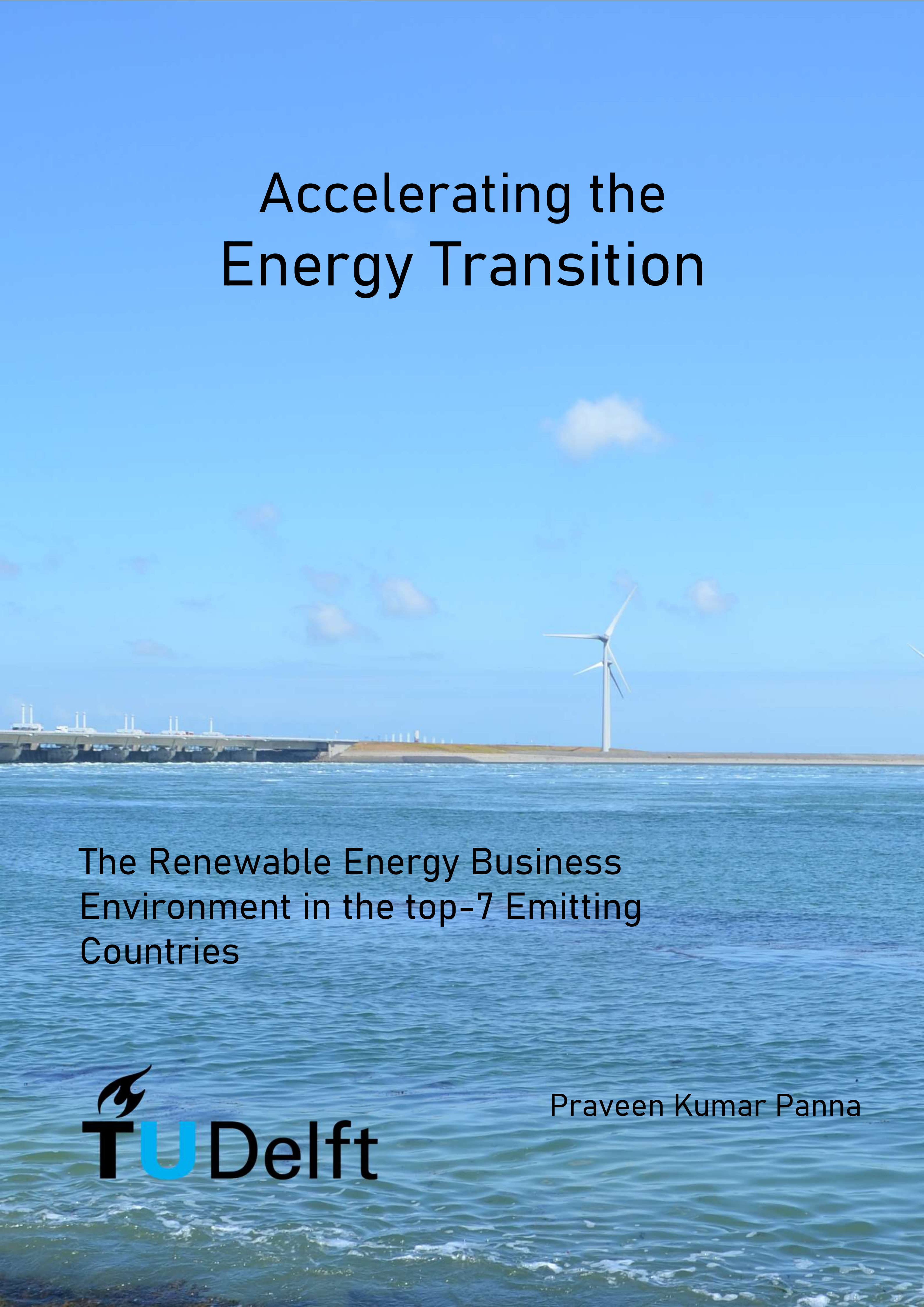

Accelerating the Energy Transition

The Renewable Energy Business Environment in the top-7 Emitting Countries

Praveen Kumar Panna

TU Delft

MSc Thesis in the Department of Electrical Engineering, Mathematics and Computer Science: Graduation Report
Accelerating the Energy Transition: The Renewable Energy Business Environment in the top-7 emitting countries

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October, 2019

The cover photo is clicked by the author himself (near Delta Park Neeltje Jans, The Netherlands)

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In partial fulfilment of the requirements for the degree of
Masters Sustainable Energy Technology

Delft, October 2019

I would like to dedicate this thesis to my loving parents …

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Praveen Kumar Panna
Delft, October 2019

Summary

Combating climate change is one of the most urgent tasks for the present generation. The transition of the current energy sector may play a crucial role in combating climate change by cutting down considerable GHG emissions. Solar PV and wind power generation technologies offer a unique solution, due to their technological maturity, and capability to de-couple the growing energy demand with the emissions linked to fossil-based power generation. Although these renewable energy (RE) technologies observed tremendous growth in the last decade, they contributed towards 16% of the total installed capacity and 6.7% in the generated electricity in 2017. Hence, there is a clear need to accelerate the energy transition to limit global warming to 1.5°C.

Further, since the power sector is heavily capital-intensive and the current technological-policy-market system is designed to support the conventional power system, it is crucial to create a conducive business environment to accelerate the deployment and power generation through solar PV and wind power. Furthermore, the energy transition of the power sector of the top-7 countries with the highest emissions has the potential to reduce around 29% of global emissions, which led to the research question, *"How good is the business environment for renewable energy in the top-7 emitting countries?"*.

Literature Review: Literature review revealed that the business environment of renewable energy may be referred to the macro-business environment existing in a country, which is composed of or affected by the political and legal structure, laws and policies, macroeconomic scenario, and the combination of all the external forces and situations, which are outside of a business but have influence on the deployment of renewable energy. It also suggested that the binding RE consumption directives, motivations for economic development, suitable RE policies, economic factors, and technological factors may contribute towards driving the RE deployment. Hence, the literature survey systematically collected and presented the concept of the business environment, factors of PESTEL framework, interactions among pertinent factors, and policy and regulatory indicators designed by the World Bank and International Energy Agency (IEA).

Methodology: Based on the literature survey, the RE business environment framework was developed to map and assess the renewable energy business environment of a country.

The framework incorporates the external-business environmental factors such as the national political will for the adoption of renewable energy (RE), RE policy and regulatory environment, economic incentives for RE, industrial growth, technological preparedness for high share integration of variable RE, and interactions among these factors. This research further explores these interactions among factors.

Results and Analysis: The developed framework was applied to the power-sector of China, the USA, India, Russia, Japan, Germany, and South Korea. The results captured a snapshot of the current status of the RE business environment in the concerned countries, which were compared, analyzed, and discussed. The RE business environment also showed a close resemblance to the current growth in the RE industry. Countries in the order of decreasing conduciveness of the RE business environment were Germany (good, RE industry growth factor > 66%), Japan, China, and the USA (moderate, between 33% and 66%), South Korea and India (low, below 33%), and Russia (extremely poor, 2.5%).

The strong influence of the technological preparedness on the RE industry in Germany is also restricting the accelerated deployment of renewable energy due to the technological limitations in the country. Japan's strong influence of the good economic incentives have boosted the RE deployment share, and with the present influence of the political will and the technological preparedness on the RE industry, these two latter factors need to be strengthened to expand the domestic RE market. China needs to strengthen the limited power dispatch capacity between the generation centres in the northern and northwestern China to the load centres in the central and eastern China, as due to the strong influence of technological preparedness on the RE industry, the limited capacity is restricting the further RE deployment. The RE industry of the USA is supported by the strong influence of the mandatory RPS scheme (in some states) on the RE industry, however, needs strengthened political support. The good influence of the RE policy on the RE industry (along with moderate economic incentives) is driving the RE deployment in South Korea; however, accelerated deployment is restricted by the influence from the political will which is supporting a low target RE share. Political will, which is one of the main drivers in most countries, could not sufficiently influence the RE policy and the RE industry in India. Inconsistencies and weak influence of the RE policy on the economic incentives and the RE industry are observed in India. All the necessary interactions among factors are absent in Russia along with the insufficient influence of the existing capacity based renewable support scheme (CRESS) on the RE industry.

Discussion & Conclusion:

The research fulfils the purpose by providing an overview and a broad understanding of the renewable energy business environment in the top-7 countries responsible for the highest GHG emissions. Although, the research revealed limitations in the methodology, factor selection, interactions, comprehensiveness and depth of the framework, concurrence with the observed growth in the RE industry validates the findings.

The results validate the initial expectation and assumption, that in order to create a conducive renewable energy business environment, it is crucial to strengthen the factors of the RE business environment, and these factors must be able to influence (interact with) each other positively, and such healthy interactions create a conducive business environment for the growth of renewable energy, as observed in Germany. On the other hand, factors acting in isolation, weak influences and interactions among these factors add to the challenges in the growth of renewable energy, making RE diffusion quite challenging in the existing dominant fossil-powered electricity sector, as observed in Russia. Technological preparedness and the political will were found to have the strongest influence on the renewable energy (RE) industry. Influence of the economic incentives on the overall growth of the RE industry is observed to be of comparatively secondary importance. Influence of the renewable energy policy on the RE industry is found to be quite weak, with the weakest correlation observed in the economic incentives created by the renewable energy policy. Secondary influence of the economic incentives on the growth of the RE industry is due to the inherent market failures in the power industry and the insufficiency of the market forces to drive the growth of the RE industry. The weak influence of the RE policy on economic incentives is due to the role played by the electricity prices and the fossil electricity cost in the country. Furthermore, the RISE indicators used to map the RE policy environment is found to be inefficient in reflecting the ground realities of the suitability of the RE policy, the effectiveness of RE policy in achieving the desired renewable energy deployment, and the capacity to measure the economic incentives for renewable energy.

Hence, the national political will with the available technological preparedness was primarily responsible for driving the RE business environment in Germany, China, India, Japan, and South Korea. In the absence of the national political will, the state political support in terms of the mandatory state RPS targets with the economic incentives created due to expensive electricity prices and fossil electricity drive the RE business environment in the United States. Almost absence of the political will and the lack of technological preparedness failed to create the RE business environment in Russia, which is further exacerbated by the availability of abundant and cheap fossil fuel and subsidized electricity.

Furthermore, in addition to contributing knowledge about the current status of the renewable energy business environment in these countries, which are continuously changing and evolving, especially in the recent years, this research contributed by developing a framework, which can map the RE business environment of a country in an absolute scale, and which may be further extended to a more extensive set of countries or for in-depth study any country of interest. Hence, this research provides an appropriate starting point and lays a basic framework to portray and further explore into the better understanding of the business environment of renewable energy to help the RE industry to identify the available opportunities, help the policymakers and stakeholders to take the required steps to improve the RE business environment.

Solutions: Key recommendations to improve the RE business environment include the following solutions: (a) adoption of legally binding and ambitious RE targets at the federal level, (b) availability of the official detailed road-map for energy transition and planning for future RE projects, (c) RE policies designed to satisfy the requirements of the RE industry and create suitable economic incentives to overcome the market challenges and market failures, (d) compulsory grid access and connectivity to the RE projects with sufficient dispatch capacity, (e) priority dispatch, (f) improving RE forecasting, and scheduling & dispatch of the conventional power generators, (g) technology-specific policy and price support, and (h) grid-connected energy storage capacities.

This research further uncovers opportunities for future research in multiple ways: (a) extending the research to a more extensive set of countries, (b) by conducting time-dependent analysis, (c) inclusion of statistical analysis for quantifying the strength of interactions among factors, (d) improving the comprehensiveness of factors, (e) developing country-specific comprehensive framework, and (f) further adaptation to mathematical model and computer algorithm for simulating the RE business environment of a country.

Hence, this research along with the field of renewable energy business environment offers a range of possibilities for future research, which may contribute towards a better understanding, improved solutions, and may eventually accelerate the energy transition.

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Nomenclature

Acronyms / Abbreviations

COP Conference of Parties

IEA International Energy Agency

IRENA International Renewable Energy Agency

GHG Greenhouse gases

Gt Gigatons

GW Gigawatt

IPCC Intergovernmental Panel on Climate Change

LCOE Levelized Cost of Electricity

Mtoe Million tonnes of oil equivalent

PJ Peta Joules; 1 PJ = 0.023884 MToe = 0.277778 TWh

RE Renewable Energy

RES-E Renewable Energy Sourced Electricity

RES Renewable Energy Sources

RETs Renewable Energy Technologies

TWh Terawatt hour

UNFCCC United Nations Framework Convention on Climate Change

VRE Variable Renewable Energy

Chapter 1

Introduction

"Our house is on fire, and according to the IPCC (Intergovernmental Panel on Climate Change), we are less than 12 years away from not being able to undo our mistakes. In that time, unprecedented changes in all aspects of society need to have taken place, including a reduction of our CO_2 emissions by at least 50%". The 16-year-old Greta Thunberg did not mince her words to express the urgency to take action against the climate change, in the World Economic Forum Annual Meeting in Davos, in January 2019 (Greta Thunberg, 2019).

Combating climate change would require specific measures from different sectors, including the transition of the current energy sector, which is responsible for around 80% of the global emissions (IEA, 2018*c*). Renewable energy has a potential to play a very significant role in reducing global emissions, as it can decouple emissions from the growing energy demand by reducing 91-95% of CO_2 equivalent emissions (per kWh in a life-cycle) as compared to the conventional fossil-fuel generated electricity (IPCC, 2012). A better understanding of the renewable energy business environment would further help to accelerate the energy transition of the power sector. Hence, this thesis attempts to improve the understanding of the business environment of the renewable energy.

This chapter presents a background of the growing global energy demand, CO_2 emissions, electricity consumption and the need for the energy transition in Section 1.1. Although, the share of solar and wind is increasing in the electricity sector (26.5% in 2017 (REN21, 2018)), to limit the global warming within 1.5°C, the energy transition needs to be accelerated (IPCC, 2018), which motivates this research discussed in section 1.2. Further, Section 1.3 defines the goals and objectives of the research. The main research question is discussed in section 1.4, followed by the framework of the research in section 1.5. Section 1.6 summarizes the structure of the report.

1.1 Background

The global energy structure is changing. However, the energy transition seems to be a very complex, region-dependent and multi-variable speed process which is taking shape based on the pressing energy demands (IEA, 2018*c*). According to the current policy scenario of the World Energy Outlook 2018, the world primary energy demand is expected to reach 809,000 PJ by 2040 as compared to 582,000 PJ in 2017, pushing the carbon dioxide (CO_2) emissions up by over 30% to 42.5 Gt (IEA, 2018*c*). Although energy is the backbone of any economic system, and crucial for the development of the human civilization, anthropogenic greenhouse gas (GHG) emissions have led to the concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere to increase at an unprecedented level as compared to the last 800,000 years (IPCC, 2014). GHG emissions in the last 50 years have increased the atmospheric CO_2 levels by over 34%, and burning of the fossil fuels for power generation, transportation and industrial use are the major contributors towards GHG emissions which are driving the climate change (NOAA, 2014) (WHO, 2018).

One hundred ninety-five countries signed the Paris Agreement 2015 under the United Nations Framework Convention on Climate Change (UNFCCC), to set out global actions to limit the global warming to well below 2°C above pre-industrial levels and to pursue efforts to limit it to 1.5°C (UNFCCC, 2015). According to this agreement, all the parties were required to put forward their best efforts or comprehensive national climate action plans (INDCs). Although the adopted steps are not sufficient to keep the global warming below 2°C, the agreement would try to find ways to achieve this target.

To limit the global warming to 1.5°C, IPCC has recommended reducing the net global emissions by around 45% by 2030 (net emissions budget of around 25-30 Gt CO_2 equivalent per year by 2030), as compared to the 2010 levels and net zero emissions by 2050 (IPCC, 2018). However, the trend of global emissions over the last two decades do not show any cumulative conscious effort to reduce emissions, but it is just a reflection of varying global economy (Enerdata, n.d.; International Monetary Fund, n.d.). Hence, to achieve the IPCC targets, a tremendous collaborative effort from all sectors would be required, and especially from the energy sector which alone contributed to 32.6 Gt CO_2 equivalent in the year 2017 (IEA, 2018*c*). Over the last 25 years, the high share of fossil fuels like coal, oil and gas, while fulfilling the global energy demand has resulted in such high emissions. In 2017, fossil fuels supplied 81% of all the global primary energy demand (IEA, 2018*c*).

Due to the above presented scenario, the energy transition has become one of the most critical issues of the present time. Technological advancements and plummeting prices of the modern renewable technologies have offered suitable alternatives for the contemporary fossil-based energy structure. Electricity has also emerged as the second-largest used fuel in terms of end-use, increasing the share in total final consumption to 19% (in 2017) as compared to just over 15% in 2000 (IEA, 2018*c*). Global electricity consumption has increased by over 70% since 2000, reaching 22,200 terawatt-hours (TWh) in 2017 (IEA, 2018*c*). Solar photovoltaics (PV) and the wind power have shown tremendous growth in the last decade and by the end of the year 2018, the total global installed capacity of solar photovoltaics (PV) exceeded 500 Gigawatts (GW), and the wind power capacity reached almost 600 GW (Sources). However, when compared with the total installed capacity of over 6950 GW (2017, including all renewables), and 6.7% contribution in the generated electricity (Enerdata, n.d.), solar and wind power are yet to cover a fair share (IEA, 2018*c*). The fig. 1.1 presents the growth trend in the global capacity installation of solar PV and wind power in the last decade and fig. 1.2 presents their share in the electricity produced.

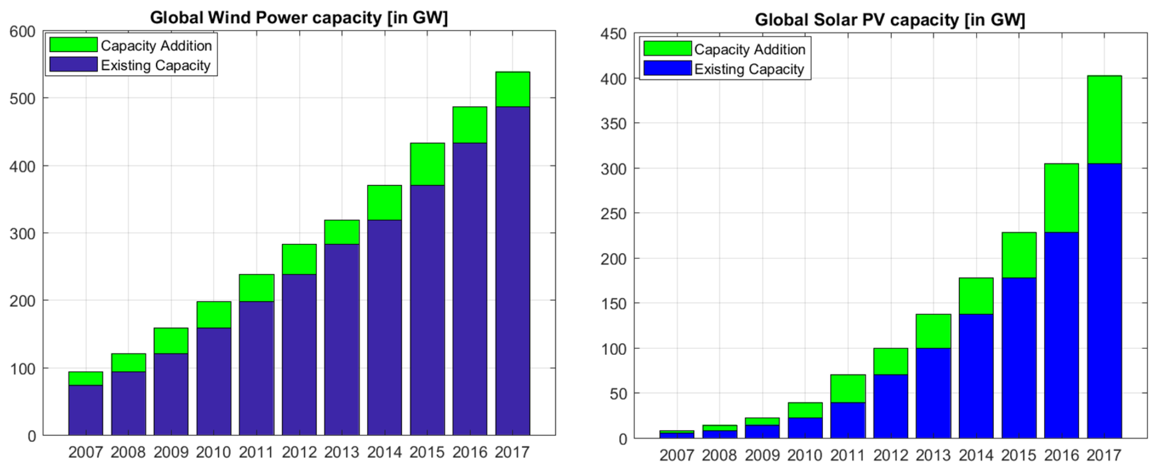


Fig. 1.1 Trend in global solar PV and wind power (2007-2017)(Source: REN21 (2018))

1.2 Research Motivation

Considering the small share of solar and wind power, and growing electricity demand, there is a clear need to accelerate the energy transition. The growing share of renewable energy would contribute towards (a) increasing access to affordable and clean energy, and (b) combating the climate change, which is also the goal 7 and 12 respectively, of the United Nations' Sustainable Development Goals (United Nations, n.d.).

If we look at the global electricity market, it is that it is not a homogeneous or a single big market, rather it is a combination of a large number of small pockets of the energy markets. The consumption and emission pattern of these energy markets vary from each other. The top-7 countries are responsible for over 60% of the global GHG emissions, and the complete

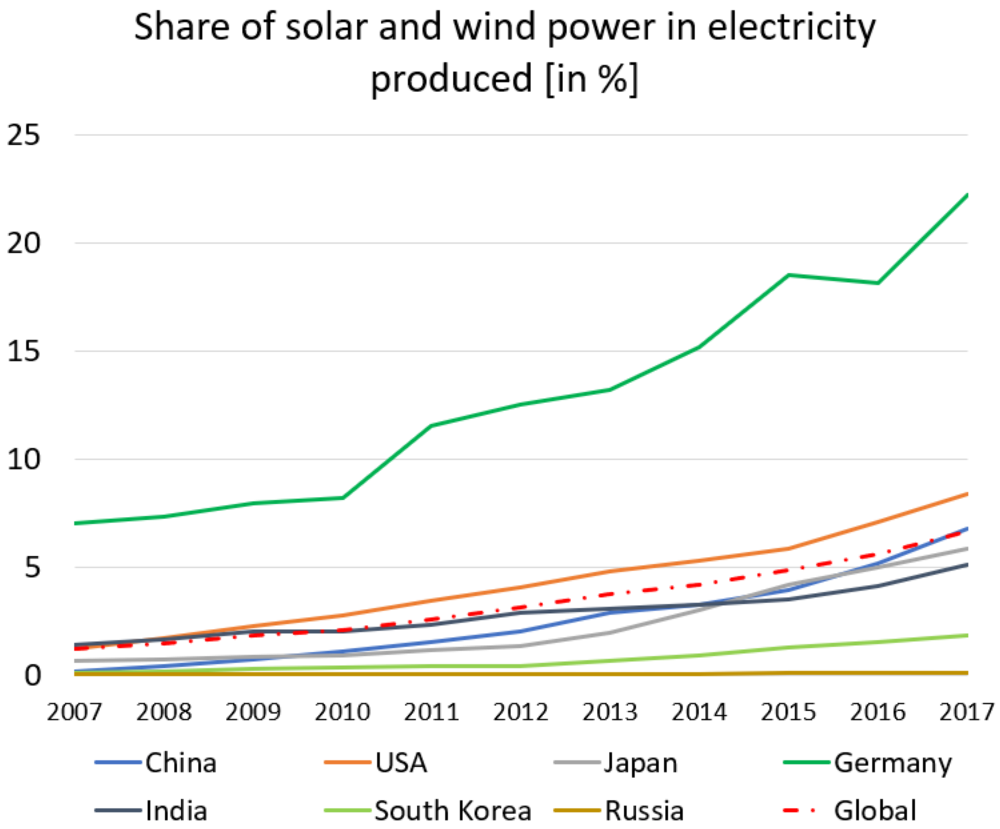


Fig. 1.2 Share of solar and wind power in the electricity produced (2007-2017) (Source: Enerdata (n.d.))

energy transition of the power sector of these countries has the potential to reduce around 29% of these emissions (IEA, 2017*a*). Hence, this research covers the power-sector of top-7 emitting countries. Table 1.1 summarizes the annual emissions of top-7 emitting countries in 2016.

Solar PV and wind power generation technologies offer a unique solution, due to their technological maturity, and capability to de-couple the growing energy demand with the emissions linked to the fossil-based power generation. Hence, it is essential to understand how the deployment of solar PV and wind power can be accelerated. Further, since the power sector is heavily capital-intensive and the current technological-policy-market system is designed to support the conventional power system, it is crucial to create a conducive business environment to accelerate the deployment and power generation through solar PV and wind power. A business environment is the combination of all the external forces, situations, institutions, laws, which are beyond the control of a business, but they influence the business (Fernando, 2011). Although, many researchers have conducted region-specific researches to understand the potential, factors, and barriers influencing the deployment of

Table 1.1 CO_2 emissions from fuel combustion (Source: IEA (2017*a*).)

Country	CO_2 emissions ($MtCO_2$ in 2016)	Share in global emissions	Emission by power sector ($MtCO_2$ in 2016)
China	9100	28%	4390
USA	4800	15%	1900
India	2100	6%	1070
Russia	1400	4%	780
Japan	1100	4%	573
Germany	732	2.25%	320
South Korea	589	2%	310

new RETs, a good understanding of the renewable energy business environment is not yet developed. Hence, conducting the case studies of the top seven emitting countries, which are in different stages of the economic development and energy transition, this research would attempt to design a basic framework to assess the business environment of solar PV and wind power. An improved understanding of the renewable energy business environment would help to accelerate the desired energy transition.

1.3 Goal and Objectives

The goal of this research is: *to develop a better understanding of the business environment of solar PV and wind power*, which would eventually help to accelerate the energy transition of the power sector. A business environment of renewable energy may be referred to the macro-business environment existing in a country, which is composed of or affected by the political and legal structure, laws and policies, macroeconomic scenario, and the combination of all the external factors and situations, which are outside of a business but have influence on the deployment of renewable energy. To achieve this, the first objective of this research would be *to design a framework to understand the business environment of new RETs*. The second objective would be *to use the framework to assess and analyze the suitability of the business environment in the concerned countries.*

Renewable energy (RE) business environment caters directly to the whole spectrum of RE industry comprising of the RE deployment and installation industry, the renewable power generators, utility-scale power producers, independent power producers, RE equipment manufacturing industry, RE equipment supplying industry, public and private investors, domestic or corporate prosumers (consumers who also participate in electricity production), and service providers involved in the renewable energy business. The government-owned companies, public, private, and even small start-ups can benefit from a conducive RE business environment and may contribute towards energy transition.

A better understanding and assessment of the business environment would help various actors and stakeholders, by providing them a better market signal to understand the available opportunities in the renewable energy market, which would help them to take required steps to grow in the existing market or to identify necessary improvements to strengthen the renewable energy business environment.

The purpose of this research is not to build an exhaustive list of factors and drivers of the energy transition; however, to use the pertinent factors and analyze their interactions. This research deals only with the solar PV and wind power market in the electricity sector. Interaction and interconnections between the different value chains with the RE business environment, like with the heating or cooling sector, hybrid models like hydrogen and PV, wind and fossil, or electrification of other energy-dependent sectors are not covered as a part of the thesis.

The objectives mentioned above would help to answer the following research question presented below.

1.4 Research Question

"How good is the business environment for renewable energy in the top 7 emitting countries?"

As the current technological system (centralized power generation, transmission, and distribution system), policy framework, and the business environment are designed to support conventional power-generation through non-renewable energy sources (74% share in global electricity produced in 2017 (REN21, 2018)), new renewable energy technologies face significant challenges in increasing share in the existing power system. Hence, this research would explore the business environment in the top-7 emitting countries and would attempt to assess them for their conduciveness for the growth of solar PV and wind power.

This would be achieved in two steps, (i) Framework selection or design: business environment of renewable energy would be explained through an existing framework or by developing a suitable framework, and (ii) implementation of the framework to assess and analyze the suitability of the business environment in the concerned countries.

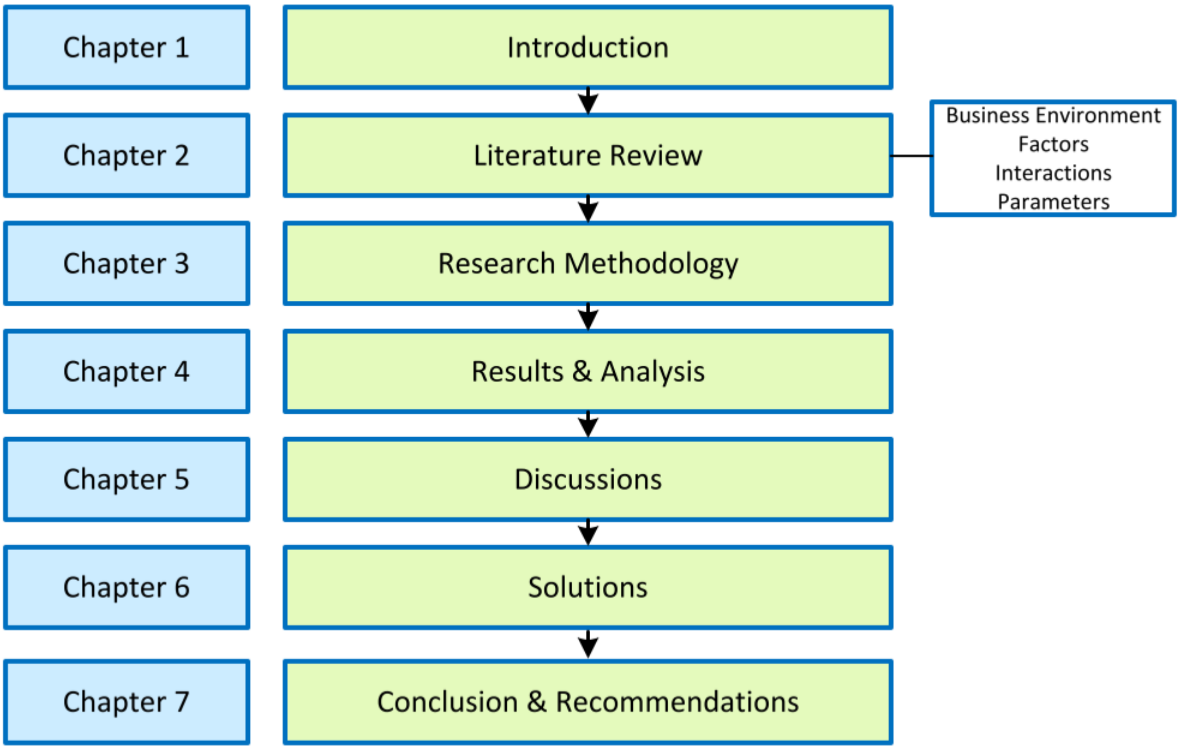


Fig. 1.3 Thesis Structure

1.5 Structure of the thesis

The fig 1.3 summarizes the structure of this report. *Chapter 1* introduces the thesis while presenting the necessary background and motivation to the research, then further defines the goals and objectives, and frames the research question, which this thesis would aim to answer here on-wards.

