Renewable Energy Technologies: Barriers and Policy Implications

Jyoti Prasad Painuly and Norbert Wohlgemuth

1 Introduction

Between 1990 and 2017, total worldwide energy demand increased at an average annual rate of 1.7%, hardly outpaced by renewables which increased by 2% annually on average [1]. Solar PV and wind energy were the fastest growing forms of renewable energy, with average annual growth rates of 37.0% and 23.4%, respectively (Fig. 1). The use of solid biofuels and charcoal increased by a mere 1.0%, dragging – as a result of their weight within the renewables category – the annual average growth rate of all renewables to 2.0%.

With these impressive growth rates, can it still be said there are barriers to the growth of renewables? First, the share of renewable energy in total primary energy supply is still as low as 10.2% in the OECD (in 2017). This share ranges from 0.4% in the Middle East to 9.0% in China to 47.3% in Africa. Second, there is a huge potential for the development of renewables and increasing its share in the total primary energy supply. Third, even the current pace of renewable development owes to support from various quarters, including governments and donors, absence of which may throttle its development, and finally, the growth is uneven, with a few countries primarily contributing to renewable energy development and potential remains untapped in others due to a variety of barriers.

Though barriers exist, these may vary in their intensity (importance) requiring major efforts where intensity is high. For example, high subsidies to fossil fuels in a country can make economic viability a major barrier, and coverage, for example, some barriers are specific to a technology or a country/region. Also, barriers have interdependencies, and addressing the key barriers can help others getting addressed more easily. For example, high subsidies to fossil fuels in a country can make economic viability a major barrier. Barriers can also be specific to a technology or a country/region.

2 Literature on Barriers to Renewable Energy

The European Union has an ambitious "Green Deal" that requires almost complete decarbonisation of the Union's energy system by 2050. The study in Ref. [2] provides a meta-analysis of projections for the shares of renewables in selected EU states. They find that "a favourable investment climate also requires the absence of severe barriers in the non-economic environment". Their paper provides a detailed overview of the main barriers and enablers for individual EU countries. Not surprisingly, countries face similar barriers and can achieve deployment through common enablers. Consequently, there is significant potential to learn from each other. The study referred here [3] presents a comprehensive literature review of barriers to large-scale market integration of intermittent renewables in the EU's electricity market. The study cited herein [4] provides an overview of public policy initiatives to promote renewable energy. They stress five pivotal actions for a sustainable energy future: strengthening policy commitment to renewable energy; mobilising investment; institutional, technical,

J. P. Painuly (✉)
UNEP DTU Partnership, Technical University of Denmark, Copenhagen, Denmark
e-mail: jypa@dtu.dk

N. Wohlgemuth
Department of Economics, University of Klagenfurt, Klagenfurt, Austria
e-mail: norbert.wohlgemuth@aau.at

A. Sayigh (ed.), *Sustainable Energy Development and Innovation*, Innovative Renewable Energy,
https://doi.org/10.1007/978-3-030-76221-6_60

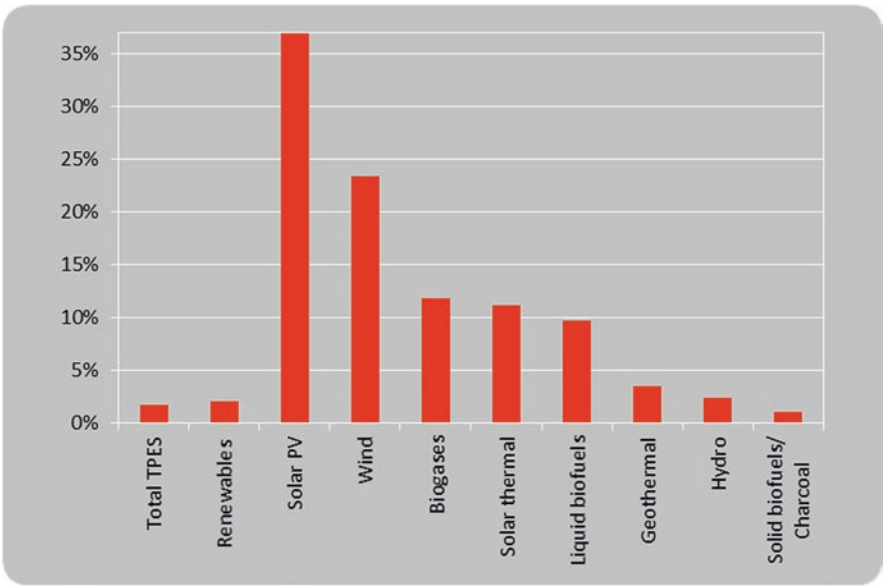

Fig. 1 Average annual growth rates of world renewables supply, 1990–2017. (Source: [1])

