficient renewable energy producers than others, due to solar radiation, wind speeds, biomass stocks, etc. being more favorable in certain locations. This leaves less fortunate countries with a choice: should they produce renewable energy themselves (good for supply security) or should they buy it elsewhere (good for affordability)? In other words, while the distinction between net-producers and net-importers blurs it continues to exist in a different fashion. Nonetheless, more leverage is given to current consumers as they can more easily diversify away from gas and oil, and competition between consumers to get access to overseas fossil fuel reserves lessens. Producer dominance is further eroded by a decrease in demand (growth) for oil and gas as the transition progresses. Were peak oil and energy scarcity core terms a few years ago, nowadays oil depletion is overtaken by demand decline in some regions. This essentially creates a situation of oil abundance and low prices, which in turn make oil majors and producer countries worry about stranded assets and an impending carbon bubble. As revenues get less, political instability in exporting countries and regions can be expected. This is why net-exporters are generally perceived as the 'losers' of the energy transition. One needs to keep in mind here though that the capital reserves and geographical position make Gulf countries strong contenders to become future solar energy exporters. While markets are set to become less oligopolistic, market prices could be more inherently volatile[18] due to the intermittent nature of some renewable

[17]It needs to be kept in mind that while renewables currently represent a source of diversification, towards the end of the energy transition (when fossil fuels are being phased out and renewables dominate the energy mix) this no longer holds true.

[18]Inherently, because solar and wind sources are intermittent by nature and oil and gas price instability is usually caused by specific economic and political developments.

sources, with predictability also varying.[19] This would replace price volatility induced by political instability in oil and gas regions. Moreover, the intermittency could make availability at the right time more pressing than import dependence, moving emphasis from strategic reserves to grid balancing and short-term storage. Countries with unique storage possibilities such as alpine lakes or other balancing technologies are strategically well-positioned, especially if they can deliver at times of peak demand or supply. In all, we may expect a shift from strategic leverage of producers to many countries having leverage: efficient producers, large consumers, and countries able to render cheap balancing services. This also results in a shift in concerns about getting access to overseas resources, diversification policies, and strategic reserves to a strategic make-or-buy decision between secure domestic production and cheap imports, availability at the right time and price volatility, and access to biomass and more geographically bound renewable sources.

A second set of expectations surrounds the increasingly decentralized nature of energy production by and for a new and more varied set of local actors, enabling new business models and local empowerment. Energy is currently produced and refined using large, i.e. high capacity, centralized facilities either close to the extraction point or demand centers. Generation requires a continuous input of raw materials but produces a stable output. Markets are dominated by big (multi)national companies. In contrast, renewable energy lends itself to the production of smaller quantities via local facilities or units run by private individuals, businesses, and cooperatives. This not only introduces new business models (less oriented towards maximizing profits, more towards minimizing costs), but also takes market shares away from established companies in energy markets. Power companies are hence likely to share residential markets with households, small businesses, and cooperatives. As the heavy industry needs large-scale centralized production due to their high energy demands, energy markets themselves are likely to become a more business to business affair. Moreover, issues of integrating new decentral renewable production technologies into existing grids and managing the intermittency of local power generation may require new modes of operating these systems. Local balancing and storage, grid reinforcements and reserve capacity, demand side management, and a good spatial distribution of renewables might be paramount in facilitating local generation. The role of smart grids (ICT) and flexibility will be instrumental in this. In addition, decentralized energy generation may reduce energy

[19]Wind and solar energy production is characterized by relatively high capex and very low opex per kWh. Solar panels and wind turbines operate at near zero marginal costs. In times of plenty sun or wind the market is hence flooded with extremely cheap electricity. Because of this effect, Germany experiences negative electricity prices several times a year (Nicolosi 2010). Of course, the opposite also holds: in times of little sun or wind, electricity is likely to have a higher price than current coal power plants provide. Such fluctuations send strong price signals to consumers to balance their energy use over the day, given on the spot pricing, and to producers to invest in generating capacity of those renewables that can be harvested at peak-demand. They also signal the need for balancing capacity, not just for operational reliability, but also for market stability's sake. Options in this regard are large-scale storage facilities and interconnector capacity to link various sources to the same cross-border grid to manage intermittency effects.