Chapter 2 presents the literature review conducted for this research. As depicted in the fig 1.3, this chapter is divided into five subsections. Firstly, the underlying theory of the business environment is discussed in section 2.1. Section 2.2 discusses the basic theory of factors impacting the business environment from the existing literature. Section 2.3 discusses the available literature on the interactions of these factors. Section 2.4, talks about the existing policy and regulatory indicators as designed by the World Bank and International Energy Agency (IEA), followed by a conclusion and learning from the literature review in section 2.5.

Chapter 3 presents the Renewable energy business environment methodology designed in this research. This chapter is composed of eight subsections. The first six subsections define the underlying theory of renewable energy business environment, the adopted factors, which are political will, RE policies and regulations, economic incentives, industrial factor, technological preparedness and explains the methodology adopted to quantify and measure them. Section 3.7 covers the theory on relationship and interactions of these factors, and their combined effect on the renewable energy business environment. Further, section 3.8 presents a summary of the sources used for collecting input data for this research.

Chapter 4 presents the calculation, results and analysis of each of the factors mentioned above in section 4.1 to section 4.5. Results and analysis of the interaction of these factors are presented in section 4.6, followed by the comparative analysis of the overall national business environment in the concerned countries.

Chapter 5 discusses the strengths, limitations, and the scope of improvement in the research in section 5.1, presents a reflection on results in section 5.2, and a comparison with the existing research and contributions of this research in section 5.3. Section 5.4 briefly presents the error analysis of interactions discussed in section 4.6.

Chapter 6 presents the solutions and recommendations to improve the current state of renewable energy business environment in the concerned countries.

Chapter 7 presents the overall conclusion of the results, summarizes the answer to the research question, and learning from this research and recommendations for future research.

Chapter 2

Literature Review

Based on the research question formulated in chapter 1, this chapter presents a literature review to explain the background knowledge, already existing concepts and theories, which would help to develop a better understanding of the research topic. This literature review is based on the desk research based on reviewing relevant research papers and reports by international research agencies.

Although, the literature survey was aimed at reviewing the existing literature for the available methodology to measure and compare the renewable business environment of different countries, and their current status, the literature is available in the fields of business environment (Fernando, 2011; Worthington and Britton, 2009), PESTEL framework, Regulatory Indicators for Sustainable Energy or RISE (World Bank Group, 2017), which cover different segments of renewable energy business environment but does not provide an overall framework that can map, represent, and compare the complex nature of renewable energy business environment of a country. Hence, this literature review chapter systematically collects the various elements from the existing literature, which would be used later in chapter 3, to develop a framework for renewable energy business environment.

To achieve this, this chapter starts with the basic background theory on the business environment in section 2.1, and then narrows down the discussion to external business environment, which is relevant for this research. After this, section 2.2 explains the external factors based on PESTEL framework which may have influence on the business environment of renewable energy based on the existing literature. Further, section 2.3 presents the scarcely researched area of interaction of these factors through existing relevant research papers. Section 2.4, talks about the existing policy and regulatory indicators as designed by the World Bank and International Energy Agency (IEA). Section 2.5, concludes with learning from the literature review.

The author does not suggest that the literature reviewed were completely exhaustive but they represent the important relevant literature in the concerned field of study, in the time frame from the year 2000 and later, and for the countries relevant for this research. Further literature were included for supporting facts, explaining required contexts and for developing the arguments.

2.1 The Business Environment: Theory and role in deciding the future of a business

In order to accelerate the energy transition, it is important to understand the business environment of renewable energy, within which it operates. Business environment may be referred to all the external factors which influence the activities and growth of a business (Fernando, 2011). A generic business environment is represented by the fig. 2.1. Although a business environment may refer to internal and external environment, this research is mainly focused on the external-business environment. The external environment may be defined as the combination of all the external forces, situations, institutions, laws etc. which are outside of the business and their control, but have influence on the business. The external-business environment can be further divided into the micro and macro environment. This research is mainly focused on the macro-business environment of the renewable energy. Understanding the macro-business environment of renewable energy is important because the current business environment is designed to support the conventional fossil based energy industry, which needs to be modified in order to support the growth of renewable energy and hence, help in the energy transition. The business environment of a country is composed of or affected by the political and legal structure, laws and policies enacted by the central or state governments, available institutional structure, monetary and fiscal policies, import and export policies, macroeconomic scenario, social beliefs and practices, and so on.

Understanding the business environment becomes important because it suggests the constraints and opportunities a business environment may offer (Fernando, 2011). This information may be very useful to the different stakeholders involved in the business. This would help investors and existing companies to select a better market for investment or project the growth of business in the future. For the start-ups, it can be very helpful in selecting their beachhead market. For the governments and lawmakers, this would help to identify the focus areas of improvement, which would boost the current and future business environment, and drive the economy.

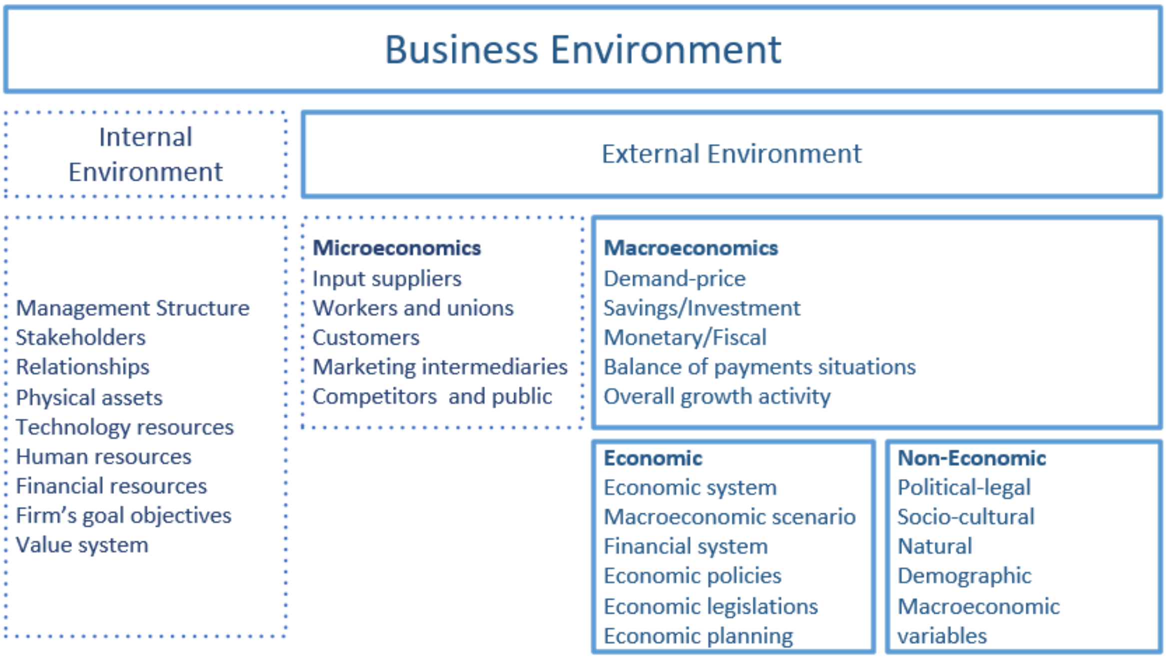


Fig. 2.1 Business Environment (Source: Fernando (2011))

Although the business environment is an established field of study, there is a research gap in the adaptation of business environment for large scale diffusion of renewable energy, especially solar photovoltaics (PV) and wind power. Hence, this literature survey attempts to collect elements from multiple sources and field of studies, to create a suitable framework to understand the business environment of renewable energy in the electricity sector. Furthermore, although the business-environment study suggests interactions among the factors (Worthington and Britton, 2009), these interactions and their combined effect on business has not been explored.

2.2 Factors impacting the RE business environment

After understanding the basic theory of business environment, this section explains the pertinent factors which may impact the renewable energy business environment based on the existing literature. Political, economic, social, technological, environmental and legal factors (which are also described as PESTEL framework) are discussed in detail in this section. Table 2.1 presents the list of literature discussed in detail in section 2.2 and section 2.3.

Political Factor: This covers all the political and governmental factors influencing the business environment. This factor helps to analyze the ways and the degree of government intervention in the economy. This may include multiple factors like the national or state

Table 2.1 Overview of literature review

Author	Factor categories	factor interactions	Section
Aguirre and Ibikunle (2014)	Political, socio-economic, country specific	-	section 2.2
Cadoret and Padovano (2016)	Political drivers, economic factors, environmental, political economic	factors impacting political will	section 2.2, 2.3
Ecofys (2014)	Technical factor	-	section 2.2
Gallagher (2013)	-	factors influencing political decisions	section 2.3
Hake et al. (2015)	Political factor	influence of politics on energy policy	section 2.2, 2.3
Kroposki et al. (2017)	Technical factor	RE integration	section 2.2, 2.3
Lewis and Wiser (2007)	-	RE policy and RE industry	section 2.3
Lin and Zhu (2019)	Economic factor	-	section 2.2
Liu et al. (2019)	RE Policy		
Lund (2009)	-	RE policy on commercialization and industrial expansion	section 2.3
Marques et al. (2010)	Political factor	factors influencing political decision	section 2.2, 2.3
Marques and Fuinhas (2011)	Economic, environmental	-	section 2.2
NREL (n.d.*a*)	Technical factor	-	section 2.2
NREL (n.d.*b*)	-	RE integration	section 2.3
Renn and Paul (2016)	Political factor	influence of politics on energy policy	section 2.2, 2.3
Shah et al. (2018)	macroeconomic factors, RE policy		section 2.2
Song et al. (2017)	PESTEL	-	section 2.2
Gottschamer and Zhang (2016)	-	policy-policy, technological-societal, environmental - RE deployment, technology - technology	section 2.3
Zalengera et al. (2014)	PESTEL	-	section 2.2
Zhang et al. (2013)	-	RE policy and RE industrial policy	section 2.3

political environment, political stability/instability, government policies, government promotions and programs, corruption level, special tariffs, taxes, and even the international political influences, international agreements, international co-operation, foreign trade policies, import duties etc. Further the direct involvement of the government with the educational and infrastructural development would also influence the economy and the business environment.

Renn and Paul (2016) and Hake et al. (2015) have presented detailed case studies of convoluted relationship between the national politics and energy policy in Germany, the pioneer of the energy transition. Hake et al. (2015) presents a historical path dependent developments in the country, and emergence of political parties promoting nuclear shutdown, environmental agendas, fueled by the local protests and public opposition, and emergence of political support for renewable energy, leading to the finalization of the Energiewende, the German's road-map for energy transition. Renn and Paul (2016) through historical study, found out that although public protests and opportunities reaped by the political parties resulted in strongly diminishing the nuclear power industry, but led to the paradoxical result of increased emissions (from 2011 to 2013) due increased dependence on coal.

Cadoret and Padovano (2016) suggests that considering political and institutional factors are very crucial to develop the understanding of renewable energy deployment as investment in renewable energy resources is mostly a political decision, resulted due to political pressure and other political factors. So, the research conducted panel data analysis to study the influence of political factors as drivers of RE policies and RE deployment in European Union countries. The research concluded the following results: (a) Lobbying by the existing market players have a strong negative impact on the RE deployment, (b) left-wing parties were found to be more supportive in promoting RE over right-wing parties, and (c) EU's involvement with the target based RE consumption directives, are the main stimulus in investing and increasing the renewable energy infrastructure, and market based forces were insufficient. Marques et al. (2010) after an empirical analysis in the European countries also concluded similar results of strong negative influence of lobbying of actors involved in conventional (fossil-based) power generation and strong positive drive for RE deployment due to the binding directives.

Economic Factor: This includes the macro and micro economic factors which directly and indirectly influence the industry and the business environment. This may include multiple factors like investment(including their sources, distribution, scale), economic growth, inflation, exchange rates, interest rates, income level, disposable income, credit availability and price fluctuations. These economic factors influence the market by impacting the demand and supply of the product and services.

Marques and Fuinhas (2011) after studying 24 European countries concluded that the income level and the oil/coal/gas prices did not have any significant driving force in RE deployment. Lin and Zhu (2019) based on panel data model analyzed the driving factors of RE technological innovation in China, and concluded that the effect of energy prices (fossil) have insignificant effect on RE technology innovation. Surprisingly the literature review suggests non-conclusive evidence of direct relationship of GDP (Gross domestic product) on the RE electricity production. To understand the complex relationship between the economic state and RE deployment or in other words insufficiency of the market forces to boost the growth of renewable energy, Cadoret and Padovano (2016) conducted statistical significance tests, while including one lag in the GDP per capita, and rate of growth of GDP per capita with a lag. The results suggested that increased economic activities, increases demand of energy. However, this immediate additional energy demand is met by flexible power generators, which are fossil-based. This leads to reduction in overall share of RE power consumption. However, continued increase in energy demand leads to additional investment in RE deployment and hence, having positive impact on the RE share. Shah et al. (2018) conducted unrestricted VAR model analysis for USA, UK and Norway to analyze the impact of macroeconomic factors on the RE investment and concluded that the influence of macroeconomic factors are country dependent and countries with little support for RE adoption would be more sensitive to changes in the macroeconomic variations. Cadoret and Padovano (2016) also suggests that the poor countries give more importance to economic development, even at expense of the environment, however the rich countries may show opposite behaviour.

The economic factor which have potential to impact the supply or deployment of renewable energy is the economic viability and competitiveness of renewable electricity, which makes it an attractive option for energy production (REN21, 2018). Various international agencies and researchers monitor and assess the cost/price trend of solar PV and wind power annually. Economic viability of renewable energy can be assessed by comparing the cost of electricity generation or localized cost of electricity by RE sources against the electricity prices and/or the incentives available for renewable power generation/installation. This factor needs further detailed analysis, which would be conducted as a part of this research.

Social Factor: This covers the whole spectrum socio-cultural environment represented by the overall cultural beliefs, public concern, values, norms, behaviour and trends. This includes the demographic distribution, population trend, age distribution, preferences, consumption behaviour, lifestyle and so on. All these factors directly impact the demand and the consumption behaviour and may become a very important external factor deciding the success of any business.

Although, distributed renewable power generation from solar and wind power sources, benefit the society and should be given priority Nijhuis et al. (2015), there is hardly any conclusive literature evidence of social factors getting translated into major RE deployment or RE power consumption. This may also be due to the lack of sufficient technological and market mechanisms, to connect the social factors or public preferences to influence the RE demand/supply at a reasonable level.For example, if private consumers or companies, wish to consume power only from renewable sources, then suitable mechanisms should be available to provide an option to such consumers. However, with development of suitable mechanisms to include public preferences, contribution by social factor may increase renewable energy demand in the near future. With the recent up-gradation to mandatory smart meters by 2020 in EU, consumption behaviour can be monitored and hence, can be modified, contributing towards demand side management. Consumers can further be motivated towards energy neutrality through distributed renewable power generation.

Technical Factor: For the success of any business (product or services), this becomes a very important fact. This may include the level of technological development, trend of technological changes and practices, technological awareness, research and development (R&D) activities, the level of automation and innovation. This factor helps to analyze how fast the technology would diffuse in the market, would it even be accepted or rejected by the market and if there is sufficient technological growth and support which would help the adoption of the technology.

Since, development of renewable energy is strongly dependent on various dimensions of technological development and adoption of the new technologies, technical factors would be one of the strong pillars or deciding factors of large scale deployment of the technology. Technological factors can be assessed in the following categories:

a) Research and development of solar PV and wind power technology:

Solar PV technological development: There has been good research focus towards the technological development and up-scaling of solar photovoltaics which has brought 68% reduction in the installation cost of utility scale solar projects and 73% reduction in the overall levelized cost of electricity (LCOE) during the period 2010 to 2017 (IRENA, 2018*c*), and this is expected to continue in the near future without any reasonable barrier towards large scale diffusion of the technology. Fig. 2.2, presents the up-scaling of solar PV technology with falling trend of total installation cost, LCOE, and increasing capacity factor of utility scale projects.

Wind power technological development: Wind turbine technology is also growing at a very good pace and this also expected to continue in the coming decades. Hence, based on the current developments, technological aspect of the wind power is not expected to present

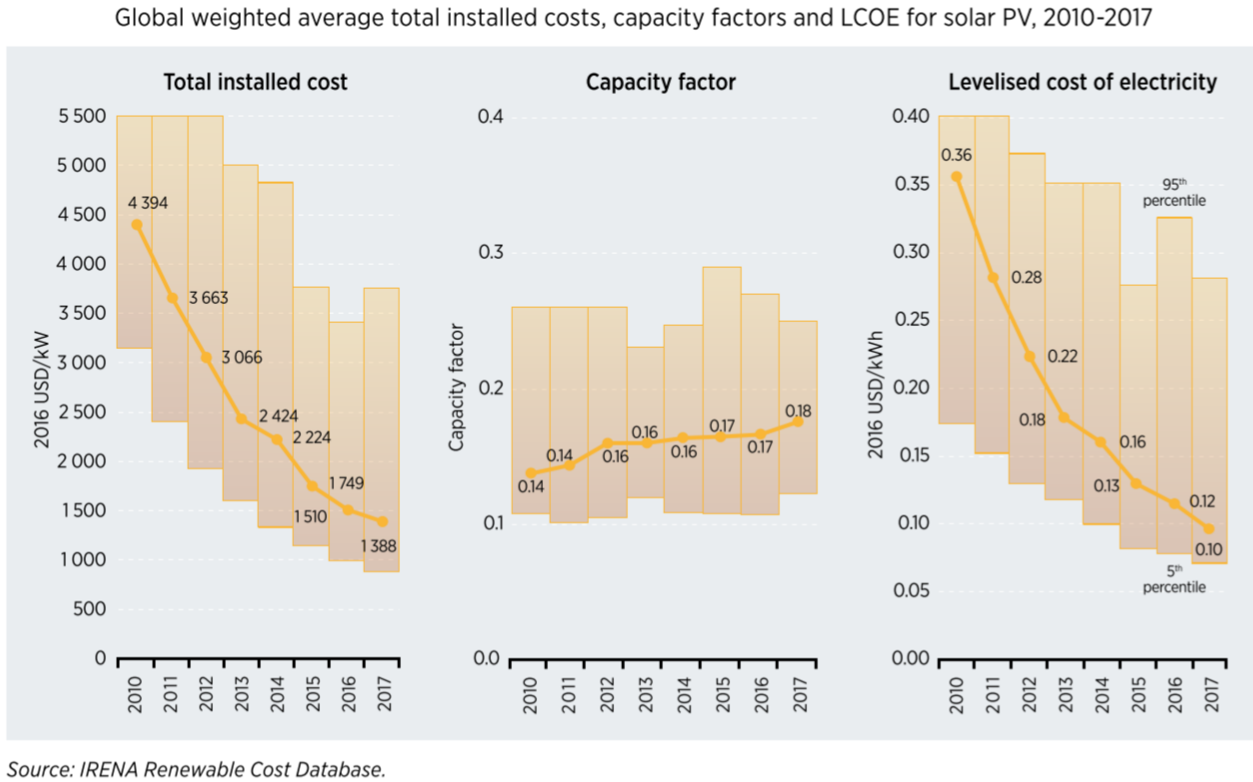


Fig. 2.2 Solar cell efficiencies (Source: IRENA (2018*c*))

any barrier towards the deployment of technology, rather the fast improvement is making the technology more economically competent. Fig. 2.3, presents the recent development in increase in size of wind turbines.

b) Integration challenges in high share of variable renewable electricity (VRE): Study of integration of high share of variable RE generated electricity is a very broad field of research, and discussion of all possible challenges and solutions available in existing literature is beyond the scope of this research. Integration challenges faced are usually country and region specific, and based on the local conditions. Hence, a very brief overview of different fields of study on this segment is presented here.

National Renewable Energy Laboratory (NREL) conducts Electric sector integration analysis to study the challenges and possible impacts of increasing share of RE on grid operability and future requirement in infrastructure upgradation (NREL, n.d.*a*). The analysis is done in the following four areas: (i) Studying impacts of high share of variable solar PV and wind electricity penetration through modeling and analysis, and electric system capability. (ii) Flexibility analysis of the electric system, to study the available flexible power generation, factors required to improve the grid flexibility, power generation technology mix, responsible and shiftable loads, energy storage capacity, or new transmission requirements,

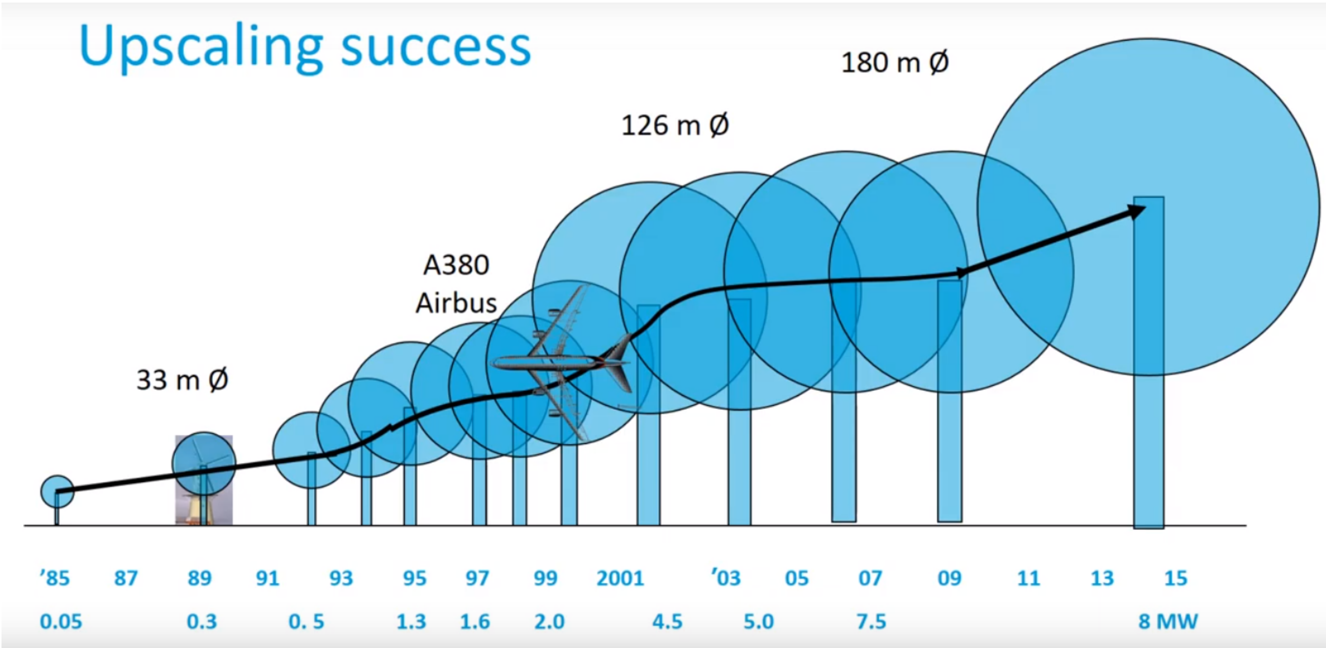


Fig. 2.3 Wind turbine technology growth (Source: TU Delft (n.d.))

to balance the supply and demand with increased share of RE. (iii) Quantifying the impacts on the conventional power generators, by studying the adjustments required in terms of output level, frequent ramp-up/ramp-down or shutdown/start-up required and impacts on their operation efficiency (reduction in plant efficiency) and emission levels (increase in emissions), to accommodate variable RE. (iv) Transmission infrastructure analysis to study and plan location specific transmission upgradation required to provide the power delivery capacity, while maintaining the robustness and reliablity of the transmission system. Fig.2.4 summarizes electric sector integration analysis by NREL.

Kroposki et al. (2017) have analyzed the challenges of high VRE penetration level in the USA in the following six categories: (i) Handling the uncertainty and variability of VRE: The literature suggests following solutions to handle this challenge: increasing geographical diversity for smoothing the net power output by VRE sources, transmission line expansion to connect the VRE generation centres and load centres, improved coordination for power balancing and power exchange, deployment of energy storage capacities for improving temporal shifting capacity of supplied power, demand-side management and inclusion of electric vehicles to provide flexible load. (ii) Reduction in synchronizing torque and system inertia, and increase in inverter based power generation. DC (Direct current) power generated by solar PV and wind power need inverters to feed power to AC (Alternating current) grids, and these inverters are zero inertia systems, whereas conventional power generators are synchronous machines which provides mechanical inertia and stability to the electric system

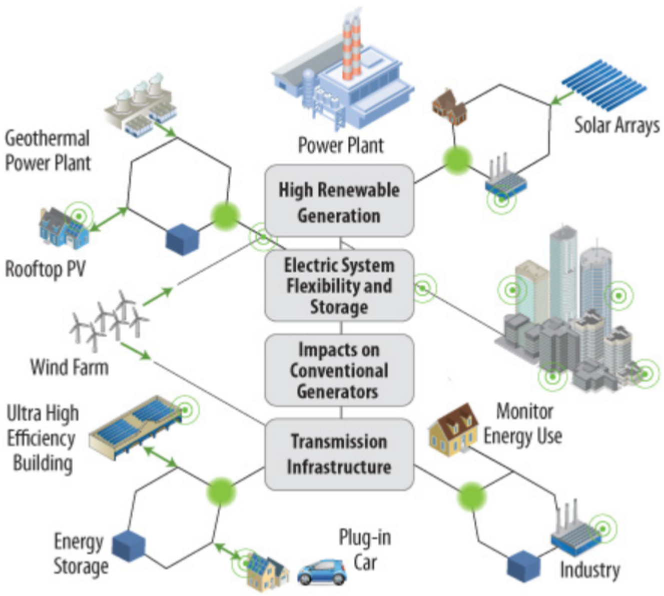


Fig. 2.4 Electric sector integration analysis (Source: NREL (n.d.*a*))

during contingencies. It would be very challenging to control the voltage and frequency if the grid becomes a zero-inertia system and might become unfeasible to handle it. Hence, the literature suggests grid forming inverters with seamless power flow path between different technologies, huge number of decentralized and geographically distributed power generating units, capability to operate without synchronous machines, and availability of control methods for maintaining power quality. (iii) Stability of the power system: Increasing VRE penetration reduces the synchronous generator connected to the power system, which affects the power system stability by affecting the transient and small signal stability, power frequency stability, and power reliability while maintaining stable voltage/voltage-ampere (VAR). Increased share of VRE electricity also increases the need of inertial response. (iv) Protection of power system: The protection system of the existing power system would need to be upgraded, as the existing system uses relays based on high fault currents produced by synchronous generators, however, inverter connected VRE power sources, does not produce such levels of fault currents or thermal overload that can trip protective relays and provide protection to the grid. (v) Increased distributed power generation makes the power system distributed, which increases the risk of uncontrolled islanding or isolation from the main grid during faults. Hence, better anti-islanding technologies would be required with improved communication infrastucture. (vi) The inverter based high VRE share power system would need to adapt to provide black start to restart the grid, while acting as a voltage source and high current inflow to feed in adequate power.