and human capacity building; harnessing cross-cutting impacts of renewable energy on other sustainable development goals; and enhancing regional engagement and international cooperation. Government policies that complement each other (e.g. in the areas of land use, transportation, employment, agricultural, food security, water, trade concerns, infrastructure) are more likely to be effective. Sen and Ganguly conclude that a shift towards renewables might begin with a prominent role for energy efficiency, the "hidden fuel". Conserving energy by increasing efficiency in its use increases, ceteris paribus, the share of renewables [5].

The integration of (low cost) renewables in the electricity system causes organisational problems in many cases, for example, concerning utility resource planning methods and processes that ensure the least cost service provision. The study referred in here [6] concludes that, to overcome these barriers, regulators and utilities "will need to expand and upgrade their analytical capabilities".

In regions with little growth in electricity demand, such as Europe, increasing generation by renewables depresses wholesale electricity prices, making renewables somehow victims of their own success, indicating the limits of marginal cost pricing. Wholesale electricity prices slumped from about € 80/MWh in 2008 to € 30–40. In an industry where marginal costs are of great importance to the overall economics (merit order), the economics of renewables affects electricity markets to an extreme extent, leading electric utilities to separate their renewables (and grid) businesses from (loss-making) conventional generation. The study referred herein [7] claims that the world is caught in a vicious circle: renewable energy subsidies increase their deployment, which depresses prices, thereby further increasing the need for financial support. In the extreme case of 100 percent (non-dispatchable) renewables, the marginal cost-driven market price would fall to zero, deterring any investment that is not fully subsidised. Therefore, the more successful policies to support renewables are, the more expensive and less effective policies become. The utility model of generating electricity is in many cases broken, as are markets. The "zero marginal cost society" (Jeremy Rifkin) may not be as easy to achieve as commonly thought, but lessons can be learned from the communications industry [8].

The study cited herein [9] analyses the effect of higher penetration of renewables on the price of fossil fuels. Usually, fossil fuel prices are assumed to be exogenous; however, a massive increase in the use of renewables is likely to depress fossil fuel prices, keeping all other factors constant. Lower prices for fossil fuels, as a result of the increasing use of renewables, are, therefore, likely to inhibit the economic competitiveness of renewables. They fall victim to their own success. This "green paradox" and carbon leakage are examples of this development. On the other hand, the crude oil price crash of March 2020 also makes renewables less cost-competitive as a result of changing relative prices between fossil fuels and renewables.

The economics of individual fuels is to a large extent affected by market failure – the lack of correct pricing. The study under Ref. [10] shows that internalisation of negative environmental spillovers of fossil fuels "would serve to hasten this transition process" towards renewables. This internalisation could take place, for example, by fuel and carbon taxes and provides an important contribution to the much-cited levelling of the playing field between different types of energy.

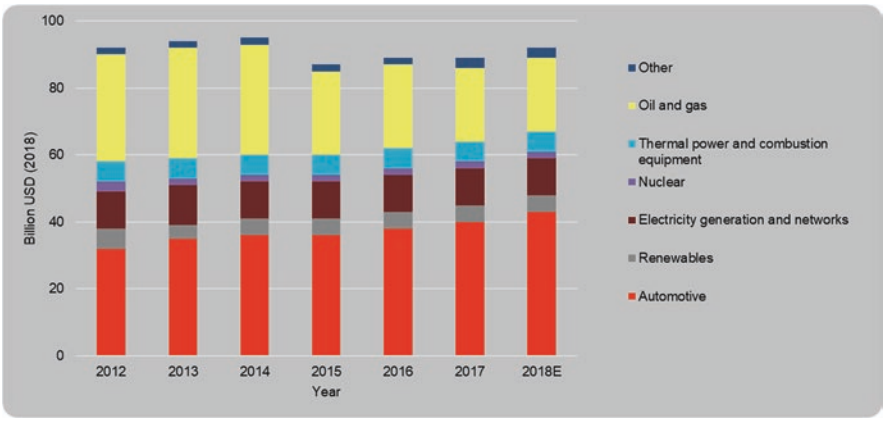

Fig. 2 Global reported corporate R&D spending in energy-related sectors, 2012–2019. (Source: [5])

A sub-optimal level of R&D expenditure can also be considered a case of market failure. The composition of public energy-related R&D expenditure changed substantially over time. In 1974 most of public energy-related R&D in OECD countries had been spent on nuclear energy research. Had this amount been spent on renewables, they would probably already have achieved full cost competitiveness. Concerning the private sector, Fig. 2 shows worldwide corporate R&D spending in energy-related sectors between 2012 and 2018. In contrast to public-funded energy R&D activities, private R&D activities account only for a modest share in total R&D expenditure.