poverty, spur local development, and empower local communities as it provides energy access, employment, and revenues to areas now lacking them. In short, cash flows do not leave the area and the independence empowers the community. This potentially lessens social unrest but could also fuel separatist tendencies to the dissatisfaction of national governments. Local production may also go off-grid. Apart from raising operational and regulatory issues, this 'island mode' provides countries with the means to protect domestic markets from foreign competition because without a physical connection these local networks essentially go off-market, though prices in energy markets may still guide prices in off-grid areas.[20] One additional effect of decentral renewable energy generation is the localization of environmental impacts. The impact of hydropower dams, the stench of biogas digesters, and nimby reactions towards onshore wind parks are much more local than CO_2 emissions. Growing competition and conflict over various uses of land are also to be expected as the smaller, but more plentiful renewable energy sites take up much more space per kWh than a few large fossil installations.[21] In any case, future electricity grids will need to combine decentralized production with existing centralized facilities, i.e. be ready to accommodate a more varied set of actors, technologies, and issues.

A third expectation is that of increasing competition for rare earth materials and clean tech know-how between countries that aspire to be industrial leaders in renewable generation technology. Currently, most materials used in oil and gas infrastructures are relatively abundant, but renewable energy generation technologies rely on a variety of rare earth materials. For example, solar PV panels, batteries, and wind turbines use indium, lithium, neodymium respectively (among others). Moreover, renewable energy is not a dense form of energy and requires more generation equipment, and hence more rare materials, to generate the same amount of kWh as fossil fuels. It may thus be expected that countries harboring these materials will find a comfortable position whereas some clean tech producers will develop new dependencies on countries possessing such materials. This development is made worse by the fact that modern economies are increasingly using a more diverse set of rare earth materials in a variety of sectors. Then again, this expectation may not materialize because alternative materials and technologies, recycling of materials, the single-import nature of these materials,[22] and the likely

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[20] A benefit from decentralization and 'island mode' is a decrease in vulnerability to deliberate (cyber) attacks that target the system as a whole. The risk is, however, that the consequences of a disruption in the local network might be more severe as there is no option for rerouting. Another drawback is that if power would become markedly cheaper abroad, the off-grid areas cannot purchase/import it.

[21] This relates not only to the fuel versus food debate for biofuels but also to local spatial planning regarding the use of scarce land in communities. Space availability may well prove to be the most limiting factor to the share decentral renewables can take in the energy mix.

[22] Once solar panels and wind turbines are constructed, they can produce power throughout their life-cycle. Coal and gas fired power plants, in contrast, require a continuous supply of resources throughout their life-cycle to produce electricity.

(re)opening of mines if these materials are used as political pressure[23] provide possibilities to remedy the situation. Countries exporting rare earth materials for their part must avoid the pitfalls of a new resource curse. Clean tech generation know-how, in contrast, is of high industrial value and certain to be of great interest. Renewable energy generation technologies are a fast-growing market in which industrial leadership could reap great benefits in terms of revenues and employment. We can already observe how the US, Germany, and China, for example, consider renewables an important export sector. Access to technical know-how, patents, and finance is crucial for the ability to exploit this economic opportunity to its fullest. It can be safely expected that industrial rivalry over clean tech equipment will intensify the coming decades as the energy transition picks up speed. It may only diminish once the market is saturated, i.e. until capacity is widely installed and demand is limited to replacement.[24]

A final set of expectations centers around the electrification of energy systems.[25] Fossil fuels are transported as raw materials in a solid, liquid, or gaseous state across the globe using a variety of means (pipelines, tankers, rail, road) and without much loss of energy content. The infrastructure consists of technically separable assets and allows for efficient storage in depots and strategic reserves. In turn, elaborate long-distance infrastructures over sea and land connect user centers with coal, oil, and natural gas producing countries via hubs and transfer facilities across the globe. Geopolitical risks stem from crucial infrastructure bottlenecks like pipelines and shipping lanes vulnerable to (deliberate) disruption. In contrast, electricity is the energy carrier for most renewable energy sources, and certainly those with the most potential (Ellabban et al. 2014). Moreover, the increasing use of electric vehicles is likely to add to the growing importance of the electricity grid in future energy distribution.[26] Electricity has distinct features compared to coal, oil,

[23]Of course, it is questionable whether the mining sector can keep up once the energy transition picks up speed; the opening of new mines knows long lead times (many years, if not a decade) before they are fully operational. Then again, rare earth materials are not actually rare, they are mostly hard to extract from their surroundings and chemical bonds.

[24]It is important to stress that this expectation only reflects the market for generation equipment, not those for energy sources or energy carriers. There, things are set to change more drastically. Fossil fuels are traded in large volumes after production facilities are in place; gas-fired power plants or small-scale oil generators need a continuous supply to produce electricity. In contrast, wind and solar radiation are free goods. Moreover, renewable energy is likely to be traded less. As part of consumption is met by local generation, there is less demand on wholesale markets for energy from centralized installations.