Ecofys (2014) provides a summarized study of the available flexibility options which can help to improve the flexibility of future power systems for integrating high share of VREs. The reports provides information regarding reaction time of ramping/cold start, plant efficiency, investment/variable costs, plant lifetime, technology maturity, potential environmental effects, economic/technical/political barriers for implementation and possible role in increasing VRE share for a wide range of technologies like flexible power generation technologies (fossil based, nuclear power, bio-gas), integration with heating, demand-side management (industrial and household loads, and services), power storage options (pumped hydro, compressed air, batteries, flywheel), power conversion to heat or gas, and further options to uncap and increase the market/and network flexibility. Similarly, Alizadeh et al. (2016) provides a summary of flexibility resource options which is presented in fig. 2.5.

Hence, it can be observed that technological preparedness of electric system is an important factor which would also influence the penetration level of VRE.

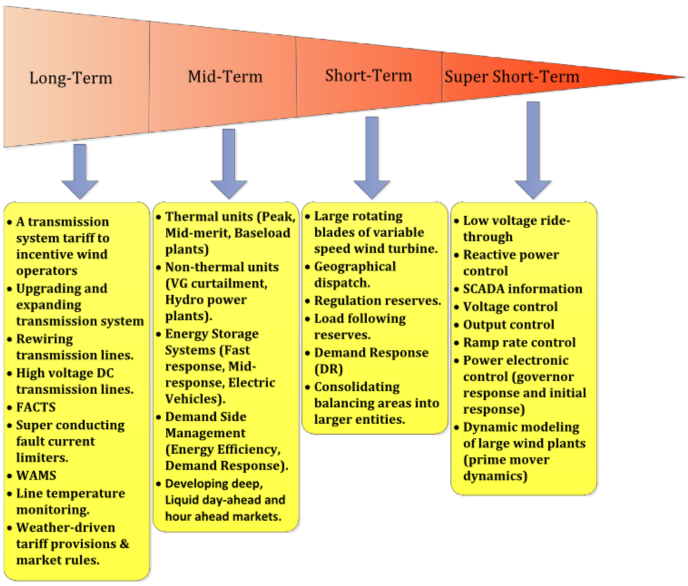


Fig. 2.5 Flexibility sources with chronological flexibility support (Source: Alizadeh et al. (2016))

c) Technological awareness: Technological awareness may refer to awareness the technology among consumers or awareness in the power industry. Since, the end users are not technologically impacted by the selected source of power generation, consumer technological awareness does not play any role in the deployment of RE power generation. Regarding, technological awareness in the power industry, although renewable power generation technologies are considered relatively modern forms of power generation, the technological skills required for production of RE power generation equipment and installation of RE projects is much simpler as compared to conventional technologically complex nuclear power plants, thermal and gas powered power plants. Hence, improving the technological awareness in the power industry is comparatively an easier problem to solve.

In this thesis we are more concerned about the large scale diffusion phase of the RE technology and less about the technology introduction, initial phase diffusion or commercialization phase. Hence, as the solar PV and wind power technologies are now relatively mature technologies, grid integration would be mainly focused in this thesis as a part of technological factor.

Environmental Factor: This factor has gained a little attention in the recent years, due to increased awareness of climate change, rising emissions, national and international targets of emission control and the restrictions imposed by the laws. Environmental factor can also become important due to increased pollution level in a local area, scarcity of clean natural resources like water and air, reduced availability of raw materials, extinction of species, opposition from NGO's or it can also be guided due to positive changes like increased awareness about environmental preservation, improved attitude towards recycling, reusing and also towards supporting the renewable energy. Marques and Fuinhas (2011) after applying panel dynamic estimators for 24 European countries found that the public awareness of climate change, CO_2 emission reduction targets, or sustainability are not sufficient motivators for switching to RE sources. Cadoret and Padovano (2016) suggests hardly any direct relationship between the environmental tax and the RE deployment, as the revenue collected are usually spent on usual purposes, rather towards protecting the environment. Although, the environmental factor may not result in huge RE deployment in a country, literature suggests that at smaller geographical level like few provinces in China with extreme CO_2 levels have resulted in increased RE technological innovation and RE deployment (Lin and Zhu, 2019).

Legal Factor: This factor becomes very important for any organization or business because it concerns the legal issues regarding production, consumption, import, supply or distribution of any product or services. A few of the legal factors may overlap with the political factors. Legal factor may include the national legislation and policies involving the industry, technology or the economic and environmental protection. This may also include other laws like consumer protection laws, health and safety law and intellectual property protection laws. Any company or organization involved in the international business would also need to take care of the laws of different countries and trends in the changes in legislation which would impact the business environment. For example, current developments regarding increasing local content requirements and import duties on solar panels and wind turbine equipment, by many countries are likely to impact the deployment of renewable energy.

PESTEL tries to organize the above discussed factors under a single framework. Zalengera et al. (2014) used the PESTEL framework to answer the political, economic, social, technological, legal and environmental challenges for the deployment of sustainable energy technologies in Malawi. The study was conducted with an objective to find solutions to increase the access to electricity in Malawi, while utilizing the available renewable energy resources in the country. The literature suggests that for a country like Malawi, which is facing myriad of challenges in various domains of the power industry, PESTEL framework provides a novel and systematic approach to identify and categorize the challenges, which can be used later to systematically improve the condition of Malta's power industry. Song et al. (2017) applied the PESTEL framework to analyze the development of waste-to-energy incineration in China. The literature suggests that the framework helped to categorically asses the challenges of waste-to-energy industry in China and to suggest solutions for them. Hence, PESTEL can be used an important tool to map the factors and to get an overview of the macro-business environment, which helps to assess the viability of a business (Sandberg et al., 2016).

Researchers however, often identify the factors based on relevance, and the method of analysis also varies. Aguirre and Ibikunle (2014) identified factors influencing growth of renewable energy and categorized them as political factors, Socio-economic factors, and country specific factors (renewable energy potential, deregulation of the electricity market and continuous commitment) (Aguirre and Ibikunle, 2014). The research empirically examined the relevance of different factors impacting the adoption of renewable energy and applied Fixed Effects Vector Decomposition (FEVD) and panel corrected standard errors (PCSE) estimation method in a sample of 38 countries for a period of 1990-2010 (Aguirre and Ibikunle, 2014). The result concluded that the voluntary policy measures, fiscal & financial instruments were most commonly found to have negative impact on the deployment of renewable energy. This is due to insufficiency and failure in effective policy design, lack of certainty and possibility of discontinuation of policy, which reduces confidence of potential investors.

The external factors influencing business environment could be very large in number and it not possible to consider them all, however, it is important to consider the pertinent factors which may have much higher influence, rather than attempting to cover them all (Worthington and Britton, 2009).

2.3 Interactions among the factors and their effect

Interactions among the factors of renewable energy business environment: The literature on business environment suggests interactions among the factors (Worthington and Britton, 2009), however, these interactions and their combined effect on the business environment have not been explored. This makes the diffusion of renewable energy a complex problem to expain, as the macro-business environment factors of renewable energy (RE) does not act in isolation but interact with each other. There is a research gap to explain the interactions among the relevant factors and their cumulative impact on the RE diffusion. Most of the studies deal with the interaction of these factors in pairs. Few of the most pertinent interactions found in literature, among these factors are discussed below:

Factors influencing political will and political decisions: Most of literature works, focus on the motivators which would influence the government motivation in a negative way (like lobbying by existing market players as discussed in section 2.2 above) towards the development of renewable energy. However, Gallagher (2013) collected positive influencing factors to government decisions by conducting case studies of Germany, China, Denmark and a few states in the U.S. (Colorado, Ohio and Texas) and segregated the positive influencing factors in following four categories:

a) Economic motivation: For the economic growth of country and for job creation by developing the industrial capacity of manufacturing and deployment of renewable energy.

b) Motivation to exploit the available renewable sources and low endowment of non-renewable energy sources in the country.

c) Political motivation and support for the deployment of renewable energy and cutting down dependence on conventional energy sources.

d) Cultural values: Lower level of individualistic culture, promoting higher government intervention for higher scale up of renewable energy, even with increased electricity prices.

Furthermore, as discussed in section 2.2, researches by Cadoret and Padovano (2016) and Marques et al. (2010) suggests that international influence, like binding RE consumption directives, can play an important role in influencing the political will of a country, which is usually observed in the EU countries.

Influence of the Political Will on Energy Policy: Hake et al. (2015) have presented a detailed path dependent discourse analysis of the evolutionary process of Germany's energy strategy (Hake et al., 2015). The research has presented over 30 years of energy and environmental politics in Germany, changing the power constellations towards leaders supporting strong economic and renewable energy growth, and paving way for the Energiewende. The paper presents the strong evidence of the interweaving of the overall political belief or support towards creating windows of opportunities for radical shifts in the energy policies, which are in turn affected by the country's history (path dependence), social structures and their influence on the politics, and various endogenous and exogenous factors. Renn and Paul (2016) have presented the detailed analysis of the political parties forming the government and shaping the energy policy of Germany . In addition to the national energy context, the research also presents the strong influence of the European context towards the development of national energy policy which are in the areas of: (a) energy security, (b) climate change and (c) deregulation and liberalization of the energy markets.

Interactions of the Industrial growth and the Energy Policy: Previous studies have found links between the energy policy and their impact on the industrial growth. Lewis and Wiser (2007) after studying the 12 largest national wind energy markets, concluded that there are many cases of clear influence of the national and sub-national renewable energy policy, in the success of the wind technology manufacturing industry. The study suggests that policies providing annual sizable and stable domestic market, by incentivizing the local production and deployment, leads to successful development of local wind industry and eventually guiding the industry to contribute in the global wind market . Lund (2009) studied 20 countries (mostly EU, USA and Japan) for analyzing the impact of the energy policy on the commercialization, development of value chain, and industrial expansion of the renewable energy industry. The research suggests that R&D intensive policy supports innovation and introduction of new technology to the market, public subsidies like loans, grants, preferential taxes, loan guarantees support industrial growth, and policy measures like Feed-in-tariffs, RES, green certificates, investment grants etc. provides a market pull for deployment of these technologies. Market pull policies creates incentives for investment, thereby increasing competition and improvement in technology by learning by doing and further cost reduction, and strengthening deployment. Hence, the research concluded that the energy policy can contribute significantly in the growth and success of domestic renewable energy industry. Zhang et al. (2013) analyzed the interactions between the renewable energy policy and renewable energy industrial policy in China. The study of solar PV and wind power in China suggested that China's policy gave more priority to the manufacturing industry growth and comparatively less priority to the actual deployment of renewable energy (Zhang et al., 2013). Hence, the research concluded that the interactions among the RE policy and RE industrial policy were not very appropriate and these interactions need to be enhanced.

Dependence of RE integration on the technological preparedness and flexibility of the electricity grid:

Due to the tremendous growth of renewable energy in the last decade, many studies have been carried out to examine the changes required in the current electricity infrastructure, to integrate high share of intermittent renewable energy electricity. Based on grid integration study conducted by NREL, the United States' electric grid system can handle up to 20-50% of variable renewable power generation from solar PV and wind power sources (NREL, n.d.*b*). To achieve the demand-supply balance at such high VRE share would require flexible power generation from conventional power generators, power storage, improved transmission, temporal shiftable loads, and improved operations of the power system (NREL, n.d.*b*). Huber et al. (2014) assessed the ramping flexibility requirements of the European power system for increased penetration of solar and wind power, and concluded that to enable 30% or more RE contribution, strong grid flexibility would be required, and this flexibility requirement becomes less severe with larger geographically connected international power systems. Kroposki et al. (2017), suggests that higher RE penetration brings greater technological challenges for integration. However, there are many solutions like expanding transmission capacity, normalizing the injected variable power by increasing the geographic diversity and spread of power generation, improving coordination with the balancing facilities, implementing demand response, and/or energy storage for temporal shifting of supplied power (Kroposki et al., 2017).

Analysis of multiple interactions among factors and their overall impact: There exist a research gap dealing with multiple interactions among the factors and their overall impact on the renewable energy business environment. Only one literature by Gottschamer and Zhang (2016) was found, which deals with the interactions of the factors impacting project implementation at system level. The research has identified the interactions impacting RES-E (renewable energy sourced electricity) project implementation, and classified them in four categories of interactions within a single or across factors:

a) Inter-policy interactions: To overcome economic disadvantages and challenges in market penetration, RES usually requires simultaneous or sequential support of more than one policy. This also leads to interaction among the policies. For example, Feed in Tariff affects the supply side by incentivizing the supply of RES-E, demand side is affected by RPS, tradable green certificates accommodates for environmental benefits, and further more policies like technological subsidies, tax breaks, emission trading schemes etc. impact the RES-E penetration. However, the interactions can be positive or negative, based on their cumulative effect.

b) Interactions of the Technological and societal factors at macro, and micro level. The literature suggests that society's attitude towards land use like "not-in-my-backyard" may result in opposition to RES project implementation. However, such public perceptions are often irrational can be overcome by improving public awareness of technology through education, and community's involvement in planning, decision making and RES-E project implementation/operation, which leads to community's acceptance by building trust and acknowledgment that fair benefits are received by the community.

c) Interactions of the environmental conditions on RES-E generation and environmental consequences of the implementation of RES-E. This interaction can be studied in two ways, firstly the impact of the local environmental conditions, availability and variability of renewable energy sources, and the impact they can have on the volume and quality of RES-E generated. The later part, involves the study of environmental impacts of deployment of various RES-E technologies.

d) Technology-technology interactions: Author suggests that technological synergies among the conventional power generation facilities, renewable energy sourced electricity and their hybrid combinations may exist, but does not provide any critical review, however suggests that these may have potential to create economic and technical incentives along with being helping in the energy transition.

2.4 Policy and Regulatory indicators

In 2017, World Bank presented *Regulatory Indicators for Sustainable Energy* or RISE to map and rank national policies and regulatory frameworks for sustainable energy in 111 countries (World Bank Group, 2017). RISE was designed as a tool, which can be used by policy makers to identify and strengthen their national policy to improve the energy access, increase the energy efficiency and support the growth of renewable energy, called as three pillars. Indicators to support the growth of renewable energy is summarized in the fig. 2.6. It is composed of seven indicators, which are further monitored based on sub-indicators. The indicators cover a broad range from planning (national targets and plans), creation of supportive framework, presence of modes of financial incentives and regulatory support, provisions for access to the grid (transmission and distribution lines), measuring counterparty risk, and presence of carbon pricing and monitoring mechanism. The overall score is calculated in the scale of 0-100, and weights are distributed equally among all the indicators. Most of the sub-indicators are scored in an binary format from yes/no question &

RISE by World Bank: Renewable Energy indicators

Sl. No.	Indicators	Sub Indicators
1	Legal framework for renewable energy	Primary Legislation
		Legal private ownership of generation
2	Planning for renewable energy expansion	Renewable energy: targets and plans
		RE electricity: Targets and plans
		Institutions and meeting targets
		RE in generation and transmission planning
		Resource data and siting
3	Incentives and regulatory support for renewable energy	Financial and regulatory support for electricity
		Electricity grid access and dispatch
4	Attributes of financial and regulatory incentives	Auctions
		Fixed tariffs for small producers
5	Network connection and use	Connection and cost allocation
		Network usage and pricing
		Renewable grid integration
6	Counterparty risk	Creditworthiness
		Payment risk mitigation
		Utility Transparency and Monitoring
7	Carbon Pricing and Monitoring	Presence of carbon pricing mechanism
		Mechanism for monitoring and verification

Fig. 2.6 Renewable Energy indicators (RISE) (World Bank Group, 2018)

answers based on the best practices around the world. Quantitative answers are either on a straight scale or on an predefined existing threshold.

RISE provides a good set of indicators, and an important tool to map and compare the regulatory framework of different countries. Although, RISE is expected to evolve with time with inclusion of better indicators and methodologies, Urpelainen (2018) argues that RISE ignores the systematic research and ground realities, which need to be considered in formulation of energy policy, which may vary from country to country, especially in the developing countries. Hence, RISE's approach of one size fit for all may not be applicable, and best practices of one country may not be the best solution for other countries as well (Urpelainen, 2018).

A few of the above limitations of RISE are covered by the country specific indicators designed by International Energy Agency (IEA). IEA suggests that the difference in the deployment impact (and cost effectiveness) of renewable energy among countries with similar policy system are larger than gaps in impacts due to different support policy systems within a same country. This signifies the importance of overall effectiveness of policy package designed and implementation by a country. To identify the best policy practices, IEA developed three quantitative policy indicators (IEA, 2011):

a) *Policy impact indicator (PII):* This indicator measures the policy effectiveness by the estimated annual renewable power generation (in TWh) through the deployed RE technology as compared to the country's target projected RE power generation in 2030 as per World Energy Outlook (WEO) 450. As country wise break down of the WEO 2030 projections are required for the detailed analysis, the report covers the estimates only for the OECD member countries and five BRICS countries.

b) *Remuneration adequacy indicator (RAI):* This indicator measures the adequacy of total remuneration available/provided to the RE power generators. For comparison of remuneration among different countries, remuneration levels are corrected for the resource endowments.

c) *Total cost indicator (TCI):* This indicator is used to estimate the cost effectiveness of the support policy. To calculate TCI, the total premium payed (at wholesale level) annually for the additional RE generated power is divided with the annual wholesale value of country's total power generation. IEA accepts that TCI may overestimate the total policy cost, as it does not account the reduction in wholesale prices of new RE technology due to higher penetration and development in technology.

2.5 Conclusion and learning from the literature review

Hence, the literature survey helped to develop the understanding of renewable energy business environment in three levels. Firstly, the basic theory of business environment is discussed in section 2.1. Secondly, the pertinent factors were discussed which may influence the business environment in section 2.2. Thirdly, the interactions among these factors are presented and discussed in section 2.3.

A business environment of renewable energy may be referred to the macro-business environment existing in a country, which is composed of or affected by the political and legal structure, laws and policies, macroeconomic scenario, and the combination of all the external forces and situations, which are outside of a business but have influence on the deployment of renewable energy (section 2.1).

Section 2.2 and 2.3, suggests that political factors can have a strong influence on the deployment of renewable energy, this may be due to the binding RE consumption directives, or motivations of economic development. These political factors influence the business environment through enactment of relevant renewable energy policies. Further, lobbying by conventional power generators can negatively influence the RE deployment. The price competitiveness of renewable energy is also expected to positively influence the business environment. Increase in macro-economic factors like GDP or GDP per capita, were found to increase the energy consumption, but this does not necessarily lead to increase in the deployment of renewable energy. Social factor was not found to have any significant contribution in the deployment of renewable energy, however, negative public perception like "not-in-my-backyard" may negatively influence the project deployment. However, such problems can be resolved by improving public awareness and participation. Technological development of solar PV and wind power have observed significant growth in the recent years and this is expected to continue in the coming years, hence, this aspect is not given further attention in this research. However, the integration of high share of VRE may pose many challenges and may put restrictions in the level of adoption of VREs, hence, this would be an important factor to consider. Further, contribution by environmental factors were not found to play significant role in RE deployment at national level. Few legal factors like import and export, restrictions, duties can also influence the RE business environment, as they impact the availability of required equipment and components.

Hence, political motivation and political factors were found to be the strongest drivers of promoting renewable energy deployment through relevant renewable energy policies. Further, economical and technological factors were also strong drivers of RE deployment. Hence, these factors would be used further in building the renewable energy business environment framework.

Further, although the literature suggests presence of interactions among these factors, and influence of these interactions on the RE business environment, but due to inherent complexity of mapping these interactions and their cumulative effect, these interactions are not yet explored. Literature review as conducted in section 2.3, presents interactions among factors like factors influencing political will & political decisions, convoluted relationship between the energy policy and political will of a country, need of appropriate interactions among the energy policy and RE industrial growth, and technological preparedness of a country for increasing VRE share. So, these interactions would also be incorporated to develop the framework for the business environment of renewable energy in this research. Further, section 2.4 presents RISE indicator by World Bank, which were found to be a very useful set of indicators and sub-indicators, which can be used to map and compare national policies and frameworks for sustainable energy, based on the best practices around the world. To cover the limitations of RISE, country specific indicators designed by IEA can also be very helpful to be used directly or to develop other suitable indicators.

Chapter 3

Methodology

A thorough literature survey presented in Chapter 2, helped to develop a background knowledge on existing theories and related research done, which would be used to create a framework to assess and compare national renewable energy business environment in power sector.

This chapter has attempted to develop a framework to map national RE business environment and called it as Renewable Energy - Business Environment Methodology. This framework is developed on the basic theory of business environment by Fernando (2011) and Worthington and Britton (2009). The external-business environmental factors are selected based on their influence observed from the literature survey, accordingly, the concept of business environment is suitably adapted to represent the national RE business environment. Further, the author has also attempted to incorporate interactions among these factors, based on evidences from literature survey, and personal understanding of RE business environment (which would serve as assumptions of this research, and would be explored for their relevance), with an aim to reach a step closer to depict the actual complexity in portraying the RE business environment.

This chapter broadly consists of four sections, firstly, the concept of renewable energy business environment is explained and the introduction to RE business environment methodology is presented in section 3.1. Secondly, sections 3.2 to 3.6, define and describe methods that would be adopted to explain and measure the national political will, policies and regulations, economic factor, industrial factor and technological factor, which have strong potential to influence the RE business environment. Thirdly, section 3.7, presents the interactions among these factors which would be assessed in this research, and the overall impact of these factors and their interactions. Finally, section 3.8, presents a brief summary of sources of input data, used in this research.

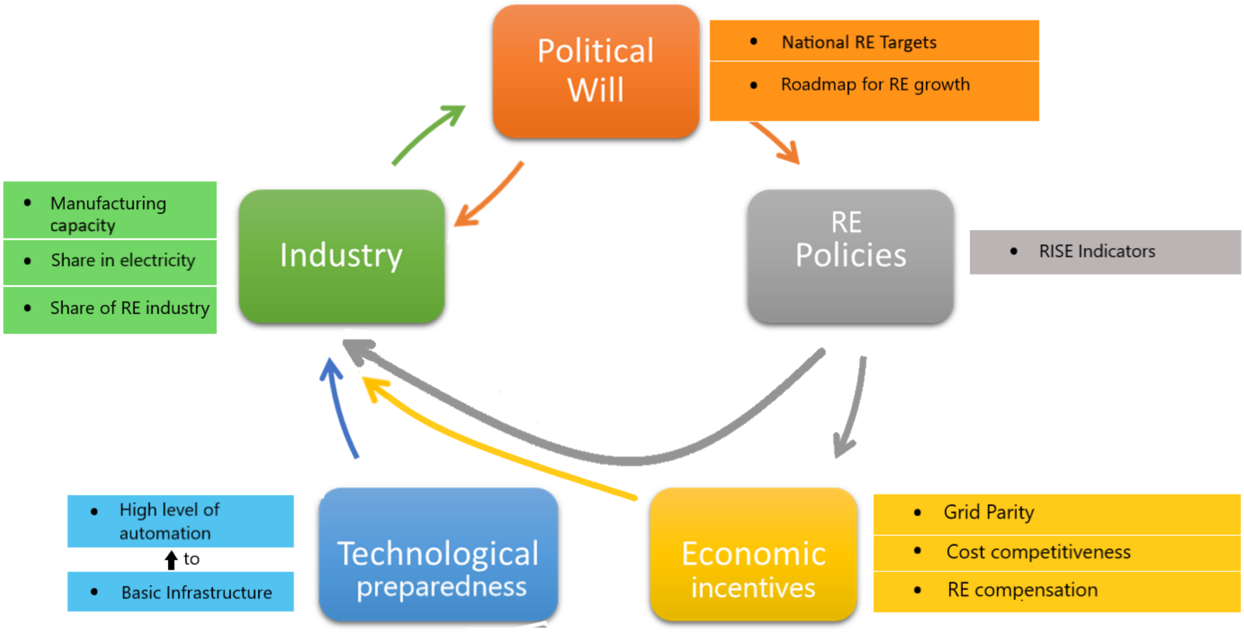


Fig. 3.1 Renewable Energy - Business Environment Methodology

3.1 Introduction to the Renewable Energy Business Environment

Renewable energy (RE) business environment may be defined as the national business environment for the deployment of renewable energy, created and impacted by the cumulative effect of external-business environmental factors like national political will, RE policies and regulations, economic incentives, industrial factors, technological preparedness to adopt large scale VRE renewable electricity, and interactions among these factors. A well designed RE business business environment, can allow and facilitate large scale deployment of renewable energy technologies (RETs) and use of renewable electricity and hence, catalyze the energy transition of electricity sector.

Fig. 3.1, depicts the framework of RE business environment methodology designed and used in this research, to map and assess the RE business environment. The business environment of renewable energy is highly dynamic in nature. It is impacted by the historical and current status, variations, and interactions of multiple factors. A few of the pertinent external business-environmental factors, which has the potential to strongly influence the RE business environment are adopted into the RE business environment methodology, and presented in the fig.3.1.

This research does not consider the global RE business environment as a single, homogeneous environment but a cumulative product of all the regional and national energy markets, guided and affected by their respective RE business environment. So, the RE business environment methodology is designed as an attempt to create a general framework to understand and map the dynamics of national renewable energy business environment. To create this generic framework, five factors are chosen from the literature survey, namely: political will, RE policies and regulations, economic incentives, technological preparedness, and industrial factor.

Additionally, this framework does not consider these factors to act in isolation, or not being influenced by other external factors. However, it goes a step ahead to try to explain the interactions among these factors. Depending on their strength, these factors has the potential to influence each other and successful interaction of these factors may allow the business environment to evolve and develop, and accelerate the deployment and consumption of large scale of renewable energy. Based on existing RE business environment in different countries, these interactions could be very complex or there could be a complete absence of interactions.

This methodology has adopted interactions among these factors, based on evidences from literature survey, personal understanding of RE business environment by the author, and suggestions from the thesis supervisor Dr. Kornelis Blok. These interactions serve as assumptions of this research, and these are explored for their relevance based on observed evidences. Further, this methodology attempts to measure the overall impact of these interactions on the national renewable energy business environment.

Developing a framework to understand the dynamics of renewable energy (RE) business environment is a very complex task and RE business environment methodology is a step forward in this direction, and has its own limitations.

3.2 Political Will

Definition: National political will towards renewable energy may be defined as political inclination and support of a country's governing body towards renewable energy (RE), specially their willingness to adopt RE to achieve the energy transition to achieve the COP21 (United Nations Climate Change Conference, Paris 2015) and IPCC targets on the Climate Change. For this research, we will focus on political will for transition of the electricity sector while implementing solar and wind power as renewable energy sources.

With growing awareness of climate change, the political leaders around the world can be seen, showing their openness and willingness to support the energy transition. However, the motivational talks about combating climate change, hardly gets translated into definitive steps. This research considers setting a national renewable energy (RE) target as the first step towards energy transition. As approval and declaration of a national RE target would require a collective political will to take definitive steps, and willingness to allocate and spend required resources to achieve this political objective. Political will and the political decisions can directly impact the renewable energy business environment during market formation, growth or may lead it to complete failure.

National RE target gives a direct market signal, showing the government's vision for country's future energy mix, which guides the market for the forthcoming changes. Further, if the government is directly involved with the purchase of electricity from the power producers, or electricity generation, then the national RE target sets the gross national demand for renewable energy and renewable power generation capacity. Based on their researches in the EU countries, Cadoret and Padovano (2016) and Marques et al. (2010), concluded that country's participation in target based binding RE consumption directives, are the strongest stimulus in investment and increasing renewable energy infrastructure, and market forces were found to be insufficient in driving these developments. Cadoret and Padovano (2016) also suggests that the political and institutional factors are very crucial factors in RE deployment as investment in RE resources is mostly a political decision, resulting due to political pressure and other political factors. Renn and Paul (2016) and Hake et al. (2015) also suggest a strong and convoluted role of the national politics in the energy policy of Germany, making Germany a pioneer of the energy transition.

Further, a country's road-map for energy transition or a time-based plan gives very clear market signal, allowing the market to prepare itself for upcoming changes with timely flow of investments. This creates a positive pressure for policy formulation and implementation, defines a time line for development of production and installation facilities, development of the required supply chain, and skill development. Hence, the national renewable energy target and the road-map for energy transition can be taken as the direct indicators or metrics to quantify the national political will to adopt renewable energy.