A literature review reveals a general consensus that technical and economic barriers are no longer the principal barriers preventing some renewables from achieving a greater role in energy systems in many countries. The study under Ref. [11], for example, by collecting data through an online questionnaire sent to energy professionals, finds that social, technological, and regulatory barriers strongly affect the deployment of renewable energy all over the globe, while economic barriers strongly influence it indirectly.

For a renewable energy policy to be successful, The study referred in here [12] concludes that policymakers have to prioritise their objectives: large deployment of renewables, speed of adoption, and cost of the policy. All three objectives cannot be achieved by a single policy. The study referred in here [13] argues in favour of the possibility of large-scale electricity systems based on 100 percent predominantly intermittent renewables that meet key requirements of reliability, affordability, and energy security. In addition, such an energy transition can be implemented much faster than historical energy transitions.

In summary, in the early years, most of the barriers were common across countries and many even across various types of renewables. The list of the barriers included awareness, economic and financial, technical, political and regulatory, institutional, capacity, market, and social and cultural. However, over a period of time, many of these barriers have been addressed for some renewables, particularly in developed countries and emerging economies, which the scale of investment in the renewables reflects. In many developing countries, most or all of these barriers still remain, but the nature of barriers in countries that are leaders in renewables has changed.

Technology-specific barriers have emerged that impede large-scale deployment. Increased use of bioenergy requires a sustainable framework that also considers environmental issues. For geothermal, economic viability and sustainability of the enhanced geothermal systems on a large scale is a challenge. Ecological and social impacts in the case of new hydropower projects can have ecological and social issues, while ocean energy development may require testing infrastructure, enabling policies and regulations. Environmental concerns and public acceptance in the case of wind energy can be an issue. In many countries, issues include complicated licensing procedures and difficulty with land acquisition and permissions.

3 Barriers Identification and Policy Frameworks

Table 1 presents a summary of the barriers indicating their dimensions and impact on renewable energy projects.

Several types of barriers and categorisations can be found in the literature beyond this general categorisation. Also, the presence and intensity of barriers may vary across countries. However, in general, though many early barriers had been addressed in most developed countries through governmental policy support, new barriers such as variable renewable energy (VRE) absorption in the grid, end-use barriers in some sectors, and similar have emerged with expansion of RETs, requiring further governmental support. Financial barriers also remain in some cases due to upfront invest requirement, and

environmental issues may also come up when installation increase. Along with many developed economies, emerging economies have also been at the forefront of promoting renewable energy with China and India among countries with large-scale installations. Some of the emerging economies still face many of these barriers including economic, technical, financial, etc., and may require international support besides national efforts to achieve their renewable energy ambition. Finally, most of the other developing countries still face all these barriers and are heavily dependent on international support to address the same.

The policy frameworks need to identify and address issues specific to a country / region. The experience from implementation of renewable energy projects and efforts to address barriers as indicated in the literature review indicates the need to consider the following issues (related to barriers in Table 1) in particular:

Table 1 Barriers and their dimensions

	Dimensions	Remarks
Economic barriers	Cost of technology is high (investment and/or cost of power in case of power production)	Typically, when technology is in the initial stage of development, ocean thermal for example
	Market failure – competing technologies are subsidised or their costs not internalised	Subsidy to fossil fuels, external costs of fossil fuels not considered
	High import duties/taxes	Sometimes levied to promote local industries
Technical and infrastructure barriers	Technology availability	Technology patents, especially for new technologies
	A lack of knowledge about technology and skill to maintain	Need for training
	Access to the grid (for renewable power)	Due to distance, it can be expensive
	Grid capacity (to carry renewable power)	Strengthening of the grid may be needed
	System capability to absorb variable renewable energy (VRE)	The system may not be flexible
	A lack of skilled personnel and training facilities	
	Infrastructure barriers for some end-use	
Awareness and information barriers	A lack of information about technology, its economics, and its features	A lack of appropriate institution to promote RE
	A lack of information about benefits compared to the existing technology	Need for capacity building
	A lack of capacity to understand the technology and its benefits	
Financial barriers	High-risk perception of renewable energy technology (RET) projects	This leads to high financing cost and also makes access to finance difficult
	Difficult to obtain project finance	This is due to a lack of familiarity with RETs with mainstream finance institutions as well as the high-risk perception of RET projects
	High upfront cost	Increases financial risk and cost of finance; can make project unviable
	May require additional investment in the system (grid strengthening) by distribution companies	Distribution company may not be interested or financially sound to invest
Regulatory and policy barriers	Absence of enabling policies/regulations	RETs may need regulations such as feed-in-tariffs, quotas, etc. to compete with a traditional technology (fossil fuels) since external costs not charged to the latter
	Uncertain policies	Policy uncertainty can lead to a lack of confidence and consequently affect investment in RE
Institutional and administrative barriers	A lack of institutional capacity to promote RETs	Leads to a lack of awareness about REs, their true costs, and benefits
	Inadequate support – for example for land acquisition	Can increase the cost of RE
	A lack of involvement of stakeholders in policymaking	This can lead to misplaced priorities and policies that do not work
	Complicated and bureaucratic licensing and other procedure	These lead to delays and increased cost
Social and environmental	A lack of public acceptance due to social reasons	It can lead to increased cost and smaller market
	Environmental barriers	Noise pollution, zoning regulations for example
	Aesthetic considerations	Visibility issues leading to public opposition in case of wind turbines for example
End-use barriers	A lack of infrastructure and high cost of its development for renewable energy heating, charging stations for electric vehicles for use of renewable electricity	These are usually technology and end-use specific barriers

- A lack of awareness/information about technology can lead to its non-acceptance. For example, the high upfront cost of a solar hot water system can dissuade users not knowing that it has a short payback period, and its life cycle costs are small, particularly in regions where there is good solar radiation and alternate source of hot water is high tariffs electricity. It is therefore important to identify and focus on the removal of such barriers.
- Some core barriers lead to the presence of other barriers, and therefore, once the core barriers are addressed, other related barriers may simply disappear. For example, the economic barrier can be on account of the high cost of technology (cost barrier), market failure (barrier due to direct or indirect subsidy to competing technologies), or high import tariffs (trade barriers). Addressing any one of these three barriers or a breakthrough in technology leading to lower cost of technology may help address not only the economic barrier but make other barriers also irrelevant.
- With maturing renewable technologies and their increased penetration, new barriers have emerged in countries with significant contributions from renewables. From "no more wind turbines in my backyard" to "no more of this intermittent power in my grid", new challenges have emerged, some requiring sophisticated approaches, complexities of which are themselves a barrier. The integration of VRE in the system requires increased flexibility in the system as well as better forecasting techniques for VRE generation. Better system operations and market designs that have incentives to absorb VRE may be other measures. Increased flexibility may require integration with other regional grids that have more flexibility, energy storage, and innovative measures such as vehicles to a grid (V2G) system that can provide flexibility. Policies that promote these measures will be needed. Danish integration of higher wind energy in the grid, for example, has been possible due to flexibility in conventional production, strong transmission and distribution networks, and a larger exchange of power with neighbouring countries. Replicating Danish experience in a different setting can be very challenging. Similarly, battery storage and vehicle to grid (V2G) technologies, which have been suggested as opportunities to address the barrier related to the absorption of intermittent renewable power in the grid, are still new and in the pilot stage with their own barriers in implementation.
- The current state of renewable energy development indicates the success of efforts made by various countries to address various barriers that renewable energy faced. The results, however, are mixed in countries depending on the availability of resources and their capacity to handle the challenges faced by them. As a result, the development of renewable energy is dissimilar across countries. Several countries where renewable energy has made good inroads have now reached to stage where besides problem related to absorption of VRE in the grid, they face new challenges that include increased application of renewable energy to heating and cooling, and transport sector, two crucial sectors to increase its penetration. In the transport sector, there is a need for integrated policies to address three issues: use of renewable fuel, vehicles that use renewable fuels, and infrastructure development for renewable fuel distribution [14]. Similarly, for greater penetration to heating and cooling, integrated policies for renewable fuel use and infrastructure development may be needed.
- Some policy areas that have good potential to push renewable energy production and use but difficult to implement include a carbon tax, energy subsidy reform, and behavioural changes. The first two send price signals to the producers as well as consumers influencing their behaviour. Often, these measures are also cited to ensure that renewables are provided a "level playing field". Energy subsidy reform and carbon tax are meant to compensate for the external costs that producers and users of fossil fuels put on the society. Behavioural changes can also be brought about through higher awareness and information, in addition to taxes and penalties. Due to difficulty in implementation, these policies have been substituted by a variety of promotional measures including incentives, tax rebates, feed-in tariffs, etc. in several countries to promote renewables successfully.