[25]This trend does not imply all things will be electric. A renewable future, for example, will likely feature biogas pipelines and district heating for heat systems and hydrogen as energy carrier for heavy trucks, shipping, and aviation. It does, however, mark an overall trend away from the use of multiple modalities to a concentration around the use of electricity.

[26]The switch to renewables also affects mobility. While oil is dominant today, battery electric vehicles, hydrogen fuel cell technologies, and biofuels will make up renewable based transport. The market is likely to be split between BEV for personal transportation on the one hand and H2FC for heavy duty vehicles, shipping, and aviation on the other, with biofuels being a transition fuel until BEVs and H2FCVs are sufficiently established.

and gas that represent new challenges. As electricity transport faces long-distance losses, grids tend to span countries and continents, not the globe. This essentially entails a regionalization of energy relations. It also implies a limit to the size of 'supergrids' and less long-distance shipping of oil, coal, and gas, i.e. a more land based transportation of energy. Electrification also implies more operational effort as electricity requires a physically interconnected grid and the instantaneous balancing of demand and supply. Moreover, electricity is costly to store besides pumped hydro storage[27] and requires on the spot emergency response to prevent blackouts, as accidents may cascade from one section of the grid to another in a matter of seconds. Such a grid has strict managerial requirements; cross-border arrangements regarding ownership and decision rights with respect to infrastructure development, operation, and regulation are a necessity. Combined with the abundance of renewables, this shifts emphasis from a focus on continuity of commodity supply to continuity of service supply. The regional and interconnected nature of the grid, however, reduces the possibility to interrupt delivery to single countries. Any interruption is likely to affect other countries and there will be a common interest in maintaining grid operations.[28] Then again, the effect of a deliberate action is immediate and cannot be circumvented by strategic electricity reserves other than maintaining domestic generation and transport overcapacity (in the absence of large-scale storage possibilities). Lastly, while renewable sources may be a source of diversification away from oil and gas, in the long run an increasing electrification of the energy system is the opposite as it implies the reliance on a single transport modality.

If we consider these expectations as ongoing trends in a world that increasingly replaces fossil fuels by renewable energy sources, we may reflect on their logical conclusion (Scholten and Bosman 2013, 2016). The combination of trends would paint a picture of an end state, if you will, of a world centered around 'grid communities', made up of 'prosumer countries'. In the grid community, countries share or even jointly operate (parts of) a tightly integrated electricity network and face a make-or-buy choice depending on their national capacity to service their energy needs, options for reliable cheap imports, reliability of energy partners, and political-economic-military capabilities to get what they want in case of emergency. The grid community would be of a continental size, a supergrid if you will, due to the losses of long-distance electricity transport. With the abundance of renewable sources and the option of more self-provision always on the table, getting access is not the primary concern for countries, but makes place for control over infrastructure (asset) development, operation, and regulation to exert influence over electricity flows. This way market access, low prices, and availability at the right

[27]While storage methods exist (pumped hydro storage, flywheels, batteries, super capacitors, compressed air energy storage, power-to-gas), their efficiency leaves much to be desired and those means with the greatest capacity have geographic limitations.

[28]This differs from oil and gas where the effect of an accident or sabotage action may be isolated to the part where it occurred and the entire network and its users need not be all, nor immediately, affected.

time can be assured. Cut-offs would be less of a concern. Targeting single countries within the grid community without affecting others would be difficult due to its joint and interconnected nature.

In this world of grid interdependence, geopolitical tensions are reduced but power politics is far from gone. Moreover, grid communities intensify near abroad and lessen overseas energy relations. First, the formation of grid communities is likely to occur around great powers rather than between them. Countries are likely to avoid membership in a grid community if rival powers hold a strong position (Japan and China or the EU and Russia for example). This leads to few connections between grid communities of great powers and limits their dependencies to countries part of their grid community. However, it is unclear how differences in economic development and political power play out within a grid community. For example, the position of the US in North-America is rather different from that of Germany in Europe as the former is hegemonic and the latter more a 'primus inter pares'. It is likely, however, that efficient producers, large consumers, and countries with cheap storage means hold strategic advantages. Nevertheless, it is uncertain whether a supergrid allows great powers to control their backyards or merely creates more dependencies. Moreover, energy politics is likely to become more complex when decentral generation and supergrids add new local and international actors and put pressure on national energy policies. Second, if demand can be met by production in the grid community, dependency on overseas resources and accompanying infrastructure corridors is greatly reduced. Only the need to import rare materials for clean energy generation technology remains. We may hence expect fewer entanglements of great powers in the MENA and CACR and frictions between them over access to resources, depoliticizing both regions in the process, but more activity in regions harboring rare earth materials and rivalry between actors aspiring industrial leadership in renewable energy production technology.