In order to measure the political will, this research has attempted to quantify the abstract idea of political willingness of a country for energy transition. Political will would be represented in percentage (%) , zero percent being the absence of any political support and vision to adopt renewable energy for the energy transition, and 100 percent representing a country's Nationally Determined Contributions (NDC) target of 100 percent with an agreed national road map to achieve this transition by 2030. The political will of a country would be calculated as per the formula below:

$$\text{Political Will} = 0.5(\tau \times Target_{RES} + P \times Planned_{RES}) \tag{3.1}$$

Where,
$\tau = 1$, if the country has ratified the Paris Agreement or if there exists any binding target for the RE share in Electricity, else $\tau = 0$. Target$_{RES}$ represents the 2030 target renewable percentage share in the final electricity of the country.
$P = 1$, if the central or the federal government of the country has published a road-map or time committed plan to achieve the energy transition, else $P = 0$. Planned$_{RES}$ is the planned renewable percentage share in the final electricity, in the country's road map or time committed plan for the energy transition. $Planned_{RES}$ is defined as a separate variable from $Target_{RES}$, as for example a country may have a national target to achieve X% share of RE in electricity by the year 2030, however, the country has released a road-map or plan for Y% transition, where Y < X. For the countries which does not have any national RE target, state cumulative political will would be calculated, which would be given by the product of the volume of electricity consumed in states and their compulsory RE target, and divided by the total national electricity consumption. Or in the other words, the state cumulative political will would be calculated for the share of electricity for which there exist compulsory state political will.

3.3 Policies & Regulations

Definition: Policies and Regulations represents the national legislation or regulatory instruments which are expected to be strictly enforced by a country's government. This research uses the *Regulatory Indicators for Sustainable Energy* or RISE developed by the World Bank to map the national policies and regulatory frameworks for sustainable energy in the concerned countries (World Bank Group, 2017).

Although the energy transition is a global target and objective, it is driven by the state and the national renewable energy business environment. The structure, composition and dynamics of this RE business environment is governed by the applicable policies and regulations in the country or the state. If the 'political will' of a country for energy transition is strong enough, then this 'will' gets translated into policies which either creates incentives through support policies or penalizes the unwanted behaviour, to direct the market in the direction of energy transition.

This research has adopted the scoring system of RISE for Renewable energy (electricity). RISE helps to rank, benchmark, and compare policies and regulatory frameworks of different countries. RISE score for renewable energy is measured using seven indicators, which are further monitored based on sub-indicators. The overall score is calculated in the scale of 0-100, and weights are distributed equally among all the indicators. Most of the sub-indicators are scored in an binary format from yes/no question & answers based on the best practices around the world. Quantitative answers are either on a straight scale or on an predefined existing threshold.

RISE by World Bank: Renewable Energy indicators

Sl. No.	Indicators	Sub Indicators
1	Legal framework for renewable energy	Primary Legislation
		Legal private ownership of generation
2	Planning for renewable energy expansion	Renewable energy: targets and plans
		RE electricity: Targets and plans
		Institutions and meeting targets
		RE in generation and transmission planning
		Resource data and siting
3	Incentives and regulatory support for renewable energy	Financial and regulatory support for electricity
		Electricity grid access and dispatch
4	Attributes of financial and regulatory incentives	Auctions
		Fixed tariffs for small producers
5	Network connection and use	Connection and cost allocation
		Network usage and pricing
		Renewable grid integration
6	Counterparty risk	Creditworthiness
		Payment risk mitigation
		Utility Transparency and Monitoring
7	Carbon Pricing and Monitoring	Presence of carbon pricing mechanism
		Mechanism for monitoring and verification

Fig. 3.2 Renewable Energy indicators (RISE) (World Bank Group, 2018)

The RISE indicators for renewable energy compares the policy and regulatory frameworks through the following indicators:

1. Presence of a legal framework for the development of renewable energy, and legal framework to allow the ownership of RE generators by the private sector.

2. Presence of an official, and legally binding planning and targets for renewable energy expansion. Presence of institution for renewable and investment planning, progress tracking and reporting of developments of renewable energy. Presence of integrated planning for generation, dispatch, and transmission of renewable energy. Availability of solar and wind resource data, and geo-spatial planning for commercial development of renewable energy.

3. Presence of financial and regulatory support for RE power generation through long term power purchase agreements (PPA's), feed-in-tariffs, or auctions etc. Presence of direct fiscal incentives, in the form of investment tax credits, capital subsidies,

preferential tax, grants etc. Presence of provisions for priority grid access and dispatch of renewable energy and compensation mechanisms for curtailed generation.

4. Use of competitive bids/auctions for utility scale renewable power generation. Presence of mechanism to provide grid access to small producers and fixed/clear tariff levels.

5. Presence of standard grid code for connection procedures for renewable energy, and clear rules for connection cost allocation. Presence of network usage policy for purchase of electricity from a third party and clear rules for cost allocation of transmission and distribution system usage. Presence of high quality forecasting, real time dispatch, grid flexibility assessment and renewable energy participation in ancillary services.

6. Measurement of creditworthiness, provisions for mitigating payment risk, and transparency and monitoring of the utilities.

7. Presence of mechanism for carbon pricing, monitoring and reporting of emissions.

To arrive at the final RE policy and regulatory score, the values of the 19 sub-indicators for renewable energy listed in the table 3.2 would be collected from the World Bank database of current set of 23 indicator (as the remaining indicators are relevant for transportation, heating and cooling). Hence, the derived scores are expected to be very close to the current RISE scores for renewable energy.

3.4 Economic Incentives

Definition: For any market or business to grow, everything boils down to economics, be it the price competitiveness of the technology, availability of capital or the overall socio-economic scenario.

From the literature survey it was observed that income level, oil/gas/coal prices, GDP were not sufficiently strong economic factors to influence the growth of VRE deployment and consumption (Lin and Zhu, 2019; Marques and Fuinhas, 2011). Gottschamer and Zhang (2016) suggests that renewable energy suffers from economical challenges of market penetration due to (a) high capital cost, (b) subsidized fossil based power generation and fossil electricity and (c) non-inclusion of environmental benefits of RE electricity and negative externalities of fossil power generation in the electricity cost. Hence, sufficient economic incentives need to be created to promote the deployment and consumption of renewable energy.

Hence, this research has attempted to measure the level of competitiveness and available economic incentives in producing variable renewable electricity. This would be analyzed in the following three levels:

a) Grid Parity: According to the broad definition, grid parity refers to the intersection of the electricity generation cost (LCOE) and the conventional electricity price as purchased from the grid. Grid parity has emerged as an important milestone to compare the financial and economic competitiveness of the electricity generated through new renewable power technologies (Munoz et al., 2014). So, to assess the grid parity, the national average levelized cost of electricity (LCOE) of each solar PV electricity, on-shore wind power and off-shore wind power would be compared with the country's average domestic, commercial, and industrial electricity prices. Availability of the grid parity information motivates the small and large consumers to install their own renewable power generation facilities as compared to purchasing electricity from the grid.

   Although, grid parity is usually studied in the context of solar PV due to the possibility of distributed solar power generation. However, this research has also tried to assess the grid parity of wind power. Grid parity of wind power becomes relevant especially for those industrial and commercial consumption, which although being power intensive, chooses to purchase electricity from the grid at the commercial or industrial prices. As wind power reaches grid parity, these industries and companies can choose to purchase electricity from wind power generators through dedicated lines or through selective consumption through upcoming block-chain technology.

b) Renewable energy source electricity (RES-E) generation cost competitiveness with the fossil electricity: Generation cost comparison of electricity, helps the the utility scale power producers to choose the right technology for power production. This comparison plays an important role to counter the common perception of the public, different actors involved in the power sector and also the policy makers that the new renewable energy technologies are still expensive means of power generation. To conduct this analysis the average of the final fossil electricity generation cost as faced by the power producers would be considered. Any of the tax rebates, and subsidies enjoyed by these fossil electricity generators, and the environmental externality cost present at the different stages would not be accounted to arrive at the actual fossil electricity generation cost. This fossil electricity generation cost would then be compared with the average LCOE of solar PV, onshore wind and the offshore wind powered electricity for each of the considered country.

c) RES-E price in comparison with the Levelized cost of electricity (LCOE): After conducting the cost comparison, this research has compared the price compensation for the electricity generated through renewable energy technologies (RES-E) with the respective levelized cost of electricity. For the countries where the electricity prices for these technologies are fixed in terms of feed-in tariffs (FITs), these FITs would be taken as the RES-E prices. Countries which arrive at the power purchase agreements (PPAs) after following the competitive public auctions, these PPA prices would not be compared with the respective localized cost of electricity (LCOE). This is because the final power purchase agreement (PPA) prices depend on a set of obligations and contract conditions, which are very different and specific to a particular market condition of the specific project and these may not reflect the actual cost of generation. If these conditions are not met by the independent power producers (IPPs), then there are chances of the PPA not being materialized and initial lowest bidder walking out of the project (IRENA, 2018*c*).

Economic incentives: The strength of economic incentives for each of the technology namely solar PV, onshore wind and off-shore wind power generation would be analyzed based on the three levels of competitiveness as discussed above. It would be scored on the scale of 0 to 3, which would be a cumulative score of 0 to 1 for each of the above levels. For each of the levels the scoring method would be as below:

a) *Grid Parity:*

if, $LCOE_{RE} <$ Grid electricity price: Grid Parity score = 1.

if, $LCOE_{RE}$ is within the range of Grid electricity price: Grid Parity score = 0.5

if, $LCOE_{RE} >$ Grid electricity price: Grid Parity score = 0.

b) *RES-E generation cost Vs fossil electricity:*

if, $LCOE_{RE} <$ Fossil electricity cost: Generation competitiveness score = 1

if, $LCOE_{RE}$ is within the range of Fossil electricity cost: Generation competitiveness score = 0.5

if, $LCOE_{RE} >$ Fossil electricity cost: score = 0.

c) *RES-E generation cost Vs RES-E price:*

if, $LCOE_{RE} <$ RES-E price: Price competitiveness score = 1

if, $LCOE_{RE}$ is within the range of RES-E price: Price competitiveness score = 0.5

if, $LCOE_{RE} >$ RES-E price: Price competitiveness score = 0.

A country's total economic incentive would also be calculated for further analysis. It would be a total of the economic incentive scores for each of the solar PV, onshore and offshore wind power, which will give a score in the range of 0 to 9, this would be converted into the percentage (%) scale for further convenience.

3.5 Industrial Factor

Definition: Energy transition, in addition to being capital intensive, requires humongous infrastructure to support the production and installation requirements. There are many parameters which need to be monitored in order to truly represent the industrial factor such as the new renewable power generation capacities, increase in the national and global manufacturing capacity, increase in the number of independent power producers, changes in the national import and export, and share in the global market.

This research uses a few of these parameters to assess the growth of renewable energy industry. In this research renewable energy industrial growth would be assessed as a combination of the following three segments: (a) RE capacity deployment industry, (b) RE power generation industry, and (c) RE manufacturing industry.

(a) *RE capacity deployment industry:* This segment of the RE industry would be assessed by analysing the trend in the RE capacity deployment, and by calculating the share of new capacity installation market captured by the solar and wind energy in a country. This would be calculated by dividing the ratio of the average solar and wind power deployment in 2013-2017, and the average new power generation capacities installed in the same period.

(b) *RE power generation industry:* As the name suggests, this segment of the RE industry would assess the share of electricity produced from solar PV and wind energy, as compared to the total electricity produced in a country. With the current trend, as it is expected that the share of solar and wind power in electricity would see positive growth, hence, the latest values of share of solar and wind in electricity produced in 2017, would selected for further analysis, rather than an average of the last 5 or more years.

(c) RE manufacturing industry: This segment of the RE industry would first test for the presence of industrial barrier. Then the RE manufacturing industry would be assessed for their capacity to supply the demands of new power generation capacity demand of the country.

Industrial barrier in the RE business environment may be defined as the industrial production capacity becoming one of limiting factors in the growth of installation of new RE capacity or in other words, industrial barrier can be observed when the domestic RE equipment production capacity of a country is insufficient to meet the domestic demand of annual capacity addition. The development of these production capacities are based on getting long term returns, due to heavy initial capital investments. Hence, strategies by different countries vary depending on their domestic market, local demand, long term plans and capabilities to develop the supply chain to cater the international markets. Hence, some countries may find it profitable to import from other countries rather than developing in-house production facilities. Whereas, some other countries with good potential demand in the domestic market may tend to develop in-house production facilities. While some other countries may target to supply in the global market and develop the production facilities accordingly. However, the above steps taken by different countries, to develop their industries, may or may not be sufficient, to support the required national or global growth.

Hence, to analyze the industrial barrier, we will look into the global demand (deployment) of new renewable power generation capacity (in GW), and compare it with the global production/manufacturing capacity of solar and wind power equipment. Similar comparison, would be done for country wise demand, for new renewable power generation capacity and actual domestic production/manufacturing capacity of renewable power generation equipment.

Finally, using the above information, growth in the RE manufacturing industry of a country would be assessed. Due to the increasing trend of RE manufacturing capacity expansion in most of the countries, RE industrial manufacturing capacity to meet new power capacity demand would be calculated as the ratio of the total RE manufacturing capacity in 2017 and the maximum annual new power generation capacity addition in the duration 2013-2017. This ratio represents the capacity of the domestic RE manufacturing industry to meet the demands of the new power generation capacity additions.

Overall RE Industrial growth factor:

The final RE Industrial growth factor, would be calculated in percentage (%) as an equally weighted summation of all the above three industrial factors: (a) Average share of RE capacity installations (2013-2017), (b) share of solar and wind in the electricity produced in 2017, and (c) share of the total new capacity addition which can be supplied by the RE manufacturing industry. This factor takes into consideration all the above mentioned three segments of the RE industry, and hence, it is expected to present a complete picture of the RE industry.

3.6 Technological Preparedness

Definition: Integration of uncontrollable and intermittent solar and wind power to the electricity grid brings multiple challenges (Kroposki et al., 2017), which need to be resolved.

Depending upon a country's level of development, the country may go through various levels of technological barriers or limitations, due to the existing energy system, which may not allow the introduction or the large scale diffusion of RE technologies.

In this research, the countries would be categorized based on the different levels or the hierarchy of technological preparedness, which they have crossed, and the level they are currently going through.

The technological preparedness can be listed in six levels of hierarchy and it ranges from the requirement of basic infrastructure, to support introduction of renewable energy, to a very high level of automation, for high penetration of renewable energy in electricity. The hierarchical order, from lowest (F) to highest preparedness (A), are presented in the Fig. 3.3. The different hierarchical levels of technological preparedness presented in this section, are developed with the help of Dr.ir. JL (José) Rueda Torres who is an Associate Professor in Stability, Control, and Optimization of Electrical Power Systems (TU Delft / Intelligent Electrical Power Grids).

The presented hierarchical preparedness information would be very resourceful for countries, to get a brief understanding of the technological preparedness required to improve the share of solar and wind power in electricity.

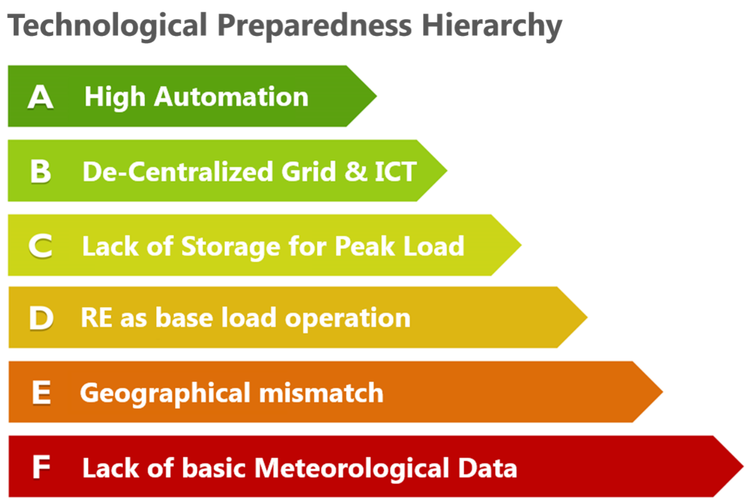


Fig. 3.3 Technical Preparedness Hierarchy

In contrast to the conventional power generation technologies (coal based power plants, gas powered, or nuclear based power plants), solar PV and wind power are powered by natural resources like solar irradiance and wind speed, which due to their inherent time varying nature makes power generation through these sources uncontrollable. Further, the nature of electricity requires the power supply to match the power demand at all times. This requires the upgradation of existing technology and existing infrastructure, as the current electricity infrastructure and technology are designed to support the conventional power generation technologies.

(F) Lack of basic Meteorological data and resource management database: The introduction of intermittent solar and wind power, requires the time based estimation of expected power generation and overall power generation potential in the project lifetime. The latter estimation helps to calculate the economic viability of the project and the first one is required for allocating the injected power into the grid from power generation sources. Hence, this requires the basic infrastructure such as the availability of meteorological data, resource management database and access to the main electricity grid. The lack of first two makes the potential mapping of solar PV and wind power impossible, and the latter one is required to transport the generated power. Lack of the detailed and credible data of renewable sources makes the power generation estimation impossible. This becomes a huge barrier for potential power generators, as the financial incentives cannot be estimated, making the project financing process almost impossible. Further, this also leads to inefficient project site selection or a complete lack of motivation to install new projects.

Furthermore, although the basic meteorological data and resource management database may be available in a country but the country also needs to maintain a historical and geographically high definition data which are updated at a reasonable time interval. This requirement becomes even more significant for wind power as a geographical variation of a few or tens of meters may lead to variation in the generated power by multiple factors.

Furthermore, due to the probabilistic nature of the weather forecast, there would always be concerns of the accuracy of the predicted data, which is again due to the highly non-linear nature of variations of weather phenomenon. Hence, advancements in projections would always be required to have a level of confidence in the projected data, which would be needed at an every stage for increasing the share of intermittent solar and wind power (Bird et al., 2016).

(E) Geographical mismatch between the demand and generation (potential generation) sites: Due to geographical separation between demand centers and potential renewable power generation sites, lack of availability of a sufficient electricity grid infrastructure can act as a strong technical barrier. The issue may become a limiting factor, as although a country may be endowed with a good potential for renewable power but the huge distances of the electrical grid from the potential generation sites or the limited transmission capacity may demotivate the power producers from installing new RE generation capacities (Zhao and Chen, 2018).

(D) Inability of renewable energy acting as base load generators and increased curtailment of variable power generation : With the availability of required infrastructure for meteorological database (and forecasting facility), and grid connectivity, the renewable power generation plants can be installed. However, the new renewable power generation capacities may not be able to operate full time as base load power generators, leading to inefficient use of the existing renewable power generation capacity. Hence, although, countries might be moving ahead with high capacity installation of RE generation, but the generated green power may be spilled over as the existing power infrastructure might not be able to accommodate the uncontrolled available power. The reason may be due to the lack of power system flexibility, lack of sufficient communication and coordination with the controlled power generators, and also to maintain the grid integrity, the grid operators may be required to curtail the renewable power (Luo et al., 2018). Even non technical aspects, like inefficient laws and market mechanisms may also lead to renewable power curtailment but this can be resolved in the policy domain.

This may not allow the renewable power to act as a base load power source. This leads to the lagging share of renewable power in electricity as compared to country's total share of installed renewable power generation capacity. Due to the above mentioned technical limitations, this gap would increase further with increased installations and although a country might focus on increasing the installed capacity but this would not get translated into the consumed renewable power or replacement of fossil electricity.

(C) Lack of power storage and capability to supply peak load: After achieving a certain level of power system flexibility and coordinated power dispatch, a hybrid power generation mix can be obtained with base load supplied by intermittent renewable energy and using fast responding gas plant or the next best coal based plants to supply the peak loads. However, if a country aims to achieve the RE penetration level where the power system can supply even the peak load with intermittent renewable power, then this would present another technical barrier. Due to the uncontrolled nature of electricity generated through solar PV and wind power, the peak load (power demand) time cannot be matched with the peak power generation time. The problem becomes severe with countries with high share of solar PV installed capacity. As the generated solar power may lead to excess power generation during peak solar irradiance hours, which may not match with the peak power demand. Hence, in order to store the excess generated renewable power during non-peak hours, sufficient power storage capacity would be required, and the lack of which may create another technical barrier (Kroposki et al., 2017).

At this level, a country would be required to be able to incorporate multiple storage technologies, such as the pumped hydro, batteries, inertial storage, and even conversion and storage of excess generated energy to other multiple forms.

Infrastructure for storage and energy conversion would avoid any spillage of extra power and would also boost electrification of other energy based sectors like transportation, industries and heating/cooling and hence, would be another major milestone in the process of energy transition.

(B) Lack of Decentralized power grid and mature ICT infrastructure: The current centralized grid structure is designed to support the conventional power generation, transmission, distribution and consumption. In order to facilitate high share of distributed power generation from renewable energy sources, the grid structure, especially distribution grids need to be transformed from passive, centralized controlled, unidirectional power flow capability to active networks. This would require bidirectional power flow, distributed control and decision making capabilities. Such active networks provides efficient means to connect and integrate distributed power generators, renewable energy sources, energy storage capacities, demand side integration and management. In order to achieve above capabilities, the network would need voltage control, power flow control and network protection technologies supported by a mature and advanced information and communication technology (ICT) infrastructure (Hatziargyriou, 2014).

(A) Tools to achieve high level of automation: In addition to the requirement of mature ICT infrastructure, the level and the complexity of automation required to handle the hybrid multi-sourced power generation, power injection and transfer, energy conversion, energy storage and load centers, both at the national and international level, would grow exponentially in the coming decades. This would need very advanced tools and intelligent algorithms for monitoring, control and optimization. To actively monitor and control hundreds of thousands, or perhaps millions of distributed power generators, intermittent renewable energy sources, energy storage technologies, and loads connected to the grid, while maintaining grid integrity and security, would need very advanced tools based on Big data and intelligent algorithms powered by artificial intelligence. Hence, although a good level of automation is already integrated into the current grid infrastructure, to achieve 100% of power transition or to shift to complete dependence on renewable energy sourced electricity, very advanced tools and intelligent algorithms would be required to achieve such a high level of automation.

For further analysis, the *Technological preparedness score* of countries for the adoption of intermittent renewable energy would be calculated based on their current level of the technological hierarchy. It would be calculated on the score of 0 to 5. Zero representing that the country is in level F and lacks the basic meteorological data, resource management database and basic infrastructure for integration of renewables. The highest score 5 would represent that country has reached the level A of technological hierarchy, with very high level of advanced tools, intelligent algorithms with the required ICT infrastructure and automation, along with the supporting infrastructure to support and capability to manage 100% renewable electricity grid. For the countries which would be observed to display different technological hierarchical preparedness, would be given an average of their level scores.

3.7 Relationships and Interactions

a) Influence of the political will on RE policy and regulations: Based on the literature survey, it was observed that the strong national political will and support for energy transition and adoption of renewable energy, paved way for *Energiewende* in Germany, which serves as the road-map for energy transition of the country (Hake et al., 2015; Renn and Paul, 2016). Further, since the design and implementation of renewable energy policy and regulations, comes under the purview of government, it can be safely assumed, that a government showing stronger support for RE or a government willing to bring energy transition through deployment of renewable energy, would also implement relevant RE policies and regulations. This interaction is important for RE business environment, because a stronger influence of political will on RE policy and regulation would imply that the government is taking actual steps in implementing RE policies and regulations, that would support the deployment and consumption of renewable energy. However, a weaker or an absence of interaction would suggest that although a government is making promises of deploying higher share of renewable energy, but actions required on the part of government is insufficient or missing.

   To explore the influence of the political will on the RE policies and regulations of a country, overall policy and regulatory framework score would be plotted for each country with respect to their political will and the influence would be analyzed in comparison with the trend-line.

b) Influence of RE policies on the economic incentives:

   Renewable energy faces a few major challenges in the economic domain which create hurdles in market penetration. First, high capital cost of the technology; second, competition from the subsidized conventional fossil based power generation; and third, non-inclusion of environmental damages by fossil power or positive environmental impacts by RE in electricity prices (Gottschamer and Zhang, 2016). Hence, to overcome these challenges of market penetration, suitable RE policy and regulations are required which can create suitable economic incentives for renewable energy. A stronger interaction would suggest that the implemented RE policies were successful in creating good economic incentives for RE. However, a weaker or missing interaction would suggest that the RE policies were inefficient or ineffective in creating suitable economic incentives. Hence, presence of a stronger interaction is desirable.

To explore the influence of RE policies on the economic incentives for RE, the level of economic incentives would be plotted against the overall policy and regulatory framework score of a country. As explained earlier, the economic incentive level for each of the technology would be scored on the scale of 0 to 3. Further a combined analysis for all the three technologies would be done to study the comparative influence.

c) Influence of economic incentives on RE industry:

As discussed in the previous section, good economic incentives supports renewable energy to overcome market penetration challenges, and hence it is safe to assume that better economic incentives would increase the demand of renewable power generation, or boost the deployment of renewable energy technologies (RETs). Hence, a stronger influence would imply that the economic incentives were strong enough to create market forces (demand of RETs), leading to increased deployment and generation of RE. Weaker interaction would imply that the economic incentives were not able to create sufficient market forces to increase the RE industrial activities. As discussed in section 3.5, there are a few exceptions to above assumption: (i) RE manufacturing industrial development is more strongly influenced by the industrial policy as compared to the RE policy (Zhang et al., 2013), (ii) Domestic market size may not big enough to motivate the RE industry expansion (Lund, 2009), or (iii) it may be more economical for a country to depend on import, rather than developing and expanding the domestic RE industry.

To explore the influence of RE economic incentives on the RE Industrial expansion, the RE Industrial growth factor, and the share of solar and wind power in electricity in 2017, would be plotted against the the country's total economic incentives for adopting these power generation technologies.

d) Influence of technological preparedness on RE industry:

As discussed in section 2.2 and section 2.3, higher renewable energy penetration brings greater technological challenges for integration (Kroposki et al., 2017). Section 3.6 presents hierarchical method to assess the technological preparedness of a country for large scale integration of variable renewable energy. Hence, it can be be safely assumed that a better technological preparedness level of country would lead to increased share of variable renewable energy in electricity, boosting further deployment of RE and increasing RE industrial activities. In contrast to the presented assumption, it can also be argued that increased industrial activity or accelerated deployment of VRE generators creates pressure to improve the technological preparedness, which also cannot be neglected.

To study the influence of technological preparedness on the industrial growth, the RE industrial growth factor and the share of solar PV and wind power in electricity in 2017 would be plotted against the technological preparedness (scale of 0 to 5) and the results would be analyzed.

e) Influence of RE policies on RE industry:

Zhang et al. (2013) argues that there should be a good interaction between the RE policy and RE industrial policy (and industrial growth). A strong influence of RE policy on industrial growth would imply that the RE policies were successful in sending clear and consistent market signal which stimulated required investments in capacity expansion and increase in the industrial activities. On the other hand, a weaker influence would suggest that either the RE policies were not clear, were inconsistent, and were not successful in garnering sufficient confidence in the market which may lead to increased industrial growth. A weaker influence would also imply lack of coordination and balanced focus on both the supply side (production and manufacturing) and demand side (RE policies) of the market.

To study the influence of RE policies on the industrial growth, the RE Industrial growth factor, and the share of solar and wind in electricity (2017) would be plotted against the overall RE policy and regulatory framework score of the country and the results would be analyzed.

f) Interactions between the national political will and the RE industry:

National political will through the means of national RE targets, sends a market signal, showing government's vision for future energy mix. A strong influence of the political will on industrial growth would be desirable, because it would represent the industry's confidence on the country's government and on government's capability to steer the market to achieve the national RE target. However, a weaker influence would suggest the RE industry is either not confident on the government in terms of capability to develop the market to meet the target, or the target growth is not lucrative enough to invest and develop the RE industry.

As the political decisions of a country are also motivated by the economic growth (Gallagher, 2013) and the power of the industry to influence the government, a strong influence of the RE industry on political will would represent a strong market power held by the RE industry. On the other hand, a weaker influence by RE industry would represent that the lobbying power of the conventional fossil based industry has a stronger influence on the political decision Gallagher (2013), or the country's political will to adopt renewable energy.

To study the interactions between the political will on the industry, the RE Industrial growth factor, and RE manufacturing capacity share would be plotted against the country's political will and the results would be analyzed.

g) Combined effect of interactions on the national renewable energy business environment:

A combined study of all the above discussed factors and the interactions are important, because the study would answer the cumulative effect of the external-business environmental factors and their interactions, on the national renewable energy business environment, which is the main research question of this thesis. The study would also help to identify the external factors which need further improvement, and the weaker interactions which can be strengthened to improve the health of the renewable energy business environment of a country.

To study the interactions of political will, renewable energy policy, economic incentives, technological preparedness, and industrial factors, and their combined effect on the solar PV and wind power business environment, country wise radar charts would be plotted, with four dimensions as political will, policy and regulation, economic incentives, and technical preparedness. The spread of the plot towards any of these dimensions would measure the strength of influence of the factor on the RE business environment, and the overall spread would suggest the status of the renewable energy business environment.