4 Conclusions

From the available literature, the following conclusions can be drawn:

Despite the growth of renewable and support by governments and other stakeholders, there are barriers to its further development. Though broadly the category of barriers has not changed, they vary across regions, technologies, end uses, and in their dimension in terms of intensity and coverage. It is therefore important to examine the barriers for technology not only for their existence but also importance, intensity, and similar other features.

Several types of barriers and categorisations can be found in the literature. A lack of awareness/information about technology still remains an important barrier, particularly in developing countries. Though the list of barriers may sometimes look long in a country, it is important to identify core barriers, as removal of such barriers may also eliminate other related barriers.

New barriers have emerged with increased penetration of renewable technologies, which in many cases are technology or end-use specific. These include absorption of VRE in the grid, and end-use barriers such as increased application of renewable energy to heating and cooling, and transport sector, two crucial sectors to increase its penetration. The solutions to address these barriers are emerging slowly and may take time to prove their efficacy. Battery storage and vehicle to grid (V2G) technologies, for example, have been suggested as opportunities to address the barrier related to the absorption of intermittent renewable power in the grid. These are still new and in the pilot stage with their own barriers in implementation.

Policies such as carbon tax and energy subsidy reform that provide level playing field and address externality issues related to use of fossil fuels have long been suggested to increase penetration of renewable technologies. These policies induce behavioural changes through price signals by shifting costs of fossil fuel production and use to their producers and end users but have been found difficult to implement due to a variety of reasons. These have been substituted by various other measures including incentives, tax rebates, feed-in tariffs etc. in several countries to promote renewables successfully. The challenge however remains to address the new barriers, particularly in developed and emerging economies where renewables' penetration is significant.

References

1. IEA (2019) Renewables 2019. International Energy Agency, Paris
2. Shivakumar A, Dobbins A, Fahl U, Singh A (2019) Drivers of renewable energy deployment in the EU: an analysis of past trends and projections. Energ Strat Rev 26:100402
3. Hu J, Harmsen R, Crijns-Graus W, Worrell E, van den Broek M (2018) Identifying barriers to large-scale integration of variable renewable electricity into the electricity market: a literature review of market design. Renew Sustain Energy Rev 81:2181–2195
4. Sen S, Ganguly S (2017) Opportunities, barriers, and issues with renewable energy development – a discussion. Renew Sustain Energy Rev 69:1170–1181
5. IEA (2019) World energy investment 2020. International Energy Agency, Paris
6. Go R, Kahrl F, Kolster C (2020) Planning for low-cost renewable energy. Electr J 33:106698
7. Blazquez J, Fuentes-Bracamontes R, Bollino CA, Nezamuddin N (2018) The renewable energy policy Paradox. Renew Sustain Energy Rev 82:1–5
8. Lo H, Blumsack S, Hines P, Meyn S (2019) Electricity rates for the zero marginal cost grid. Electr J 32:39–43
9. Foster E, Contestabile M, Blazquez J, Manzano B, Workman M, Shah N (2017) The unstudied barriers to widespread renewable energy deployment: fossil fuel price responses. Energy Policy 103:258–264
10. Owen AD (2006) Renewable energy: externality costs as market barriers. Energy Policy 34(2006):632–642
11. Seetharaman MK, Patwa N, Saravanan GY (2019) Breaking barriers in deployment of renewable energy. Heliyon 5(2019):e01166
12. Blazquez J, Nezamuddin N, Zamrik T (2018) Economic policy instruments and market uncertainty: exploring the impact on renewables adoption. Renew Sustain Energy Rev 94:224–233
13. Diesendorf M, Elliston B (2018) The feasibility of 100% renewable electricity systems: a response to critics. Renew Sustain Energy Rev 93:318–330
14. IRENA, IEA, and REN21 (2018) Renewable energy policies in a time of transition. IRENA, OECD/IEA, and REN21