The alternative to grid connection would be to opt for domestic production, as far as domestic capacity allows, foregoing cheaper imports to avoid any foreign dependency. The lack of the need for cross-border energy trade implies that geopolitical tensions are reduced to those related to rare materials and/or clean generation technology imports. Of course, tensions between provinces within countries can remain as some will compete for renewable projects for purpose of revenue and employment benefits. In this light, if generation occurs in a very decentralized fashion, through small-scale turbines and solar panels by households, cooperatives, and companies for example, a large part of energy moves out of the political realm altogether. The most likely outcome, however, will be a mixed picture, in which countries will source a strategic share of their energy domestically and exploit the efficiency gains international trade offers.

Such an end-state leads to very different strategic realities for countries than those of fossil fuels. Geopolitical dependencies do not disappear, but are different. While renewables solve many contemporary energy security issues related to fossil fuels such as dependence on overseas deposits, air pollution and climate change, pipeline politics, and shipping bottlenecks, they create a range of new challenges (see Fig. 1.2 for an overview of the most notable differences). In all, it seems that

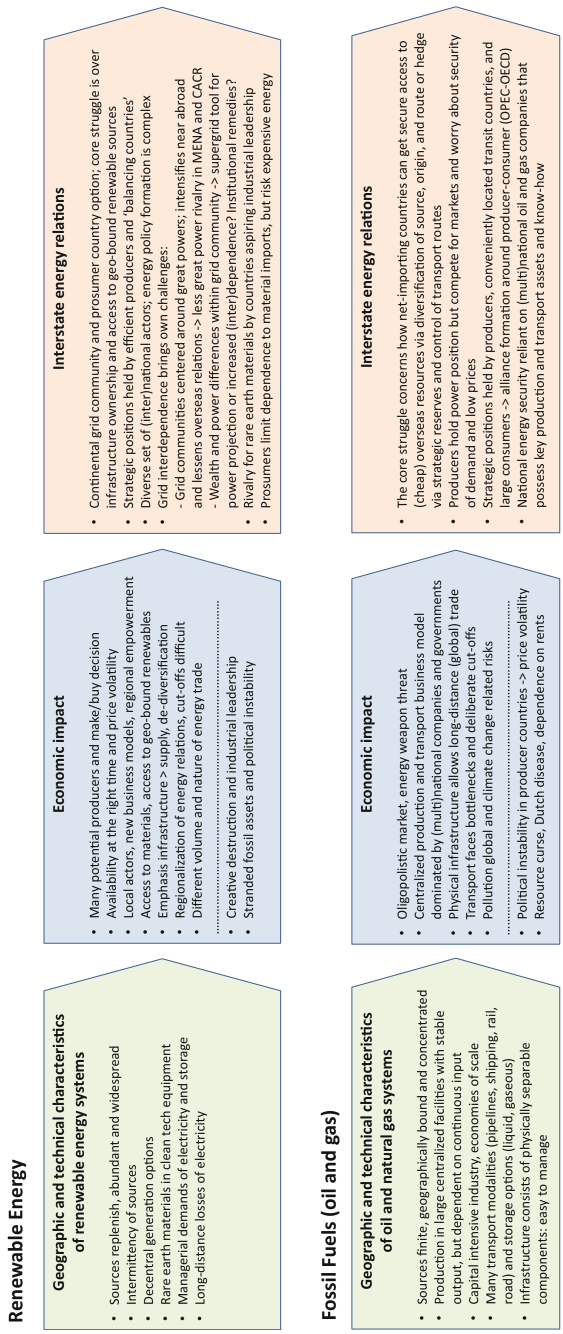

Fig. 1.2 The geopolitics of renewables and fossil fuels. *Note* The implications of the transition to renewables under the dotted lines represent those aspects that cannot be attributed to the geographic and technical characteristics of renewable energy systems but are an effect of the transition towards renewable energy (see Sect. 1.2)

renewables will alleviate interstate energy struggles overall but make them more complex and local-regional. We must not forget this. The risk of investigating the geopolitical implications of renewable energy systems is an overemphasis on the new challenges that renewables bring, not the ones that they solve. In the end, renewables add to existing considerations of countries while taking away others, redefining which dimensions are prevalent, and slowly but surely reshape the energy game.