3.8 Input Data

The number of countries considered for this research is 7, namely China, USA, India, Russia, Japan, Germany and South Korea. The country selection was done, based on the 2015 IEA data, from the list of top emitting countries.

Data for the national renewable energy targets (Target_{RES}) are from the *Renewables 2018 Global Status Report* by REN21 (REN21, 2018). Data on the national road-maps for energy transitions are from IEA/IRENA Global Renewable Energy Policies and Measures Database, and from the relevant government reports and websites.

Renewable energy targets of India are from publications by The Energy and Resources Institute (TERI), which works with the Ministry of New and Renewable Energy (MNRE) of the Central Government of India. Further the details of the Renewable Purchase Obligations (RPO) are obtained from the website of Ministry of Power of the Government of India. Information about the energy strategy of Russia is taken from the government report "Energy Strategy of Russia For The Period Up To 2030" by the Ministry of Energy of the Russian Federation. Energy targets of Japan are obtained from the Intended Nationally Determined Contribution (INDC) submitted by the Government of Japan. Further the detailed plan can be found in the report "Long-term Energy Supply and Demand Outlook for 2030" by Ministry of Economy, Trade and Industry of Japan. Targets and energy plans of China, Germany and South Korea are obtained from multiple reports by International Energy Agency (IEA) and REN21.The state wise RPS targets and progress made by the United States are from reports by Berkely Lab in collaboration with National Renewable Energy Laboratory

Latest progress details made by India, in the field of renewable energy are from publications by the Press Information Bureau of Government of India. Progress updates of Russia are obtained from available few published research papers. Information about progress made by Japan, China, and South Korea are collected from multiple reports by IEA and REN21. For Germany, good amount of quality research papers are available providing the historical background, political buildup and progress of the country towards renewable energy objectives.

For conducting the economic analysis, LCOE data for solar PV, onshore wind and offshore wind power, for all the chosen countries were latest data from *Masterfile Renewable Power Generation Costs in 2017* by International Renewable Energy Agency (IRENA). Exact value of onshore wind power LCOE in Germany is from *Report of the Federal Government on Energy Research 2017*.

Commercial, industrial, and domestic retail electricity prices of China, USA, Japan, Germany and South Korea are obtained from the National Survey Reports by IEA. Electricity prices of India are from the Open Government Data (OGD) Platform India maintained by the Government of India. Electricity prices of Russia are from the research papers. All the prices were converted to USD/kWh using World Bank average conversion rates of 2017. Conversion rates used were as follows: 1 JPY = (1/112.15) USD, 1 EUR = 1.11 USD, 1 INR = (1/67) USD, 1 RUB = 0.015 USD, and 1 KRW = 0.0008 USD. Feed-in Tariff values of solar PV and wind power in Japan and renewable electricity support price in China are from IEA. Renewable electricity price in Russia is calculated based on the LCOE value available with IRENA with added 14% ROI based on CRESS (discussed in detail in Section 4.3). The global average range of fossil based electricity generation cost is from *Renewable Power Generation Costs in 2017*, a 2018 report by IRENA. Further specific fossil power generation costs are from reports by IEA , U.S. Energy Information Administration, and from Central Electricity Regulatory Commission of India.

Historical values of RISE (*"Regulatory Indicators for Sustainable Energy"*) are taken from World Bank database (World Bank, n.d.). Information about the solar PV installations, PV production capacity and actual PV production at the global level, and country wise trend for increase in solar PV cell production capacity is from the report *Trends 2018 In Photovoltaic Applications* by IEA. The solar PV cell manufacturing capacity data of China is obtained from IEA (2018*b*), and manufacturing capacities of USA, Japan, Germany, India and South Korea are estimated based on their maximum PV cell production in the period 2012-2017. PV cell manufacturing capacity data of Russia could not obtained and hence estimated based on the local content in the installed RE power generation capacities (Smeets, 2017). Wind power average annual demand are five year average of annual wind capacity installations in the period 2013-2017 in the selected countries and the information is from Enerdata database. China's and South Korea's wind power manufacturing capacity data is from the Wind Annual Report 2017 by IEA. USA's wind power manufacturing capacity is from *2017 Wind Technologies Market Report* by the U.S. Department of Energy. India's manufacturing capacity information is from Ministry of New and Renewable Energy (MNRE). For Japan and Germany, exact wind power manufacturing capacity data could not be retrieved, however, it was established that with presence of companies Hitachi, Siemens these two countries are net exporters of wind power equipment in the global market. For representation, Germany's and Japan's wind power manufacturing capacity is estimated from the global market share of wind turbines in the year 2017 from the FTI consulting report. Wind power manufacturing data of Russia could not be obtained and also estimated based on the local content in the installed capacities.

Information about the technological preparedness of all these countries was the result of a literature survey of research papers, analysis reports by IEA, and reports by respective governments. Further, the country wise share of solar PV and wind power in electricity data is from Enerdata database.

Chapter 4

Results and Analysis

After establishing the research question in chapter 1, developing a research methodology in chapter 3, this chapter presents the detailed results obtained by applying the above the renewable energy business environment methodology and analysis of the results.

In this chapter, first the factors of the RE business environment are measured and analysed. Starting with the national political will in section 4.1, policy and regulatory framework in section 4.2, economic incentives in section 4.3, industrial factor in section 4.4, technical factor in section 4.5, followed by the relationships and interaction among factors in section 4.6, and the cumulative impact in the section 4.7.

4.1 Political Will

Table 4.1 summarizes the official renewable energy targets, projected targets and political will calculations. Calculation of the national political will for each country is calculated using the formula below:

$$Political\ Will = 0.5(\tau \times Target_{RES} + P \times Planned_{RES}) \tag{4.1}$$

The figure 4.1 presents the official national renewable energy targets in solid lines and projected national renewable energy target/state cumulative targets in dashed lines until 2030. Enerdata (n.d.) values for the share of renewable energy in electricity for the year 2017, are taken as starting points for the fig. 4.1. The figure 4.2 below presents the comparative results of the national political will in the concerned countries.

[1]National political will of USA is found to be 0, however the value represents the state cumulative political will based on the total projected share of RE electricity through compulsory RSP targets.

Table 4.1 Political Will calculation

Country	τ	$Target_{RES}$	P	$Planned_{RES}$	Political Will	Official Targets	Reference
China	1	56% (2030 projected target)	1	27%	41.5%	27% RES-E share by 2020 (210 GW wind, 110 GW solar by 2020)	(REN21, 2018), (International Energy Agency, 2018*b*)
USA [1]	-	-	-	-	12%	No national target. State cumulative RPS represents 12% electricity by 2030	(Barbose, 2018)
India	1	40%	1	21%	30.5%	40% RES-E share by 2030, 21% by 2022. 100 GW solar, 60 GW wind by 2022.	(Ministry of Power, 2018), (TERI, 2015)
Russia	1	4.5% (2030 projected target)	1	4.5%	4.5%	4.5% RES-E share by 2024	(Gsänger and Denisov, 2017),(Ministry of Energy of the Russian Federation, 2010)
Japan	1	24%	1	24%	24%	22-24% RES-E share by 2030	(Government of Japan, 2015), (METI, 2015)
Germany	1	50%	1	50%	50%	40-45% RES-E share by 2025, 55-60% by 2035, 80% by 2050	(REN21, 2018), (Hake et al., 2015)
South Korea	1	20%	1	20%	20%	20% RES-E share by 2030, 10.5% by 2022	(IEA, 2017*b*)

China scored 41.5% in the national political will. According to the 2020 energy targets of China, the government of China plans to source 27% of electricity to be consumed in 2020 from renewable energy sources (REN21, 2018). In the terms of capacity addition, the central government of China plans to install a total of 680 GW of renewable energy power

[1]National political will of USA is found to be 0, however the value represents the state cumulative political will based on the total projected share of RE electricity through compulsory RSP targets.

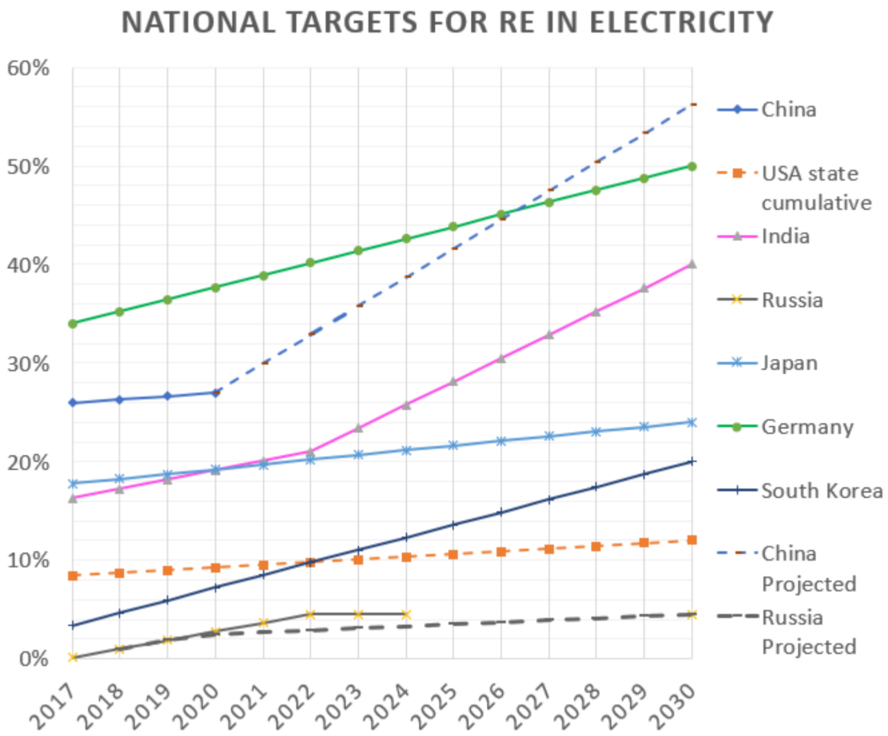


Fig. 4.1 National Renewable Energy Targets

generation capacity by 2020, which includes 210 GW of wind power and 110 GW of solar PV (International Energy Agency, 2018*b*). To achieve the planned targets, China implements five year plans and the road-map to achieve the above targets have been laid out in China's 13th five year plan (2016-2020) for power sector development (International Energy Agency, 2018*b*). According to projections by China's renewable energy outlook by CNREC (2018), China may increase renewable electricity demand to 72% by 2035 and around 88% by 2050. Linear interpolation of these targets from 2020 target (27%), gives 56% RES-E target for 2030 and a political will of 41.5% based on the 2030 projected target.

The United States scored 0% in terms of National Political Will, which is observed to be the same since 1990s when the the federal government refused to endorse the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) signed in 1997, and later also withdrew from the Paris Agreement (announcement of withdrawal on 1st June 2017) and instead preferred the market to drive the adoption of RE technologies. Hence, in the view of lack of the national renewable energy targets and plans to achieve the targets, USA receives 0% in terms of national political will.

However, according to the November 2018 report on renewable portfolio standards (RPS) by Lawrence Berkeley National Laboratory, 29 out of the 50 states and Washington, D.C., have implemented the mandatory state RPS policies and targets (Barbose, 2018). Hence, although the political will at the federal government level is missing in the United States, the state political will can not be ignored. The cumulative RPS state targets for 2030, accounts for around 12% of the total projected retail electricity sales by 2030 (Barbose, 2018). Hence, the state cumulative political will of the USA is 12%.

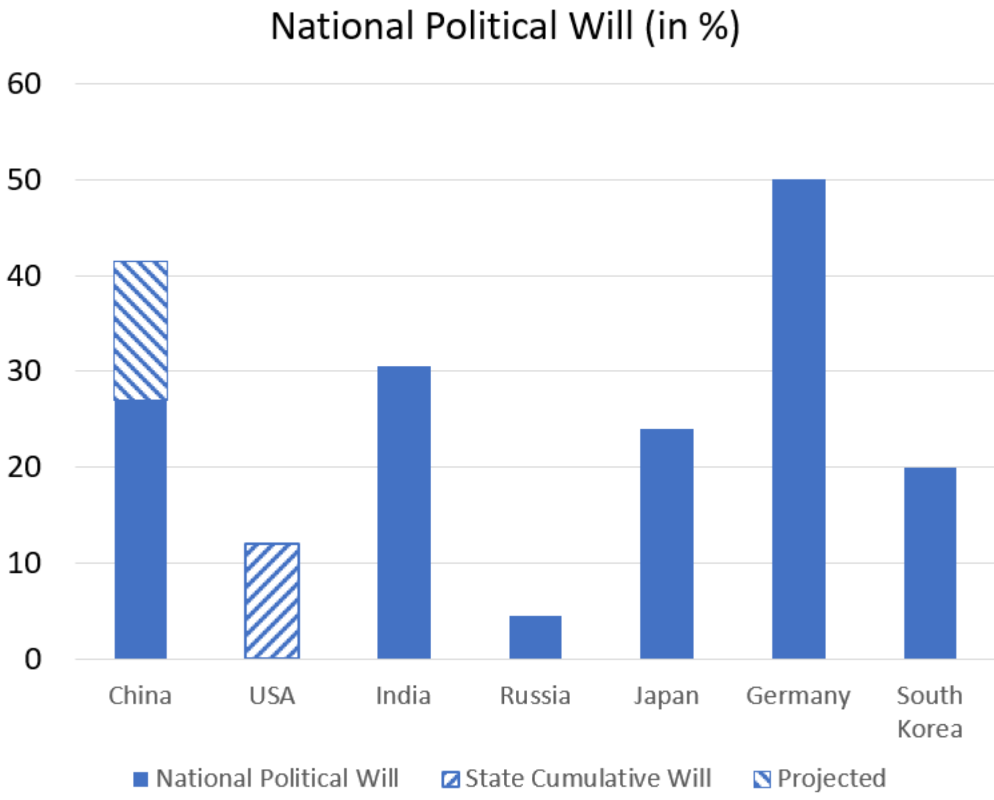


Fig. 4.2 National Political Will Comparison (Refer: Table 4.1)

Due the comparatively higher 2030 targets, India scored 30.5% in the national political will. India has a vision to achieve 40% contribution of electricity by renewable energy sources by 2030. However, the central government has laid down plans to achieve only 21% Renewable Purchase Obligation [2] (RPO) by 2022 (Ministry of Power, 2018). Hence, due the lack of time based plan above 21%, the national political will comes down to 30.5%. In terms of the target renewable energy generation capacity, the central government of India plans to achieve a total installed capacity of 175GW [3] by 2022, which includes 100 GW of solar PV and 60 GW of wind power (remaining by the small hydro and biomass power generation) (TERI, 2015).

[2] Similar to the concept of RPS in the USA and other countries. However, RPO in India can be implemented at the state level, for specific industries, sectors or projects.

[3] India does not include hydro power over 25MW under the category of renewable energy capacity.

The prospects of renewable energy in Russia is very weak, except for the large hydropower. According to the Government Executive Order Nr.1-R of 08.01.2009 the federal government of Russia, aimed to achieve 4.5% contribution by renewable energy by 2020. However, the target was later reduced to 2.5% and the target of 4.5% was extended to 2024 (Gsänger and Denisov, 2017). The plan to achieve the 4.5% renewable target has been laid down in the Energy Strategy of Russia by the Ministry of Energy (Ministry of Energy of the Russian Federation, 2010). Russia does not include large hydro projects over 25MW under the category of renewable energy. Hence, the national political will of Russia for the adoption renewable energy is just 4.5%. Due to the very slow progress by the country, the 4.5% target is expected to extend to 2030.

Japan scores around 24% in terms of the national political will for adoption of renewable energy. In July 2015, Japan submitted INDC (Intended Nationally Determined Contribution) to the UN Framework Convention on Climate Change (UNFCCC) (Government of Japan, 2015). According to which, Japan has a long term plan to have an overall energy mix, comprising of 22-24% of renewable energy (including hydro) in the electricity by 2030. This includes 7% of solar PV and wind power of 1.7% (rest of the target renewable energy mix comprises of 8.8-9.2% hydro power, 3.7-4.6% biomass and 1% of geothermal). The Ministry of Economy, Trade and Industry (METI) launched the Long-Term Energy Supply and Demand Outlook for 2030 in July 2015, to achieve the above mentioned targets (METI, 2015).

Germany's national political will for 2030 is 50%. Germany has a time based plan to achieve 40-45% renewable share by 2025, 55-60% by 2035 and 80% by 2050 (REN21, 2018). Germany passed legislative support for 'Energiewende' (energy transition) in 2010, targeting to reduce GHG emissions by 80-95% by 2050, as compared to 1990 (and 40% by 2020), and phasing out nuclear power by 2022. Energiewende covers all the major sectors of Germany's energy system to move towards more efficient and green energy consumption. Energiewende aims to increase the use of renewable energy to 60% of the gross final energy consumption by 2050 (and 18% by 2020), and targets share of renewable energy in electricity to be 35% by 2020, 50% by 2030, 65% by 2040 and over 80% by 2050. Currently Energiewende plays the most important role in laying the road map of country's energy transition (Hake et al., 2015).

South Korea scored 20% in the national political will. The government of South Korea has announced targets and detailed implementation plan for the expansion of renewable energy in the electric power system. According to the country's long term plan, South Korea plans to incorporate 20% of renewable energy by 2030, 10.5% by 2022 and 7% by 2016. In the terms of capacity addition, South Korea plans to install 63.8 GW of renewable energy by

2030, including 36.5 GW of solar and 17.7 GW of wind power (remaining by hydro power, biomass and waste to energy) (IEA, 2017*b*).

Hence, summarized national political will of the concerned countries for adoption of renewable electricity can be observed in fig 4.2.

4.2 RE policy and regulatory framework

This section compares the presence of renewable energy policies and regulatory framework for the support of renewable energy based on the World Bank RISE indicator scores.

As it can be observed from the Fig 4.3, the concerned countries have done major improvements in their national renewable energy policy and regulatory measures since 2011. Reference table is attached in Appendix B.

Although, all of these countries had some form legal framework for renewable energy, however, implementation of policy measures to create conducive environment for deployment of renewable energy had been slow (World Bank, 2018). In 2011, only Germany had considerable better RE policies and regulatory measures (more than 70% score). However, by 2017, India (87%), South Korea (83%), Japan (76%) and China (70%) made considerable improvements. RE policy environment of Russia (65%) and USA (58%) are not sufficiently conducive for the deployment of renewable energy.

Germany was successful in strengthening all the major indicators of renewable support policies. Germany scores the highest score of 97%, as the country not only developed the legal framework for renewable energy and implemented a detailed plan for RE expansion, but improved on all the other parameters by creating support policies and regulations, for long term financial incentives for RE electricity production, provisions for grid access and priority dispatch, ensuring cost competitiveness for large scale RE deployment through auctions, competitive bidding, ensuring clear grid codes and standards for VRE, provisions for renewable energy to participate in ancillary services, strengthening creditworthiness and implementing mechanisms for carbon pricing, monitoring and reporting (World Bank, n.d.).

India scored a second highest score of 87% in terms of conducive renewable policy environment. Compared with Germany, India loses score due to zero score in creditworthiness, and reduced counterparty risk of the country in renewable energy investments. Further, high quality forecasting and scheduling of renewable power is not available in the country. Furthermore, although the expansion plan for renewable energy is existent, mechanisms for adjusting expansion plan based on RE deployment is not present. Also, the country is lacking in geo-spatial planning for commercial development of RE sources (World Bank, n.d.).

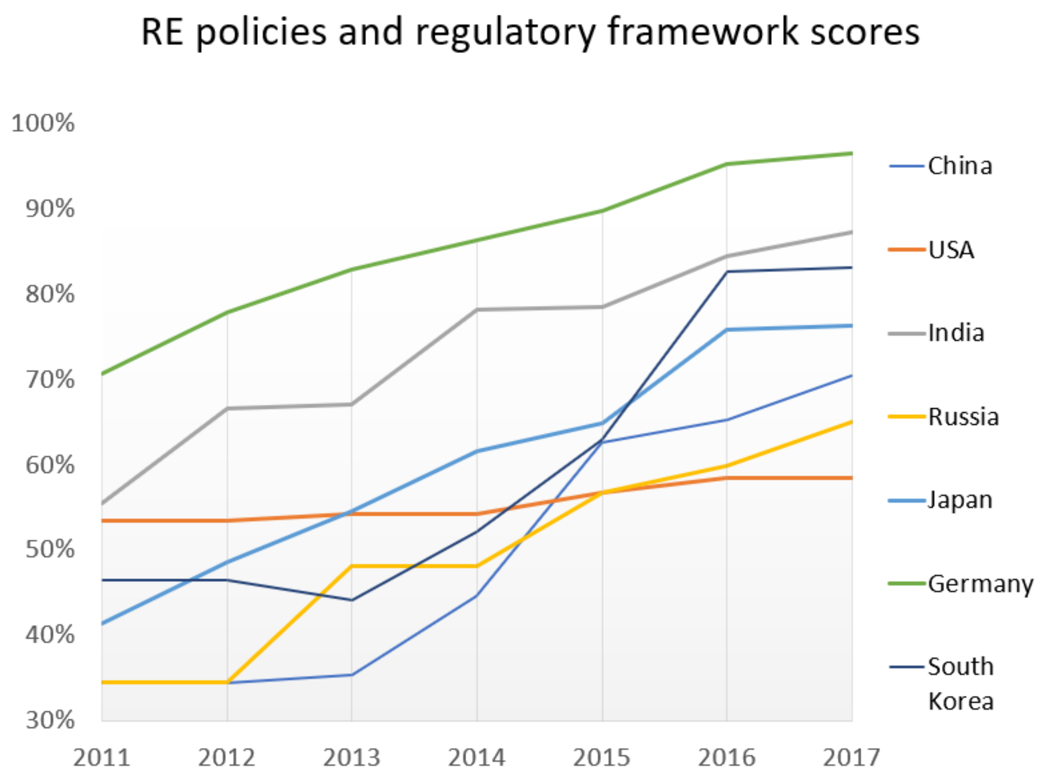


Fig. 4.3 Trend of RE policy and regulatory framework score (2011-2017) (Source: World Bank (n.d.))

South Korea scores the next highest RE policy and regulatory framework score of 83% in 2017. When compared with Germany and India, South Korea gets a little less score, because of the following reasons: (a) the country doesn't allow direct purchase of electricity from sources other than the respective utility, (b) lack of provision for renewable energy projects to participate in ancillary services and power balancing, (c) lack of integrated high quality forecasting for RE power dispatch, (d) reduced counterparty risk, (e) lack of provisions to compensate for delay in providing power dispatch infrastructure, and (f) lack of provision for compensation due to VRE power curtailment (World Bank, n.d.). South Korea suffered a little dip in RE policy environment in 2013, due to drop in counterparty risk, however, to improvements in RE incentive and support policies, South Korea could sharply improve the RE policy environment during 2014-2016 (World Bank, n.d.). .

In 2017, Japan's RE policy environment scored 76%. In comparison with Germany, India, and South Korea, Japan lost a few scores due to the following reasons: (a) Due to lack of clear grid code for variable RE integration, (b) lack of clear rules for cost allocation of network charges (transmission & distribution system), (c) lack of provision for renewable power to provide ancillary services and power balancing, (d) lack of provisions for real time

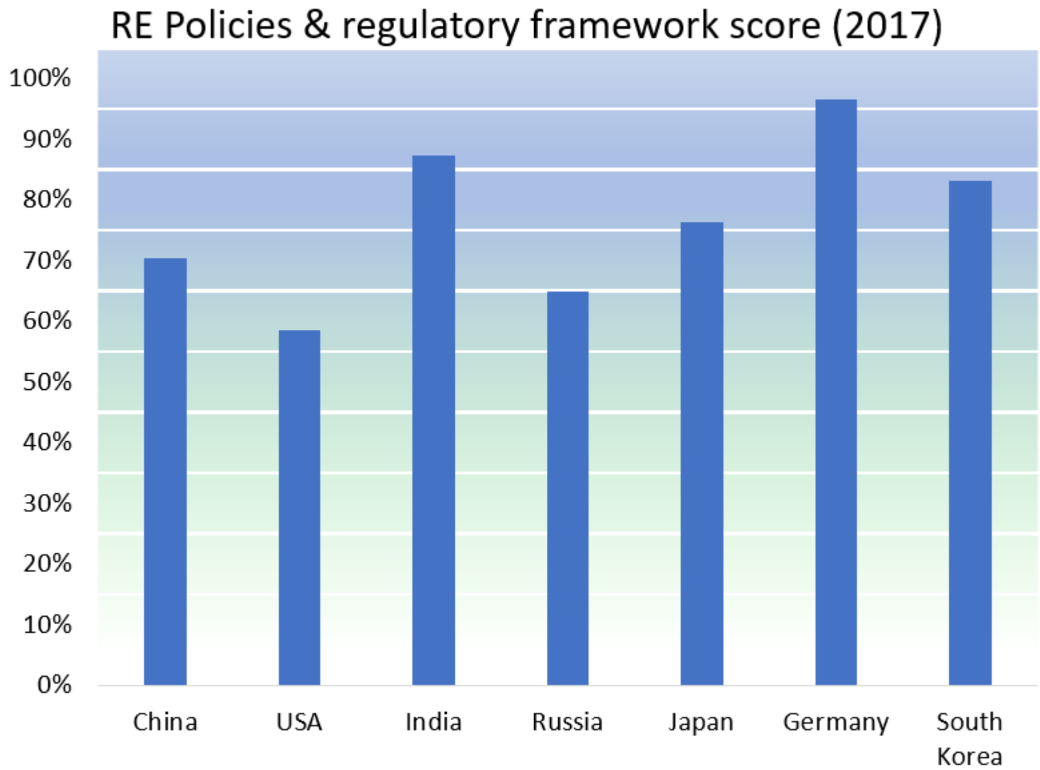


Fig. 4.4 RE policy and regulatory framework score

dispatch operations, (e) due to comparatively lower creditworthiness, (f) lack of priority grid access and dispatch of RE power, (g) lack of provisions to compensate for delay in providing power dispatch infrastructure, and (h) reduced planning scores as the RE targets are not legally binding, and investments, generation and transmission planning are integrated (World Bank, n.d.).

China scored 70% in RE policy environment in 2017. Improvements required to increase the policy environment rating of China as of 2017 are as follows : (a) By making the information of future planned schedule of RE project auctions public, inclusion of pre-qualification for bidders' selection, indexing tariffs for inflation or an international currency, (b) providing security to small producers through fixed/inflation corrected tariff contracts, (c) by increasing the counterparty risk by improving creditworthiness of RE projects, by making the financial statements of public utility generators and retail seller public, (d) improving grid integration of VRE electricity through real time dispatch operations, implementing rules for allowing seamless VRE power balancing and exchange. (e) improving the planning of RE expansion, by including investment as a part of RE target plan, mechanisms for reporting the progress and adjusting the deployment plan, by conducting geo-spatial planning for RE commercial development, and (f) by implementing mechanisms for monitoring and reporting emissions (World Bank, n.d.).

Russia scored 65% in RE policy environment in 2017, which is quite insufficient for creating a conducive policy environment for improving deployment of renewable energy. Russia needs to work on multiple indicators to improve this policy environment in following ways: (a) by implementing a RE energy target through transparent methodology, making investment a part of renewable expansion plan, by making the resource map of solar/wind power available in the country, in line with the best practices around the world, (b) by providing required incentives and support, and safeguarding RE projects by making provision of compensating for delayed power dispatch infrastructure, and VRE power curtailment, (c) improving the auctions by including pre-qualification for bidders, and tracking auctions/bids for delay, by creating provisions for grid connectivity to small producers, (d) by improving network connection through grid codes for VRE electricity, by carrying out regular grid flexibility studies, and by integrating high quality RE forecasting, and (e) by implementing mechanisms for carbon pricing (World Bank, n.d.).

USA scored 58% in 2017, which is lowest among the above mentioned countries. To improve the RE policy environment, USA would need to strengthen all the indicators in following ways: (a) creating a nation wide legal framework for renewable energy, (b) creating provisions for nationwide legal and binding renewable energy deployment and consumption planning, (c) by implementing fiscal incentives to support RE power generation, and allowing priority dispatch, (d) by providing inflation corrected tariff contracts to large scale RE projects, (e) implementing rules for allowing seamless VRE power balancing and exchange, (f) improving the counterparty risk through increasing the creditworthiness and creating provisions for mitigating payment risk, and (g) by implementing nationwide carbon pricing, monitoring and reporting mechanism (World Bank, n.d.).

4.3 Economic Incentives

This chapter studies the level of economic incentives in renewable power generation through the following three parameters: a) grid parity, b) generation cost comparison with the fossil electricity and c) renewable electricity prices in comparison with their respective LCOEs.

a) *Grid Parity* is an important economic factor because it provides an option for the electricity users (domestic, commercial or industrial) to self-generate renewable electricity instead of purchasing electricity from the grid. Fig 4.5, shows the comparison of the electricity prices (domestic, commercial and industrial prices) from the grid and the localized cost of electricity (LCOE) for solar PV and wind power (on-shore and off-shore) in different countries. The yellow line represents the LCOE of solar PV, the blue line represents the LCOE of on-shore power and the purple line represents the LCOE of the off-shore power generation. Rest of the three shades represents the grid electricity price range for different consumers.

According to IRENA the global weighted average of solar PV LCOE reached 0.10 USD /kWh in 2017, while ranging from 0.09 to 0.17 USD/KWh. The global weighted average LCOE of on-shore wind power was recorded 0.06 USD/kWh in 2017 (according to the 2018 data this value is crossing the lower limit of 0.05 USD/kWh) (IRENA, 2018*c*). LCOE of off-shore wind power ranged between 0.15 USD/kWh to 0.24kWh in the observed countries.

Data sources for fig 4.5 : LCOE data for solar PV, onshore wind and offshore wind power, for all the chosen countries were latest data from *Masterfile Renewable Power Generation Costs in 2017* by International Renewable Energy Agency (IRENA, 2018*c*). Values of onshore wind power LCOE in Germany is from *Report of the Federal Government on Energy Research 2017* (BMWi, 2017). LCOE values of Russia are from Letova et al. (2018).

Commercial, industrial, and domestic retail electricity prices of China, USA, Japan, Germany and South Korea are obtained from the National Survey Reports by IEA (IEA, 2016*a*) (International Energy Agency, 2018*a*) (IEA, 2018*a*) (IEA, 2016*b*) (IEA, 2019). Electricity prices of India are from the Open Government Data (OGD) Platform India maintained by the Government of India (Government of India, n.d.).Electricity prices of Russia are taken from Letova et al. (2018). All the prices were converted to USD/kWh using average conversion rates of 2017 (X-rates.com, n.d.). Conversion rates used were as follows: 1 JPY = (1/112.15) USD, 1 EUR = 1.11 USD, 1 INR = (1/67) USD, 1 RUB = 0.015 USD, and 1 KRW = 0.0008 USD.

It can be clearly observed that the solar PV has become competitive with the grid electricity in most of the countries, except in Russia. In the advanced economies as in Japan and Germany, solar PV generated electricity is on an average more economical than the grid electricity. This is also due to the expensive domestic electricity in both Japan and Germany. Russia's domestic retail electricity price is exceptionally lower due to the subsidized rates and solar PV LCOE is exceptionally high at 0.5 USD/kWh as the technology is in introduction phase in the country (IRENA, 2018*b*).

On-shore wind power has become more economical than the grid electricity in most of the countries, and competitive in India and South Korea. Again with an exception in Russia due to the reasons mentioned above.

Off-shore wind power has become economical than grid electricity in Japan and Germany, competitive in the other economies like USA and South Korea. In India and China, it is still expensive due to the comparatively lower grid electricity prices. Russia is currently not

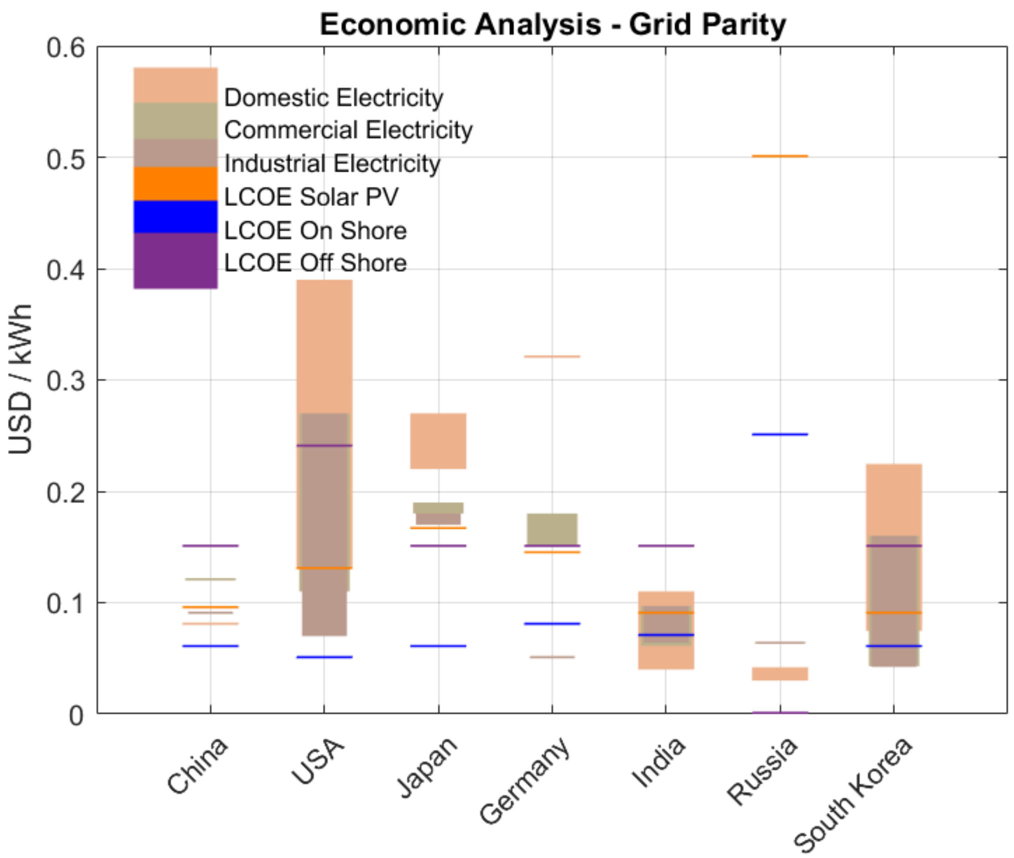


Fig. 4.5 Economic Analysis: Grid Parity (Data source: refer text)

seeking development of off-shore wind power and the zero LCOE value represents "*no data*" in this figure and all the subsequent figures.

b) *Generation cost comparison of renewable energy electricity with the fossil electricity:*

Data source for fig. 4.6: Fossil electricity generation costs (LCOE) are collected from IRENA (2018*c*), International Energy Agency (2018*b*), U.S. Energy Information Administration (2013), Letova et al. (2018), Government of India (n.d.).

As the major share of the current power sector in most of the countries is currently dependent upon the fossil electricity, it becomes important to compare the electricity generation cost of modern renewable energy technologies with the long existing fossil power generation technologies.

From the Figure 4.6, it can be be observed that the on-shore wind power has emerged as a winner and has become very competitive with the fossil electricity. It can also be observed that in USA, Japan, and South Korea, the on-shore wind generation is very close to the lowest generation cost of fossil electricity and with current rate of development, it can be easily estimated that the On-shore power would become more economical in these countries in

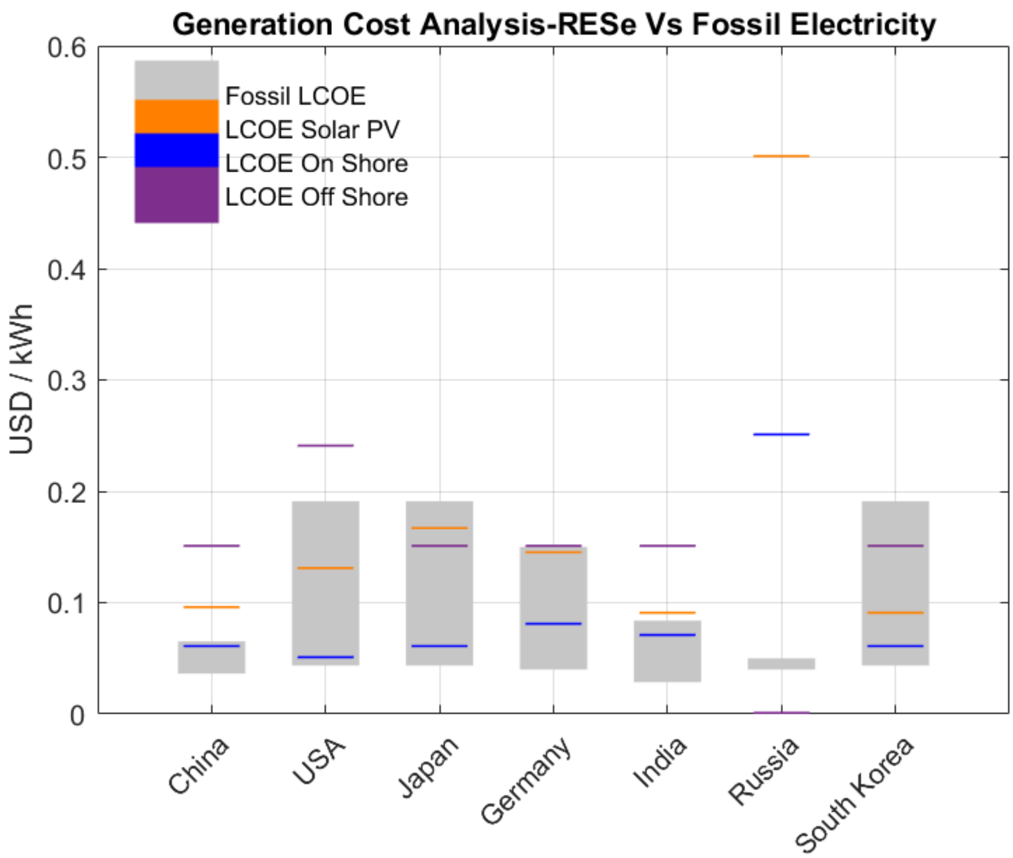


Fig. 4.6 Generation Cost comparison: Fossil electricity Vs RESe (Data source: refer text)

the next few years. In India and China, onshore wind power is competitive with the fossil electricity but lies towards the higher end. The low cost of fossil electricity is also do the subsidies in the fossil fuels. Onshore wind is quite expensive than the fossil electricity in Russia due to exceptionally low cost of coal and natural gas in the country (IRENA, 2018*b*).

Solar PV has become competitive with the fossil electricity in USA, Japan, South Korea and Germany. However, they are not yet competitive in China, India and Russia.

Off-shore wind power has become competitive in Japan and South Korea due to the advancement in the technology and very close to the upper limit of fossil electricity generation cost in Germany. In China, USA and India, off-shore wind power is still expensive than the conventional power.

Furthermore, it must be noted that the represented LCOE of fossil electricity has not internalized the externalities caused due to emissions and has not excluded the fossil fuel subsidies available in these countries.

c) *Renewable electricity price compensation as compared to the generation cost:*

Data source for fig. 4.7: Tariff rates if applicable are obtained from the *National Survey Reports* by IEA (IEA, 2016*a*) (International Energy Agency, 2018*a*) (IEA, 2018*a*) (IEA, 2016*b*) (IEA, 2019). Electricity tariff rates for solar and onshore wind power in Russia are based on 2014 data, and these are calculated by author based on LCOE calculation by IRENA by adding 14% ROI according to the CRESS scheme (IRENA, 2017).

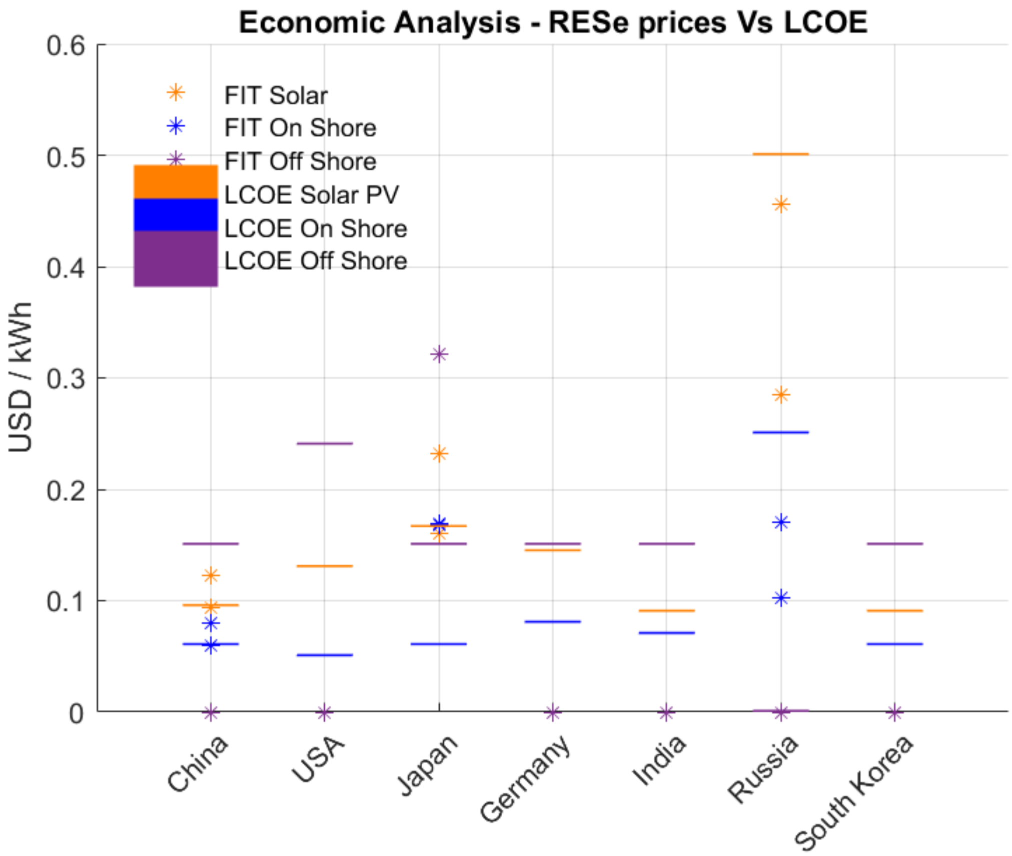


Fig. 4.7 Cost and Price Analysis: RESe prices Vs LCOE (Data source: refer text)

To support the large scale deployment and consumption of solar and wind power, the generated variable renewable electricity needs price support in the form of clear and long-term fixed (or adapted for inflation) tariff or price support, to overcome the market challenges in the existing power system. As per the latest data available during the time of writing this report, only China had feed-in tariff applicable for solar PV and on-shore wind, and Japan for solar, on-shore and off-shore wind power. In can be observed for China and Japan, that the applicable generation based tariff for solar and wind power are sufficiently higher than the respective LCOE to create sufficient incentives for investment in these technologies while promoting innovation through cost reduction.

Russia does not provide price support mechanism for RE power generation, but the country has capacity based renewable energy support scheme (CRESS), which provides tariff with 14% ROI (Return on investment) (before 2014) to the selected qualified renewable energy projects. However, the CRESS scheme is only applicable to the grid connected wholesale electricity market (for capacity higher than 5MW) and not for the retail electricity market and also not for the off-grid supply (Smeets, 2017). Hence, the only incentive for the medium scale renewable energy generators (above 5MW) through CRESS is further reduced to 12% ROI (rate applicable since 2015), which is further limited by the maximum capex limit on investments and volume of tenders annually released by the Administrator of the Trading System (ATS), the price support schemes for renewable energy is very weak in Russia. Further, the decentralized retail market is limited to a maximum capacity of 1 GW with unsure tariffs (Smeets, 2017).

The United States does not have generation based fixed tariff system applicable [4], however allows the Net Metering tariffs. Hence, consumers are eligible to claim the Net Excess Generation (NEG) accumulated in terms of kilowatt-hour (kWh) credits at the end of the year refundable at the rate of unbundled generation charges (Energy.gov, 2015). Hence, the independent renewable power generators can sell the electricity in the wholesale electricity market by achieving cost competitiveness and there is no direct price support for RE power generation.

With the latest amendment to the Renewable Energy Sources Act (EEG 2017), which came into effect from 1st January 2017, Germany has completely withdrawn the feed-in tariff scheme for new projects and has introduced the public tender procedure for onshore wind, offshore wind and solar projects. The electricity price are finalized based on the accepted bids and contracts applicable for 20 years. The price ceiling for different technologies are decided as EURO cents 7/kWh for onshore wind, 12/kWh for Off shore, 8.91/kWh for solar PV (rates based on initial tenders of 2017) (IEA, 2017*b*). Hence, the ceiling prices are very competitive with the respective LCOE, however, the long term contracts provide fixed long-term incentives for investment to the large scale power producers. Hence, the market created by government bids/auctions would be highly competitive and limited to the volume of tenders released by the government. The independent renewable power producers can however, benefit from the cost competitiveness in the day-ahead electricity market.

South Korea discontinued feed-in tariff in 2011, and currently relies on RPS scheme along with auction system for utility scale RE projects, where the minimum and maximum allowable tariffs are fixed by the government (IEA, 2019). Instead of providing high economic

[4] As of 2016, FIT was mandated in the 6 U.S states and voluntary in some utilities, however the scheme closed application by 1st April 2019 and rates were not reviewed at the time of writing this report.

incentives for RE power generation, South Korea focuses on reducing RE LCOE through technological innovation and provides long term contracts, at competitive rates through power purchase agreements.

India discontinued the feed-in tariff scheme in 2017, and adopted tariff based competitive reverse e-auction bidding process to discover the lowest tariff rates for solar and wind projects (MNRE, n.d.*b*). Hence, this would result in long term contracts with project specific very competitive tariff rates. Hence, in contrast with South Korea, which provides floor tariff price, reverse e-auction based arrived tariffs in India would be just enough to cover project cost and earn profit through long term operation while maximizing operational efficiency.

Table 4.2, table 4.3, and table 4.4 presents the calculation of level of economic incentives based on the above discussed parameters and methodology discussed in section 3.4. Table 4.5 presents the overall percentage economic incentive for solar and wind power in the concerned countries.

From the table 4.5, it can be observed that Japan has been successful in creating the best economic incentives for renewable energy deployment with a score of 83%, due to strong fiscal support and advancements in renewable energy technologies. This is followed by South Korea, with an overall economic incentive score of 67%, specially due to the strong technological development in the country and reduction in RE power generation cost. Germany comes next with an overall economic incentive score of 61%. The reduction in economic incentives due to recent policy changes in Germany (as discussed above), shows country's shifting reliance on technological maturity, from strong economic incentive support. For the rest of the countries like the USA (50%), China (44%), India (39%), economic incentives are not strong enough to drive the deployment of renewable power, and for Russia, economic incentives are extremely poor with a score of only 6%.

4.4 Industrial Factor

Renewable energy industry can be broadly divided into three segments: (a) RE capacity deployment industry, (b) RE power generation industry, and (c) RE equipment manufacturing industry. Hence, as discussed in section 3.5, the growth in the renewable energy industry would be assessed as a combination of the above three segments of the RE industry:

(a) *RE power generation capacity deployment industry:* This segment presents the trend in the RE power generation capacity deployment, and measures the share of new capacity installation market captured by the solar PV and wind energy in a country. Fig. 4.8 and fig. 4.9 presents the trend in the deployment of solar PV and wind power in the concerned countries in the period 2011-2017 Enerdata (n.d.). It can be observed that China has shown sharp

Table 4.2 Economic incentive calculation for solar PV

Country	Grid Parity (a)	$LCOE_{RE}$ Vs fossil electricity (b)	$LCOE_{RE}$ Vs RES-E price (c)	Economic incentive for solar PV (a+b+c)
China	0.5	0.0	1.0	1.5
USA	0.5	0.5	0.5	1.5
Japan	1.0	0.5	1	2.5
Germany	0.5	0.5	1.0	2.0
India	0.5	0.0	1.0	1.5
Russia	0.0	0.0	0.5	0.5
South Korea	0.5	0.5	1.0	2.0

Table 4.3 Economic Incentive calculation for onshore wind

Country	Grid Parity (a)	$LCOE_{RE}$ Vs fossil electricity (b)	$LCOE_{RE}$ Vs RES-E price (c)	Economic incentive for onshore wind (a+b+c)
China	1.0	0.5	1.0	2.5
USA	1.0	0.5	0.5	2.0
Japan	1.0	0.5	1	2.5
Germany	0.5	0.5	1.0	2.0
India	0.5	0.5	1.0	2.0
Russia	0.0	0.0	0.0	0.0
South Korea	0.5	0.5	1.0	2.0

Table 4.4 Economic incentive calculation for offshore wind

Country	Grid Parity (a)	$LCOE_{RE}$ Vs fossil electricity (b)	$LCOE_{RE}$ Vs RES-E price (c)	Economic incentive for off-shore wind (a+b+c)
China	0.0	0.0	0.0	0.0
USA	0.5	0.0	0.5	1.0
Japan	1.0	0.5	1	2.5
Germany	0.5	0.0	1.0	1.5
India	0.0	0.0	0.0	0.0
Russia	0.0	0.0	0.0	0.0
South Korea	0.5	0.5	1.0	2.0

Table 4.5 Total national economic incentive calculation for renewable energy

Country	Solar PV (a)	Onshore wind (b)	Offshore wind (c)	Total Economic Incentive (a+b+c)	Percentage Economic Incentive ((a+b+c)/9)
China	1.5	2.5	0.0	4.0	44%
USA	1.5	2.0	1.0	4.5	50%
Japan	2.5	2.5	2.5	7.5	83%
Germany	2.0	2.0	1.5	5.5	61%
India	1.5	2.0	0.0	3.5	39%
Russia	0.5	0.0	0.0	0.5	6%
South Korea	2.0	2.0	2.0	6.0	67%

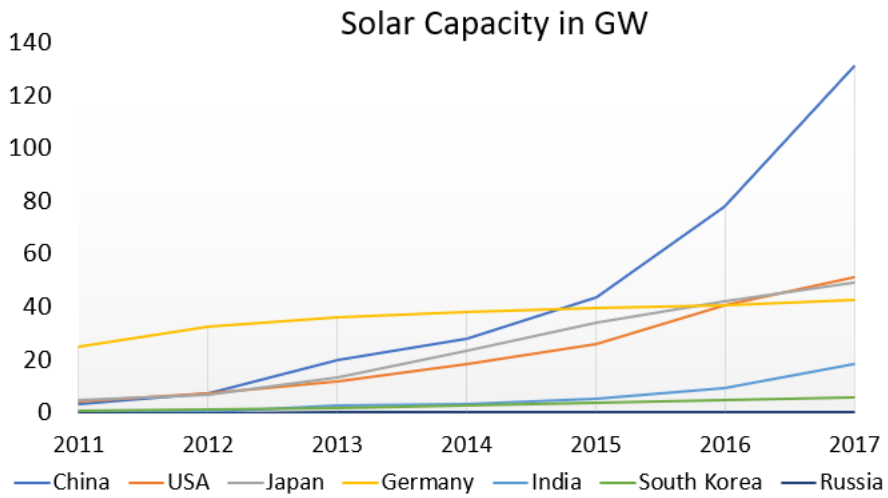


Fig. 4.8 Solar PV power generation capacity (Source: Enerdata (n.d.))

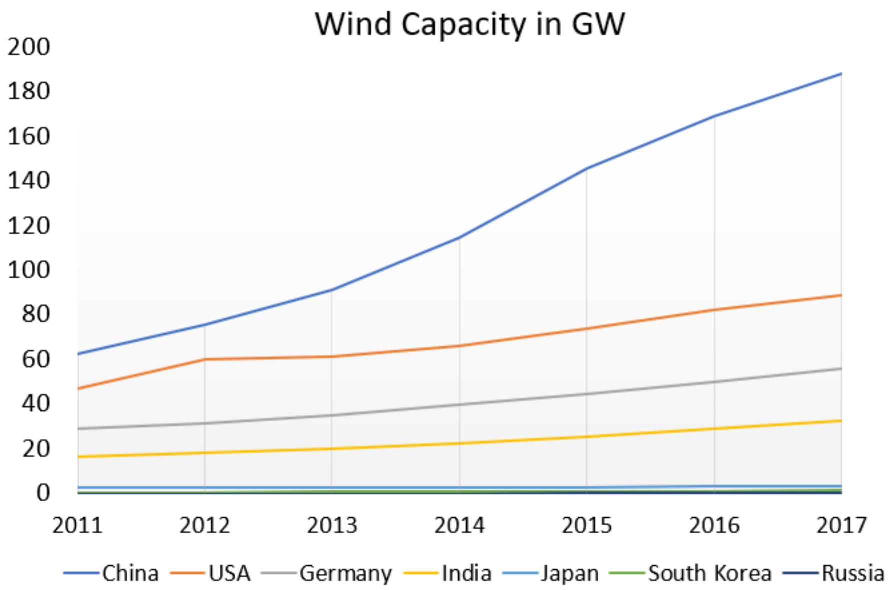


Fig. 4.9 Wind power generation capacity (Source: Enerdata (n.d.))

increase in the deployment of both solar (average 25 GW/year (2013-2017), average growth rate 89%/year) and wind power (average 22.6 GW/year, average growth rate 20%/year) in the last few years. Germany, which was leading in solar power generation capacity till 2014, has shown very slow progress afterwards (average 2 GW/year, average growth rate 5%/year). In terms of wind power capacity addition, Germany is growing steadily (average 5.2 GW/year) with an average growth rate of 13% year. Japan's deployment of wind power has been very slow (average 124 MW/year, 4% growth per year) and the end of 2018, the country had a total installed capacity of only 3.4 GW. In the field of solar power deployment, Japan is growing with a sharp growth rate (8.6 GW/year, 53% growth per year), and reached 49 GW capacity by the end of 2017. The United States is deploying both solar (8.7 GW/year, 48% growth per year) and wind power (6 GW/year, 9% growth per year) steadily. India started deployment of wind power quite early and the deployment has been steady but quite slow (2.86 GW/year, 12% growth per year). Solar power deployment in India, started to kick-off since 2013, however, the deployment rate increased only after 2016 (3.2 GW/year, 84% growth per year). Solar and wind power in South Korea, are still very less (total 5.6 GW of solar and 1 GW of wind power) to make any reasonable contribution, however, the country has been able to maintain an annual average wind power capacity addition of 130 MW and 960 MW for solar power, in the last five years (2013-17). Solar and wind power in Russia, appears to be in the introduction phase, without any considerable deployment of these two power generation technologies. At the global level, solar PV deployment was 75 GW/year at an average growth rate of 32% per year (2013-2017) and wind power deployment was 52 GW/year at an average growth rate of 14% per year, for the same period.

Table 4.6, adds more insight to the new RE power generation capacity deployment (average for the period 2013-2017) by comparing it with the average of total new power generation capacity installations in the same period. It can be observed that, although China is leading globally in new RE capacity deployment, when compared with the annual new power capacity demand of the country, the RE industry has not captured a major share and the new RE capacity deployment is a result of high additional power demand, and this is not acting as a replacement of the existing power generation capacities. The United States is comparatively doing better as the RE capacity deployment covered 63% of the new power generation capacity installations. Japan and Germany are doing good, as solar and wind power contributed towards 87% and 97% of the new capacity installations. The RE deployment share was observed to be quite low for India (25%) and South Korea (17%), and very low for Russia (2.6%).

Data sources for the table 4.6: New solar PV and wind power generation capacities of the concerned countries are from Enerdata (n.d.). Total new power generation capacity installation data of China, the USA, Japan, Germany, South Korea are collected from the National Survey Reports database of IEA (IEA, n.d.). Average new power generation capacity installations of India is from CEA (n.d.). New capacity deployment data of Russia is from IRENA (2017).

(b) *RE power generation industry:* Fig. 4.10, presents the trend in share of solar and wind power in the electricity produced by these countries. Power generation trend by solar and wind power would follow very similar trend as their capacity deployment, with observed variations/fluctuations occurs mostly due to annual variations in the wind resources, as in

Table 4.6 RE capacity addition share (Data source: refer text)

Country	Average RE deployment (2013-2017) (in GW) (a)	Average total new capacity installations (2013-2017) (in GW) (b)	Average RE capacity installations share (a/b)
China	48	125	38.3%
USA	14.7	23.4	62.8%
Japan	8.8	10.1	87.1%
Germany	7.2	7.4	97%
India	6.1	23.9	25.4%
Russia	0.13	5	2.6%
South Korea	1.1	6.4	17.3%

case of Germany. This plot becomes more meaningful than the capacity addition, as this provides information on the share of electric power demand which can be served by the renewable sources. It can be observed from the plot that except Germany, share of solar and wind electricity is below 10% in all other countries. However, in China, USA, Japan share of solar and wind power in electricity is increasing at an average rate of 1% per year for the last 5 years. In Germany, the average increase in share of solar and wind power is 2.3% per year. In India, the average growth rate has been 0.5% per year and 0.3% for South Korea. In Russia, the increment has been negligible with average annual growth rate of 0.01% per year. At the global level, the share of solar and wind in the electricity produced is growing at an average rate of 0.73% per year (2013-2017).