The strategic realities of the end-state can be considered the general principles or determinants that shape the nature of interstate renewable energy relations. They are, however, based on the assumption that all countries are served by 100% renewable energy, a future far removed from the contemporary situation where fossil fuels dominate the global energy mix with a share of 86% (BP 2015). As this situation will only slowly change over the coming decades, the question becomes what we can already observe of our expectations and, more fundamentally, in how far we can actually expect to see them in a hybrid system stuck in a transition from fossil fuels towards renewables. In other words, what geopolitical struggles can we expect to see at 30, 50, and 70% renewables in the global energy mix or in 2040, 2060, and 2080, i.e. at various stages of the energy transition?

In addition, the strategic realities are solely based on the geographic and technical characteristics of renewable energy systems without embedding them in the broader real-life context where other technological, operational, economic, environmental, social, and political developments play an equally if not more decisive role in framing energy systems and interstate energy relations. Our expectations are hence geographically and technologically deterministic in nature. One obvious example is the lack of great power dynamics in this equation. How would our expectations differ in scenarios that represent different global political constellations (unipolarity vs. multipolarity; multilateral institutions vs. fragmentation) and degrees of trust in markets (free-trade vs. protectionism; globalization vs. regional blocks) such as the Regions & Empires and Markets & Institutions scenario's developed by the Clingendael International Energy Programme (CIEP 2002; Correlje and van der Linde 2006) or Shell's Mountains and Oceans scenario's (2013). Will policy considerations of countries differ in terms of a preference for security of supply or cost-efficiency? In addition, technical and operational breakthroughs in batteries or smart grids or a noticeable worsening of climate change and pollution also determine the shape of energy systems and the speed of the energy transition. We may also find that some of the global potential of renewable energy cannot actually be exploited; the material requirements and space available for renewable power generation are limited (and perhaps even altogether insufficient to power the globe given rising consumption levels). And what about the influence of powerful political and business interests, financial markets, consumer preferences, or more subtle forms of technological and institutional lock-in and path-dependence in determining the shape of energy systems? We would hence do well to remember that countries' energy foreign policy is not only driven by considerations stemming from renewables' characteristics; a myriad of other developments co-determine the nature of interstate energy relations.

Summing up, while we might have some informed expectations and ideas about an abstract, distant future, we lack a coherent picture of how renewables are actually changing the current energy game and what the implications of this will be for the coming decades. In other words, what impacts of renewables can we already observe and how will they manifest themselves in a setting where fossil fuels and renewables both share a significant place in the global energy mix and where a myriad of contextual factors co-determine interstate energy relations? This brings us back to the main question of this volume.

1.5 Structure of the Volume

This volume explores what the transition towards renewable energy implies for interstate energy relations. By introducing the field of geopolitics of renewables, developing an analytical framework, and posing expectations, this chapter has laid the groundwork for a comprehensive overview of contemporary developments. We do not strive to be exhaustive in this endeavor, but rather aim to showcase the key ways in which renewables are reshaping interstate energy relations. The overview is structured along three parts, representing the three levels of analysis. The first part presents the key developments that frame the emerging global energy game among great powers from a geopolitics perspective (Chap. 2), considering the energy transition as a force of creative destruction in global energy markets, and then delves deeper into the questions which countries are the likely 'winners' (Chap. 3) and how the energy transition affects current net-exporters (Chap. 4). In the process, the general picture of current net-importers and net-exporters as winners and losers respectively is nuanced. The second part zooms in on how the US, Germany, China, and India approach, experience, and handle the energy transition. This country specific perspective highlights what these established and rising powers perceive to be their main issues, the opportunities and challenges for their regional and bilateral energy relations, and the strategies that they may employ to reap the benefits and mitigate the drawbacks of the energy transition. The US, Germany, China and India are treated in Chaps. 5, 6, 7, and 8 respectively. The third part discusses how national energy systems, markets, and policy are pressured from below and above by decentral generation and microgrids on the one hand and plans for centralized facilities and supergrids on the other (Chaps. 9 and 10). The part ends with an investigation of institutional responses to the international challenges stemming from these developments (Chap. 11). The conclusion summarizes the core developments shaping the geopolitics of renewables, using the framework to reflect on the relationship under study and our expectations. It also draws overarching lessons for the field of geopolitics of renewables and regarding the challenges and opportunities countries face in securing an affordable energy supply in the emerging energy game.

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