(c) *RE equipment manufacturing industry:* Growth in RE equipment manufacturing and production industry is important, because this industry supplies the demand of RE deployment industry. Hence, the manufacturing & production industry should grow faster than the capacity deployment industry.

Fig 4.11 presents the global trend of annual annual PV installations, actual PV production and the total PV production capacity. In a global scale, the PV production capacity does not seem to pose any restrictions to the production of RE equipment and installation of RE capacity, as it seem to grow at a good enough rate. It can be observed that since 2011, the global production capacity of solar PV has been 20% - 30% higher than the actual PV production.

To understand this phenomena in more detail, trend of the solar cell production capacities of the major producers (from 2012 to 2017) are presented in the Fig 4.12. According to IEA (2018*b*), and as can be observed from the fig 4.11 and fig 4.12, around 69% of the

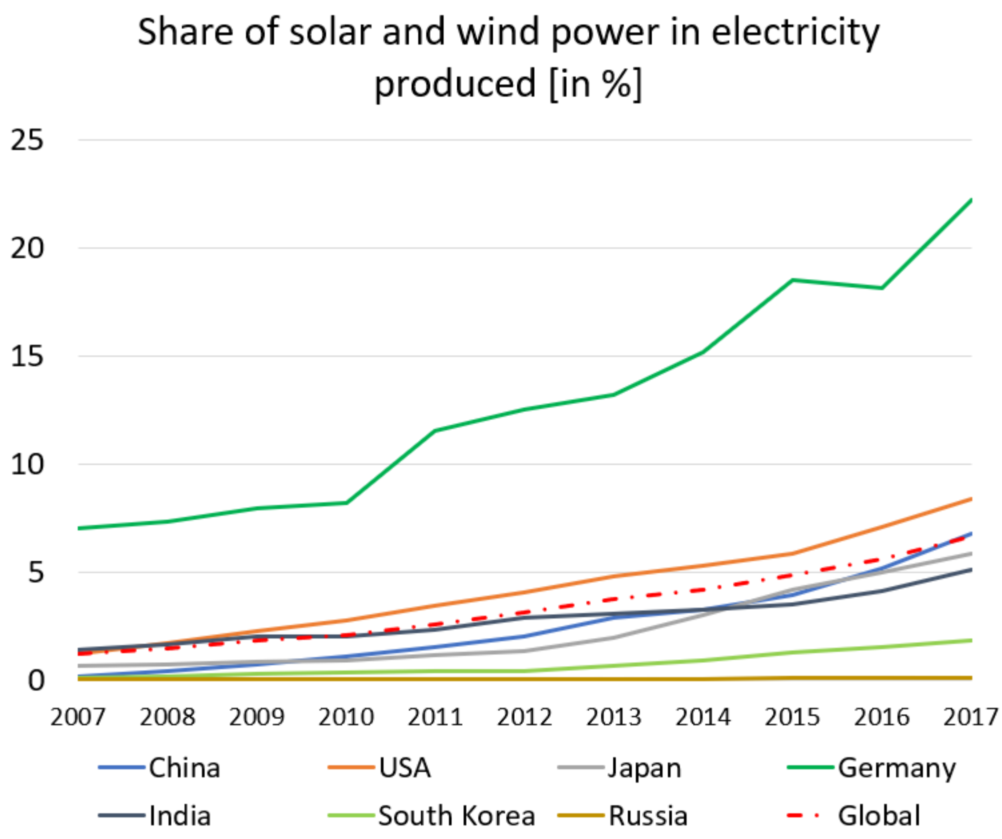


Fig. 4.10 Share of solar and wind in the produced electricity (Source: IRENA (2018*a*))

global PV cell production in 2017 came from China, and China holds around 72% of the global PV production capacity. It can also be observed that rest of the major producers like Taiwan, Malaysia, South Korea or Japan has not expanded their production capacities in response to the global market demand. Production capacity expansion in China has been the backbone fueling the solar PV industry and meeting the global increasing demand of new PV installations. Hence, it can be concluded that although the global production capacity does not seem to restrict the global annual demand of solar PV, since, the majority of the global solar PV demand is supplied by China, any changes in the Chinese solar PV manufacturing industry or their international policies will have a huge impact on the global PV market.

Figure 4.13, presents the average annual demand of solar PV for new power generation capacity installations in the period of 2013-17, annual installed capacity in the year 2017 and the existing manufacturing capacity of PV cell (in GW) in the year 2017.

Data sources for fig 4.13: Solar PV installed capacity data is from Enerdata (n.d.). China's solar cell production capacity in 2017 is from IEA (2018*b*). For the USA, Germany, Japan, and South Korea, the maximum annual solar PV cells produced in the period 2013-2017 is taken as the manufacturing capacity from IEA (2018*b*). India's solar cell manufacturing

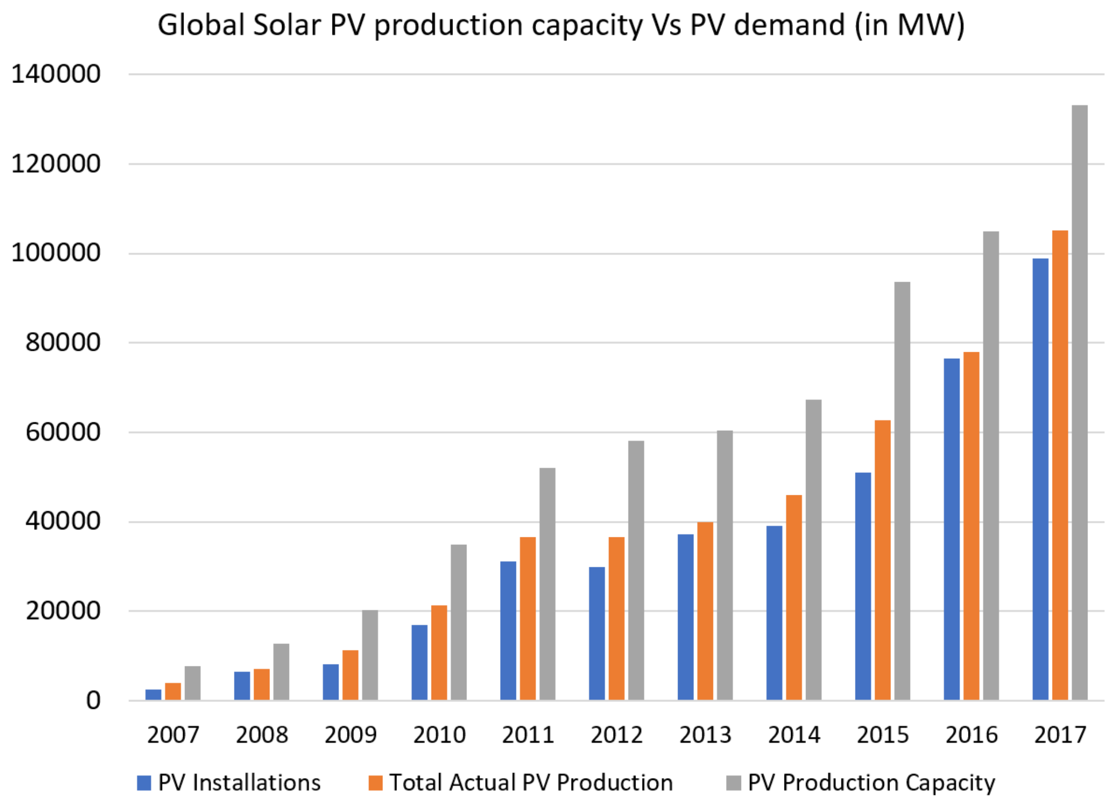


Fig. 4.11 Solar cell production capacity global trend (Source: IEA (2018*b*))

capacity is from Manju and Sagar (2017). Russia's solar PV manufacturing capacity is estimated from the new solar PV installations (with 70% local content requirement) (Smeets, 2017).

Further, comparing the individual country's demand for new solar PV capacity installations with their manufacturing capacity, it can be observed from the fig 4.13, that the manufacturing capacity of only China and South Korea are sufficient to meet their national solar PV installation demand. For USA, Japan, Germany and India, the national production capacity is indeed an barrier to meet the country's demand. Hence, with the current production capacities these countries need to depend on the imported solar PVs to support their growing PV deployment demand.

Fig 4.14 presents the average annual demand of wind turbines in the period of 2013 to 2017 in terms of new power generation capacity installations, annual installations in the year 2017 and the annual manufacturing capacity in the year 2017. Top seven Chinese manufacturers supplied over 25% (13.35 GW) of the global wind turbine demand (FTI Intelligence, 2018) and the total wind turbine manufacturing capacity in China was 19.66 GW in 2017 (IEA, 2017*b*), as compared to the average deployment of 25 GW/year (2013-2017) (Enerdata,

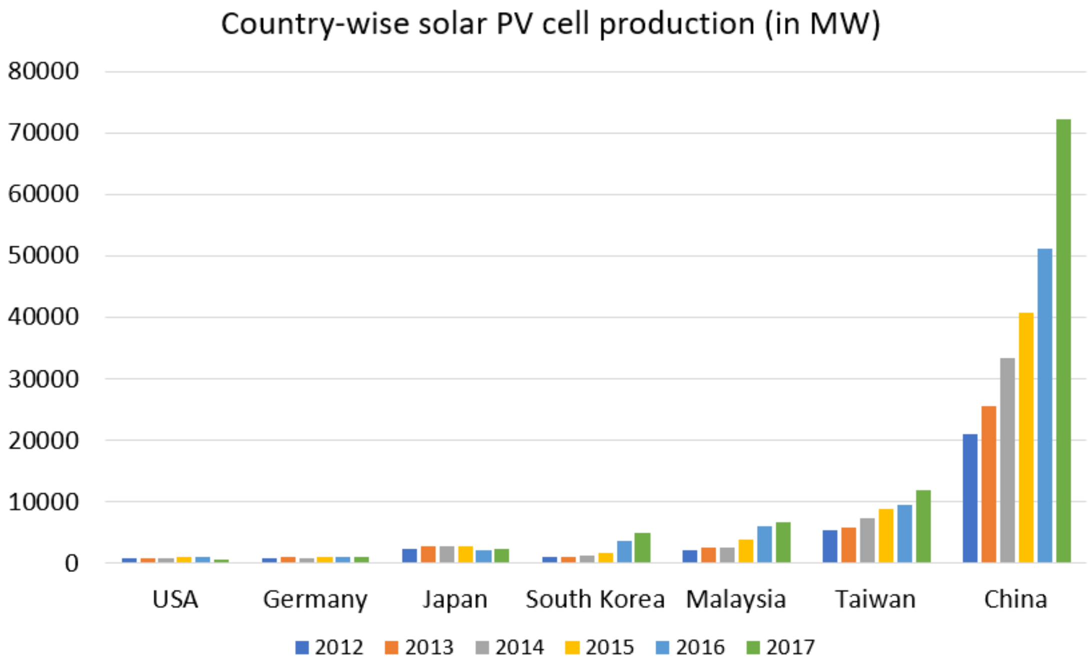


Fig. 4.12 Solar Cell Production: Country-wise trend (Source: IEA (2018*b*))

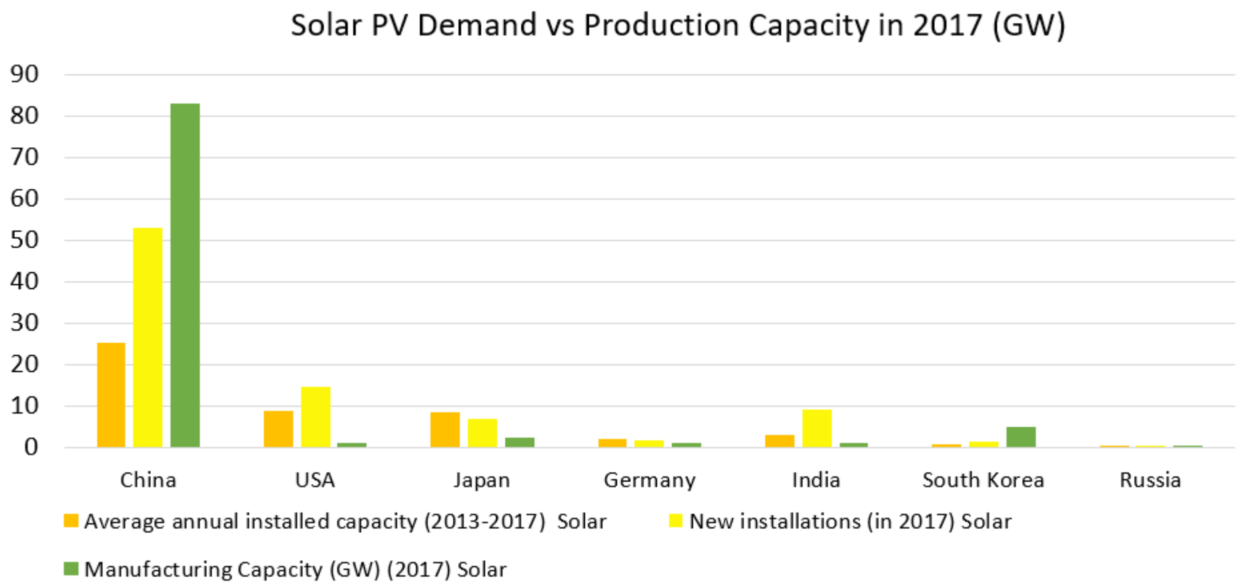


Fig. 4.13 Solar PV installation demand vs manufacturing capacity (in GW) (Data source: refer text)

n.d.). The United States had 8.9 GW of wind turbine blade manufacturing capacity in 2017 (U.S. Department of Energy, 2017). India's annual wind turbine manufacturing capacity is estimated to be around 10 GW (MNRE, 2016). The exact data of global manufacturing capacity and those of Germany, Japan, and South Korea could not be obtained. Germany is a major exporter with big suppliers like Enercon, Envision, Nordex Acciona, Senvion, and the merger of Siemens and Gamesa serving around 38% (or around 20 GW) of the global wind turbine market demand. Based on Germany's share in the global market, the wind equipment manufacturing capacity was estimated to be around 8 GW/year (FTI Intelligence, 2018). Japan's local market is very small with around 170 MW of annual installations, however, based on the global market share of Mitsubishi Heavy Industries (MHI), the manufacturing capacity was estimated to be around 2 GW/year (FTI Intelligence, 2018). South Korea also has a very small domestic market (average deployment 130 MW/year) but experiences huge competition with major suppliers being Doosan, Hyundai, Unison and Hanjin (IEA, 2017*b*) and Unison with annual production capacity of 1 GW (in 2013) is leading the manufacturing industry (Bana, n.d.). India's largest supplier Suzlon served 2.6% (1.36 GW) of the global demand and 37% of the local demand. The largest local manufacturer in the US is GE Renewable which supplied 7.6% (3.96 GW) of the global turbine demand. However, the local market of USA was dominated by international suppliers like Vestas (39%) and Siemens Gamesa (25%) (FTI Intelligence, 2018). Russia's wind manufacturing capacity is estimated from the new installations (with 65% local content requirement) (Smeets, 2017).

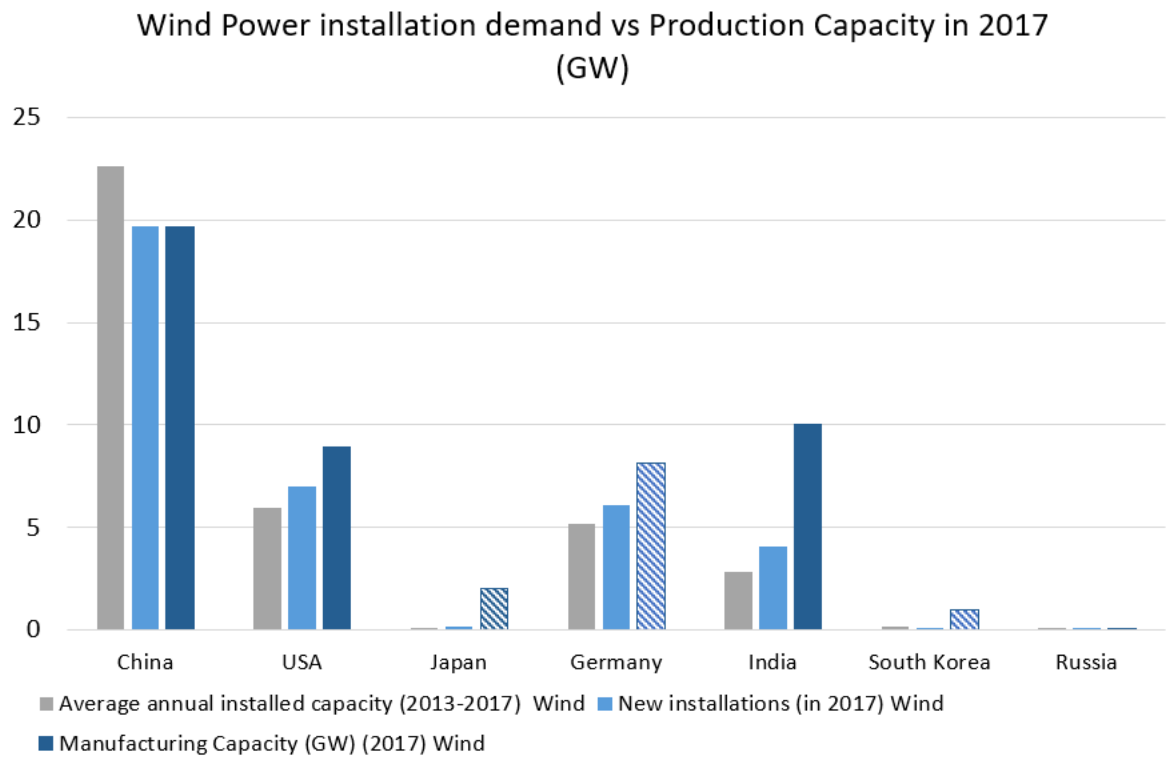


Fig. 4.14 Wind power installations and manufacturing capacity (in GW)(Data source: refer text)

Table 4.7 RE industry capacity to meet new capacity demand (Data source: refer text)

Country	Total RE manufacturing industry capacity in 2017 (in GW) (a)	Max annual new power generation capacity addition (in GW) (2013-2017) (b)	RE industry capacity to meet new capacity deployment demand (a/b)
China	103	147	70%
USA	10	32	31%
Japan	4.5	9	50%
Germany	9.3	9	103%
India	11	33	34%
Russia	0.2	5	5%
South Korea	6	11	54%

With the observed global demand trend of wind turbines which peaked in 2015 with 64 GW of new installations and then reduced to 55 GW in 2016 and 52 GW in 2017, at present the global production capacity, or the supply side of the industry does not seem to limit or restrict the global demand of wind turbine installations. Furthermore, as around 40% of the global wind turbine demand and supplying capacity is coming from China, any changes in the Chinese national consumption or production industry would impact the global wind market.

Capacity of the national RE manufacturing industry to meet the national annual new power generation capacity demand:

Table 4.7 presents the share of total capacity of the solar PV and wind power production industry of a country to meet the new power generation capacity additions. It can be observed that Germany's new capacity addition can be completely met by the domestic RE industry. China's RE industry is also very close to reaching the three quarters of total annual capacity demand with RE industry capacity close to 70% of the total new capacity demand. For South Korea and Japan, this share is 54% and 50% respectively, and for the remaining countries it is less than 50%, as India with 34%, the USA 31%, and Russia only 5%. Hence, it can be concluded that in only Germany and China, the RE manufacturing industry has received enough attention and gone through major growth to support their power industry.

Table 4.8 summarizes the final RE industry growth factor of the concerned countries. It can be observed that the maximum growth is observed in Germany (74.1%), and the only country scoring above 66%. Japan (47.7%), China (38.3%), and USA (34.2%) are in the

Table 4.8 RE industry growth factor calculation

Country	Average RE capacity installations share (2013-2017) (a)	Share of solar and wind in electricity (2017) (b)	RE manufacturing industry capacity to meet new capacity demand (c)	RE industry growth factor ((1/3)*(a+b+c))
China	38.3%	6.8%	70%	38.3%
USA	62.8%	8.4%	31%	34.2%
Japan	87.1%	5.9%	50%	47.7%
Germany	97%	22.3%	103%	74.1%
India	25.4%	5.1%	34%	21.5%
Russia	2.6%	0.1%	5%	2.5%
South Korea	17.3%	1.9%	54%	24.3%

moderate range of 33 - 66%. South Korea (24.3%), India (21.5%) and Russia (2.5%) are found to be in the lower RE industrial development range of less than 33%.

4.5 Technological Preparedness

This section presents the technological preparedness of countries' electricity infrastructure for integration of renewable energy. It ranges from the lack of the basic infrastructure for supporting renewable energy to a very high level of automation for high penetration of intermittent sources. The country wise technological challenges influencing large-scale integration of renewable energy and their level in technological preparedness hierarchy are summarized in the table 4.9. As discussed in section 3.6, a country's current level of technological preparedness hierarchy implies that the country has overcome the technological barriers which are below that level to a satisfactorily level, and it is yet to experience and overcome the barriers which are listed above that hierarchy level.

During the time of this research, it was observed that Russia was going through the introductory phase of the diffusion of solar and wind power. Russia lacks the basic infrastructure to support the growth of renewable energy. Due to huge geography and distributed demography of Russia, the majority of the regions are energy deficit. Potential wind resources are available in northwest Russia, North Caucasus, Siberia, and the Far East which are very far from the demand centres(Letova et al., 2018). Distributed and small renewable generators, which have potential to provide access to economical and cleaner electricity in the energy deficit regions, could not feed their extra generated power to the grid until 2017, and access

Table 4.9 Country wise technical limitations for renewable energy

Country	Technical Factors	Technical Preparedness Hierarchy
Japan	Insufficient grid inter-connectivity between the western Japan (60Hz) and the eastern Japan (50Hz) (International Energy Agency, 2016). Poorly interconnected EPCO's within Japan and secluded grid due to island country (International Energy Agency, 2016). Transmission problem for utility-scale solar and wind power generation(International Energy Agency, 2016).	Geographical Mismatch
Germany	9 GW of pumped storage connected to the German Grid and more storage required to compensate for low wind and low sunshine period (Renn and Paul, 2016) (Federal Foreign Office, n.d.).	Lack of storage for peak load and low renewable generation.
USA	USA would need capacity expansion of transmission lines to connect and transfer VRE power to load centres (NREL, n.d.*c*), Expansion of energy storage capacity required to provide temporal shift to peak power generated to meet the peak demands (Kroposki et al., 2017).	Geographical mismatch Lack of storage for peak load
China	High percentage of power curtailment - 14% of wind power in 2017 (Liu et al., 2018). 85% of the utility scale wind power installed in the northern and north-western China, far from demand centres and insufficient transmission capacity (Bird et al., 2016).	Inability of renewables to act as base load generators and increased curtailment. Geographical Mismatch
India	RE power curtailment a major issue with power dumping ranging from 10% to 25% in some states (NREL, 2017) (Mercom India, 2018) Mature wind and solar forecasting systems not available (as of 2015) (MNRE, n.d.*a*)	Inability to operate as base load generators. Lack of basic meteorological data
South Korea	Wind resources in uninhabited mountainous areas in the east coast, southeastern coast, and Jeju island, and land not available in the inhabited areas for large utility scale solar PV (Alsharif et al., 2018).	Geographical mismatch
Russia	Small generators do not have access to the main grid (Lanshina et al., 2018). Potential wind resources are available in northwest Russia, North Caucasus, Siberia and Far East which are very far from the demand centres(Letova et al., 2018).	lack of basic infrastructure Geographical mismatch

to the main grid is still a major hurdle due to long distances(Lanshina et al., 2018). Hence, Russia lies on the lowest level of Technological hierarchy and would have to go through all the above stages of hierarchy in future, if, Russia plans to improve the share of solar and wind power.

India: Solar and wind power in India are growing as a part of the government's Phase-II and Phase-III plan of the renewable power expansion. This includes the development of solar and wind parks. Hence, the government provides sufficient access to the main grid for feeding the generated power from these parks through strategic investments on the transmission lines. However, with growing intermittent renewable energy and installed capacity crossing over 21% share of the total installed capacity (solar and wind power including small hydro plants less than 25 MW), the power curtailment has emerged as a major issue with power curtailment ranging from 10% to 25% in some states(NREL, 2017) (Mercom India, 2018). Although, the current problem of the power curtailment is mostly commercial in nature as a few DISCOMs (Distribution companies in India) are unwilling to buy the expensive renewable electricity (Mercom India, 2018). However, only commercial willingness to buy intermittent energy will not solve the problem of curtailing altogether. In order to integrate the new intermittent renewable energy sources to the existing coal-powered electricity sector in India, which contributes almost 64% of the installed capacity, accurate generation forecasting, scheduling and dispatching would be required. According to the report by Ministry of New and Renewable Energy (MNRE) of India, mature wind and solar forecasting systems were not available in India (in 2015) and the country was dependent on foreign forecasting service providing agencies which may provide forecasting data with an accuracy of approximately 70% (MNRE, n.d.*a*). Hence, currently, the technology for the better meteorological forecasting, accurate generation forecasting, generation flexibility of the fleet of thermal power plants, co-ordination of scheduling and dispatching is not yet adopted in the country, which would be a barrier for the intermittent renewable energy to operate as base load generators and would lead to power curtailment.

China: China is soon approaching towards the target of 210 GW of the installed wind capacity, out of which, almost 85% of this capacity would be located in the utility-scale wind bases in the northern and northwestern China, while, almost three-quarters of the electricity demand in China are from central and eastern China (Bird et al., 2016) (Zhao et al., 2016). This high concentration of generation units lead to severe curtailment, as the power demand is low in these regions and the transmission capacity is insufficient to transport the excess power to other parts of the country and hence, leading to the geographical mismatch between the generation and consumption sites (Bird et al., 2016). Due to lack of power transmission capacity and insufficient electricity grid flexibility, wind power curtailment exceeded 15% in

2015, with over 33,900 GWh of wind energy being curtailed (Luo et al., 2018). For example, the Gansu transmission line has the transmission design capacity of 3200-4200 MW, which is much lower than transmission demand of 16,000 MW due to the installed wind power generation capacity in the region (Luo et al., 2018).

However, China has done major improvements in reducing RE curtailment. Wind power curtailment which was 57 TWh or 20.6% and 8 TWh of solar PV power or 11.5% in 2016, which was reduced to 14% (wind power) and 6.1% (solar power) in 2017, through market mechanisms, removing administrative barriers, and enhanced utilization of renewable energy (Liu et al., 2018).

However, China still needs to improve adaptation to flexible power generation using the thermal power plant fleet with minimum dispatch guarantees. Further, China has the option to combine the heating and power generation plants for the district heating during winters. However, for curtailment reduction and for improving penetration of renewable energy, China is implementing improved generation forecasting and scheduling, automatic generation control (AGC) systems, and wind power dispatch systems. Further to utilize the excess wind power, pilot projects of wind-heating using power electric boilers are under test. China is further constructing new transmission lines to enhance power transmission (Bird et al., 2016).

USA: Most of the electric transmission and distribution (T&D) lines of the United State's energy system were built in 1950s and 1960s. And over 1,030,000 kms of high voltage transmission lines, running across the Western Interconnection, Eastern Interconnection, and Texas Interconnections, which are interconnected through the transmission grids, many of them are operating at their maximum capacity and beyond their designed life expectancy of 50 years. These T & D lines were not designed to serve the current demand, severe weather events and they raise the concern of reliability, security of supply and power congestion over lines, limits the generation and transmission of power through renewable sources from remote generation sites (ASCE, n.d.). Study by Kroposki et al. (2017) and NREL (n.d.*c*) for high share integration of variable renewable energy into the United States power system suggests that in order to achieve these objectives, (a) USA would need capacity expansion of transmission lines to connect and transfer VRE power to load centres, and (b) expand the energy storage capacity to provide temporal shift to peak power generated to meet the peak demands, and deal with the variability and uncertainty of VRE.

Japan: Japan has around 100,000 km long transmission network and the country's electricity network is divided based on the operating frequency. Western Japan operates at 60 Hertz (Hz) while eastern Japan at 50 Hz. This difference occurred as the Tokyo region adopted the German electricity generators, whereas, the Osaka region adopted the ones which were US made. These eastern and wester regions are connected via frequency converter facilities (FCFs), and as of August 2014, the total capacity of these FCFs was 1.2 GW, which included FCFs facilities in Sakuma, Higashi-Shimizu FCF in Shizuoka Prefecture and Shin-Shinano FCF in Nagano Prefecture. Japan plans to improve this east-west grid connectivity to 2.1 GW by FY2020 (International Energy Agency, 2016). Eastern network has a generation capacity of 130 GW and the western network with around 160 GW, and lack of sufficient grid connectivity between the east and west poses a lot of problem in generation and inter-transmission of power or load sharing between different regions. Further, Japan's network is not connected to electricity network of any other country, hence, all the generation, consumption and power balance is handled within the country and majorly in each region. To improve transmission and distribution and to promote wind power generation, Ministry of Economy, Trade and Industry (METI) also plans to improve inter connection capacity between Hokkaido and Honshu by 300 MW by 2019 to 900MW (International Energy Agency, 2016).

Hence, although distributed solar PV deployment is increasing in Japan, lack of sufficient inter-connectivity due to difference in operating frequency is the major barrier for utility scale deployment of solar PV and specially for wind power in Japan (International Energy Agency, 2016). This is because Hokkaido and Tohoku, which have majority of the wind resources lies in the northern areas of Japan, which due to small population, have low power demand. Furthermore, insufficient power transmission infrastructure limits the power supply to load centres (IEA, 2017*b*), which creates a geographical mismatch.

South Korea : South Korea faces double sided challenge of improving the energy security of the country while reducing their emission level. To overcome these challenges, South Korean government plans to improve dependence on renewable energy, but solar and wind power offers technological challenges of their own in the country. The country's average wind speed in inland area is estimated to be around 4.0 m/s, while only uninhabited mountainous areas in the east coast, southeastern coast and Jeju island may receive wind speed above 7.5 m/s in winters (Alsharif et al., 2018). However, the country has established a total of 1.2 GW of wind power generation capacity by 2017, and these wind sites are yet to be explored and developed for increased power generation and transmission. Korea is also developing 2.5 GW of offshore wind farm in southwest coast, with 60MW of installed capacity by 2017 (IEA, 2017*b*). The country has good solar irradiance of an average 4 kWh/m^2 (Alsharif et al., 2018) and is growing in the utility scale solar power generation with total installed capacity of 5.7 GW (REN21, 2018). However, due to lack of availability of unused flat land, the maximum size of utility scale solar PV is only 57MW (Alsharif et al., 2018). Hence, South Korea is moving towards floating solar PV plants, with the planned largest plant of 100MW capacity is expected to be operational by 2020. Further, the country has 500 out of 3000 islands inhabited without connectivity to the main grid and which are dependent on diesel generated electricity (Alsharif et al., 2018).

Hence, although South Korea has researched on the resource potential of solar and wind in the country, the country currently faces challenges of mismatch of potential generation source locations and load centres.

Germany: Germany's annual power generation by solar and wind power reached over 22% in 2017, with at times providing over 60% of country's total electricity demand (Enerdata, 2018) (Federal Foreign Office, n.d.). The country was successful in achieving this high share as (a) in Germany, multiple RE power generation sources complement each other, with around 56GW of wind power and over 42 GW of solar power (in 2017) (further power from hydro-power and biomass), whereas country's peak power demand reaches around 80GW (REN21, 2018) (Federal Foreign Office, n.d.), (b) flexible generation provided by the gas power plants (Federal Foreign Office, n.d.), and (c) renewable power generators enjoy guaranteed grid connection and preferential dispatch of VRE power since the first enactment of Renewable Energy Sources Act (EEG) (The Federal Ministry for and Environment Nature Conservation and Nuclear Safety, 2000). These measures have helped Germany, to overcome the barriers faced by other countries like the geographical mismatch by ensuring suitable grid connectivity, and allowing VRE to serve as a base load power generator through priority dispatch into the transnational electricity grid and integrated regional electricity markets (Federal Foreign Office, n.d.).

Further, although more than 50% of Germany's total installed capacity is coming from solar and wind power, the contribution to electricity generation was around 22% in 2017. This gap is due to the volatility of the renewable energy supply. Hence, this would require installation of enough backup capacity and energy storage facilities to compensate for periods of low wind or low solar radiation (Renn and Paul, 2016). Germany has currently 9 GW of pumped storage including integrated plants in Luxembourg and Austria. However, due to limited resources for pumped hydro, Germany is in discussion with Switzerland, Norway and Austria (Federal Foreign Office, n.d.).

4.6 Relationships and Interactions

As the factors composing the RE business environment namely the political will, RE policies and regulatory framework, economic incentives for RE, technological preparedness for high share integration of VRE, and RE industrial development, are inter-dependent. So, a healthy interaction among these factors is required in order to create and drive a good RE business environment. This section explores the following interactions: (a) influence of the political will on RE policies and regulations, (b) influence of RE policies on economic incentives, (c) influence of economic incentives on the RE industry, (d) influence of technological preparedness on the RE industry, (e) influence of RE policies on RE industry, and (f) interactions between the national political will and the RE industry. These interactions are based on the assumptions as discussed in the section 3.7.

a) *Influence of the political will on country's renewable energy policy:*

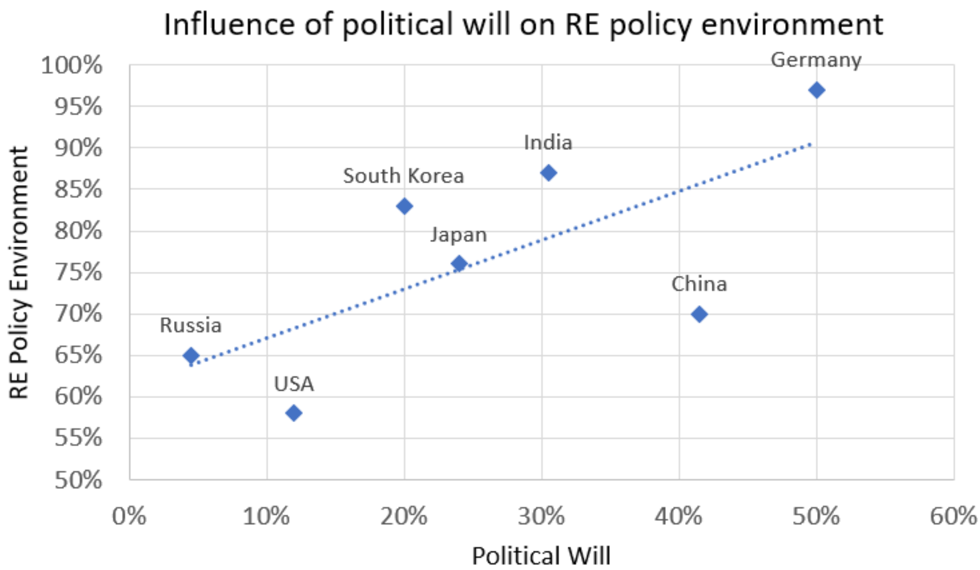


Fig. 4.15 Influence of Political will on RE policy environment

As the design and implementation of the RE policy and regulations, comes under the purview of government, a country displaying political willingness for higher share of renewable energy, should take the required steps for the formulation and implementation of the required support policies and regulations. A stronger interaction suggests that the country's government is taking the required steps, and a weaker interaction represents that the actions taken by the government to create a suitable RE policy environment are either insufficient or missing.

Fig 4.15 presents the RE policy environment as compared to the political will of a country. The trend-line shows a linear interaction. A few observations can be made from the result. Low political will of Russia for the adoption of solar and wind power, can be observed to be translated into insufficient RE policy design and implementation, leading to a low RE policy environment score of 65%. For USA, even with comparatively better political will score, due to the lack of sufficient RE policy mechanisms as discussed in the section 4.2, the overall RE policy environment of USA is insufficient. South Korea with a political will of 20% has created a better RE policy environment (83%) as compared to Japan (76%). India due to major RE support policies, was successful in creating suitable RE environment (87%), whereas China's RE policy environment was found to be much weaker with comparatively higher political will of 41.5%. Germany, with a political will of 50% was found to have created a comparatively better RE policy environment than rest of the countries.

As it was assumed that for a good RE policy environment, higher political will for RE energy may help in creating a better RE policy environment, the trend-line confirms this assumption. However, as it can be seen from the results, USA and China shows major negative deviation from the trend-line, and South Korea, India, and Germany shows positive deviation. Furthermore, as per World Bank, RE policy environment score (RISE-RE policy and regulatory framework score) of less than 66% are insufficient for the growth of renewable energy, hence, Russia and USA lies in the weak political will, and weak RE policy environment zone, or in other words, in Russia and USA, political will for renewable energy is weak and it has not been successful in creating suitable RE policy environment. In Japan, South Korea, India, even with moderate political will, influence of the political will is found to be strong and it created strong RE policy environment. China's political was found to be better than moderate but the influence of the political will in creating suitable RE policy environment was found to be weaker. Germany was found to have a strong influence of the political will on the RE policy environment.

Hence, although, the results present the evidence of influence of national political will on the renewable energy policy environment, the strength of this influence vary for each country. To further assess the strength of influence and a more elaborate trend, study of a larger set of countries would be required.

b) *Influence of policies on the economic incentives:*

To overcome the challenges of market penetration, suitable RE policy and regulations are required, which can create suitable economic incentives for renewable energy. A stronger interaction would suggest that the implemented RE policies were successful in creating good economic incentives for RE. However, a weaker or missing interaction would suggest that the RE policies were inefficient or ineffective in creating suitable economic incentives. Hence, presence of a stronger interaction is desirable.

This section explores the presence of this interaction. The analysis is done for each of the solar pv, onshore wind power, and off-shore wind power technology separately, and a comparative analysis is presented.

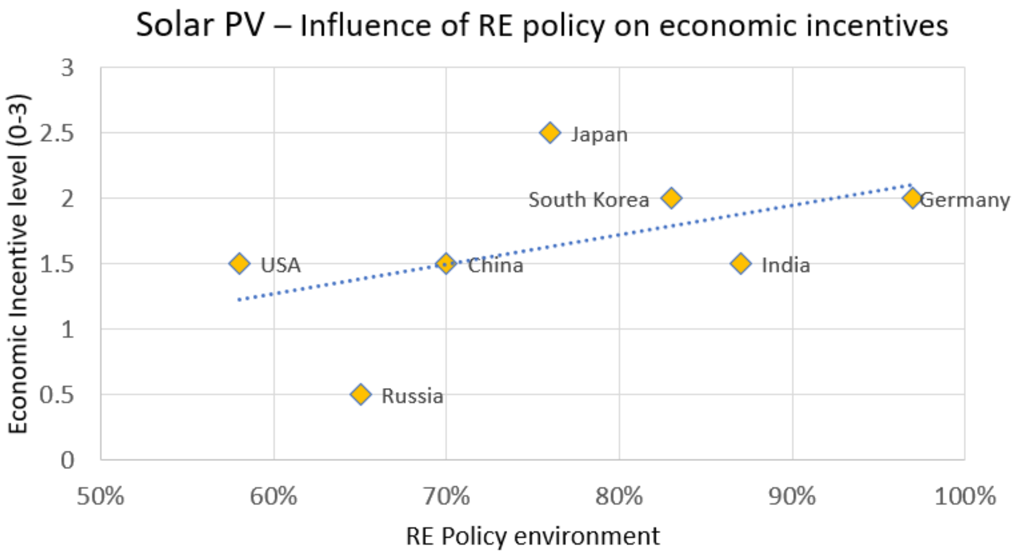


Fig. 4.16 Influence of policy on economic incentives for solar PV

Influence of policy on economic incentives for solar PV: Fig 4.16 presents the economic incentives created for solar PV in comparison with the country's renewable energy policy environment. It must be noted that, the RE policy environment with the score of 66% or less are considered inadequate and the economic incentives, with values 2 or higher are considered as good. Hence, it can be observed that Russia lies in the weak RE policy environment and weak solar economic incentives zone. USA with weak RE policy environment created average economic incentives. This can be attributed to comparatively higher grid electricity prices and fossil electricity generation cost, making solar PV LCOE comparable to these prices (International Energy Agency, 2018*a*). China and India, although with suitable RE policy environment, could create average economic incentives for solar PV. Similarly, China's solar PV LCOE is comparatively expensive than domestic, commercial grid electricity, and conventional fossil electricity. However, the average economic incentive of solar PV is improved to an average level due to applicable solar electricity price support scheme such as the feed-in tariff and subsidies for self consumption (IEA, 2016*a*). Solar PV in India were still expensive than the fossil electricity in 2016 (IRENA, 2018*c*). However, the long term power purchase agreements (PPAs) for utility scale projects, bring the economic incentives to an average level.

South Korea and Germany, were found to have created reasonably good economic incentives complementing their RE policy environment. Even though South Korea discontinued feed-in tariff in 2012, the economic incentives for solar PV are still good because the solar PV LCOE is comparable to both the grid electricity prices and fossil electricity generation cost (IEA, 2019). Further, the effectively designed fixed pricing plus obligatory RPS policy, subsidy, and incentive programs have further improved the economic incentive of solar PV in South Korea (IEA, 2019). Germany even with expensive solar PV LCOE and discontinued feed-in tariff (since 1st January 2017), manages to create good economic incentives due to comparatively higher domestic and commercial electricity prices (IEA, 2016*b*).

Japan has done exceptional well and has created very good economic incentives for solar power. Economic incentive for solar PV in Japan is very good due to comparatively expensive grid electricity and also expensive fossil electricity. Further, the RE electricity price support scheme like feed-in tariff further boosts the economic incentive of solar PV in Japan (IEA, 2018*a*).

Hence, although the results shows influence of RE policy environment on the economic incentives of solar PV, electricity pricing was also found to play a very strong role, which either enhances the economic incentives for solar PV in countries like Japan, South Korea, and Germany, whereas reduces the economic incentives in India, China, and Russia.

This explains the major negative deviation for Russia and positive deviation for Japan, which are observed in the results. Germany's lower economic incentives than the average trend-line suggests, intentional reduction in economic incentives through recent changes in the policy environment (discontinuing feed-in tariff and replacing it with the auction system). Although, the slope of the trend line (m = 2.24) reduces to m = 0.96, if Russia is not included, and hence, reducing the significance of this interaction (please refer section 5.4).

Influence of policy on economic incentives for onshore wind power: It can be observed from fig 4.17 and 4.16, that these countries have same RE policy environment for onshore wind power as solar PV. This is due to the limitations of the RE policy environmental factor, which is not calculated separately for different RE technologies. However, a lot of similarities can be observed in the RE policy environment of these two technologies due to similar energy policy for onshore wind power as solar PV in many countries.

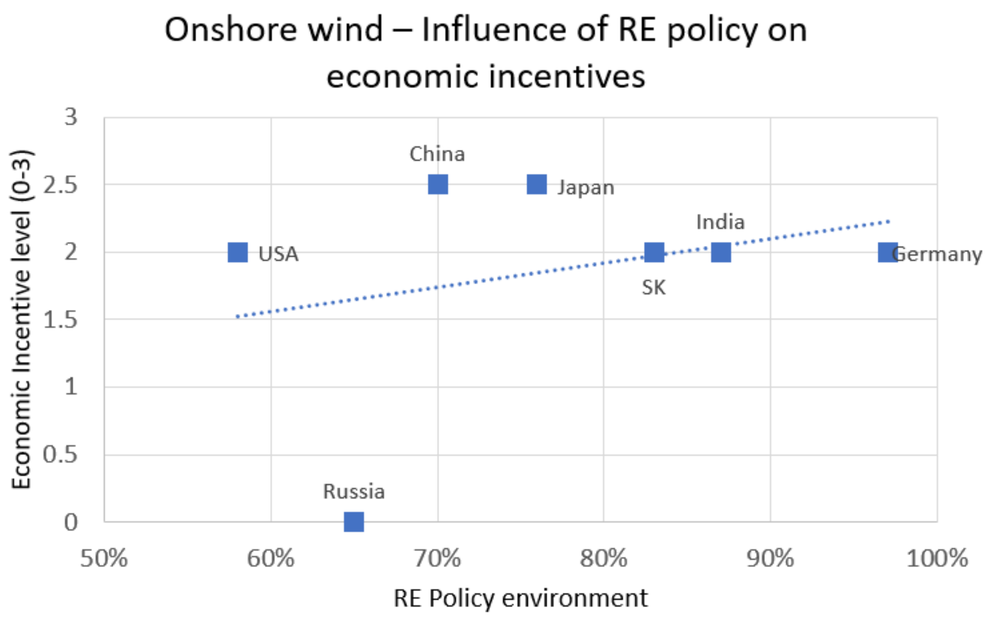


Fig. 4.17 Influence of policy on economic incentives for onshore wind power

The factors which led to differences in the economic incentives for onshore wind power as compared with solar PV are discussed in this section. Economic incentive for onshore wind power have gained boost as the technology has achieved grid parity in China, USA and Japan (IRENA, 2018*c*). In Germany, the industrial electricity prices are strategically cheaper, resulting in onshore wind power to be comparatively expensive for industries (IEA, 2016*b*). In India and South Korea, electricity prices are subsidized and hence, they are quite low (IRENA, 2018*c*), however, onshore wind power is still comparable to grid electricity prices. In South Korea, the technology is about to cross the minimum grid electricity price slab (IEA, 2019).

Although Russia implemented CRESS scheme to support the technology, the economic incentives created through the scheme was found to be negligible.

Further, as observed and explained in the previous section for solar PV, renewable energy policy of these countries also show some influence on the economic incentives of onshore wind power. Further, although the slope of the trend line in fig 4.17 shows an positive slope of m = 1.8, the slope turns negative, if Russia is not included, and hence, suggesting inverse relationship.

Hence, as discussed above, more than the influence of RE policy environment, onshore wind power was successful in creating economic incentive level of 2 or higher in most of the countries due to major advancements in the technology and cost reduction. This answers the question of more than average economic incentive created in USA, even with inadequate RE policy environment. Further, the reduced economic incentives in South Korea and Germany is due to low industrial electricity prices, and in India due to subsidized domestic electricity.

Furthermore, results from the fig 4.17 and 4.16, also suggest limitations of the RISE indicators, which does not assess the RE policy and regulatory framework of a country in terms of their capability to create economic incentives at an absolute level (with respect to the ground realities of a country).

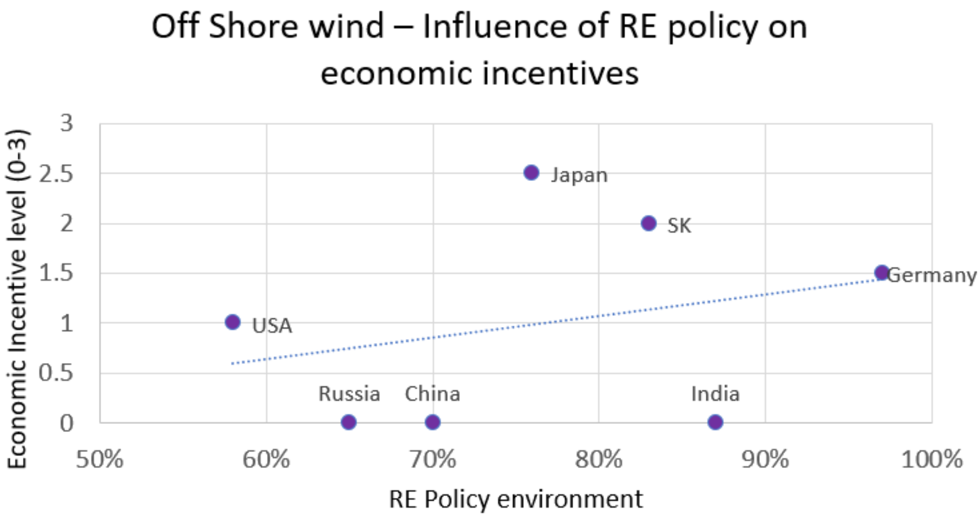


Fig. 4.18 Influence of policy on economic incentives for offshore wind power

Influence of policy on economic incentives for offshore wind power: As observed from the Fig 4.18, offshore wind power have failed to create any economic incentives in India, China, and Russia due to complete incognizance of the technology in their energy policy (TERI, 2015) (International Energy Agency, 2018*b*). In the United States, the economic incentives are low for the technology to grow, however, there may be little incentives to replace the upper slab of industrial electricity or to compete in the electricity market. Germany has created comparatively better incentives (although not good enough) due to comparatively expensive domestic, and commercial electricity, and further due to opportunity to compete in the wholesale electricity market. South Korea have created better economic incentives due to comparable grid electricity prices, fossil electricity generation costs and further gain due to specially designed RPS policy (IEA, 2017*b*). Japan leads the list with highest economic incentives for offshore wind. This is due to the following reasons: (a) offshore wind power has reached grid parity in Japan, (b) offshore wind power LCOE has become comparable to the fossil electricity generation cost, and (c) sufficient price support to the technology through Feed-in Tariff (IRENA, 2018*b*) (IEA, 2018*a*).

Hence, although the fig. 4.18 does not show much correlation between between the RE Policy environment and economic incentives for offshore wind energy, impact of the specifics of offshore policies on the economic incentives for the technology can empirically analysed based on the discussions presented above. The lack of correlation in the figure also suggests limitation of the RE Policy environment factor to incorporate and describe policy environment specific to the offshore wind power.

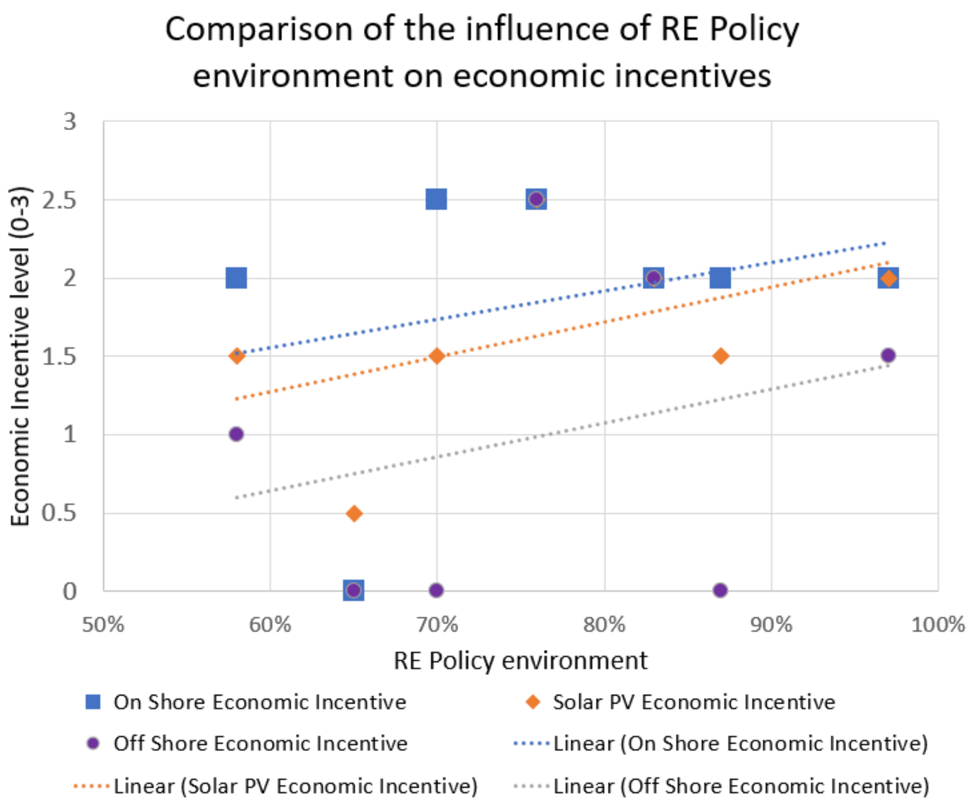


Fig. 4.19 Comparison of influence of policy on economic incentives

Comparative analysis of economic incentives created from Energy policy: Few important observations and conclusions can be made from the Fig. 4.19 which presents the comparison of the influence of RE policy environment on the economic incentives for solar PV, onshore wind, and offshore wind power, and from the above presented results:

(a) Onshore wind power has gained the best economic advantage mostly due to the technological advancements in the technology, and some RE policy support, making it most economically viable technology over solar PV and offshore wind.

(b) Renewable energy policy like Renewable Portfolio Standards (RPS) favours the renewable energy technology based on their economic competitiveness and hence, technologies which have not reached the best competitiveness level, may be left out such as the offshore wind power in the United States. However, if RPS is designed in a way to support specific technologies, then this problem can be avoided as in South Korea.

(c) Inherent market failures occurring due to the controlled or subsidized electricity prices, externalities not being internalized in the electricity cost (for both the conventional and renewable power), involvement of public goods etc., makes the government intervention mandatory to support the growth of new renewable energy technologies and make provisions for sufficient economic incentives till the technology reaches a level of maturity to compete in the electricity market.

c) *Influence of economic incentives on RE industry:*

A strong influence of the economic incentives on the RE industry is desirable, as this would imply that the economic incentives were strong enough (or sufficient) to create market forces (demand of RETs), leading to increased deployment and generation of RE. Weaker interaction would imply that the economic incentives were not able to create sufficient market forces to increase the RE industrial activities or it suggests the presence of other challenges faced by the RE industry.

This section explores the above interaction in the concerned countries. As explained earlier, to assess this interaction, the RE industrial activities are measured using the RE industry growth factor which incorporates all the three segments of RE industry: (a) RE deployment industry, (b) RE power generation industry, and (c) RE manufacturing industry.

Fig. 4.20 presents the influence of the economic incentives created for renewable energy on the renewable energy industry. Although the trend-line shows linear relationship between economic incentives and RE industrial growth, multiple deviations are observed, which can be explained by analysing the influence on the different segments of the RE industry.

With the highest economic incentives created in Japan, it was expected that the country would show highest RE industry growth factor. However, to analyse the impact, it would be important to refer to the table B.1 and assess the influence on each of the segments of RE industry. For Japan, it can be observed that strong economic incentives for solar and wind power have led to major dominance in the deployment of these technologies, with over 87% of the market captured by these RE technologies in the last five years. The RE industrial factor of Japan suffered major loss in score, due to low share (6%) of solar and wind power in electricity. The share of renewable in electricity, on the other hand, is a result of long term commitment, increased deployment, and integration of renewable energy, which takes much longer period than 5 years. The influence of the economic incentives on the RE manufacturing industry has been moderate (50%).

For South Korea, RE industry growth factor showed very negative deviation, even with second highest economic incentives. This is due to the low share of solar and wind power deployment (17%) in the last 5 years, and also very low share of the solar and wind in the generated electricity (2%). This can be explained due to very low RE target share of the country for 2016 IEA (2017*b*). Influence on the RE manufacturing industry was found to be moderate (54%).

Germany scored exceptionally high RE industry factor score of 74%. This is because of the long term high economic incentives and policy support for solar and wind power in the country, which led to the share of solar and wind in electricity grow to 22%, new power capacity installations completely dominated by the renewable energy (97%) over the last five years, and RE manufacturing industrial capacity to meet all the domestic demand, with major contribution in the global RE market. Economic incentives in Germany reduced only recently due to the changes in the RE policy.

India, China, and the United States, were found to be in the similar range of economic incentives of 39%, 44%, and 50%, and the RE industry growth factor of 22%, 38%, and 34% respectively. All these three countries have low share of solar and wind in electricity, and although the new RE capacity installations in India and China, were quite high, their share in their respective annual capacity demand were 25% and 38%. China, however, scores higher than USA and India, due to high industrial activity in the RE manufacturing industry, which can support up to 70% of total annual new capacity demand.

Due to very low economic incentives in Russia (5.6%), all the segments of the RE industry have severely suffered. None of the segments of the RE industry in Russia were able to took off, and the country scored only 2% in overall RE industry growth factor.

Hence, following conclusions can be drawn from the results:

(a) Usually high economic incentives increases the activities in the RE deployment industry, and it increases the share of renewable energy in new capacity installations.

(b) Increased share of solar and wind power in electricity is a result of long term good economic incentives, rather than good economic incentives for a short period.

(c) Creation of good economic incentives is very crucial to kick start the RE industrial activities.

(d) Other factors such as the target RE share, historical support, may undermine or affect the influence of the economic incentives.

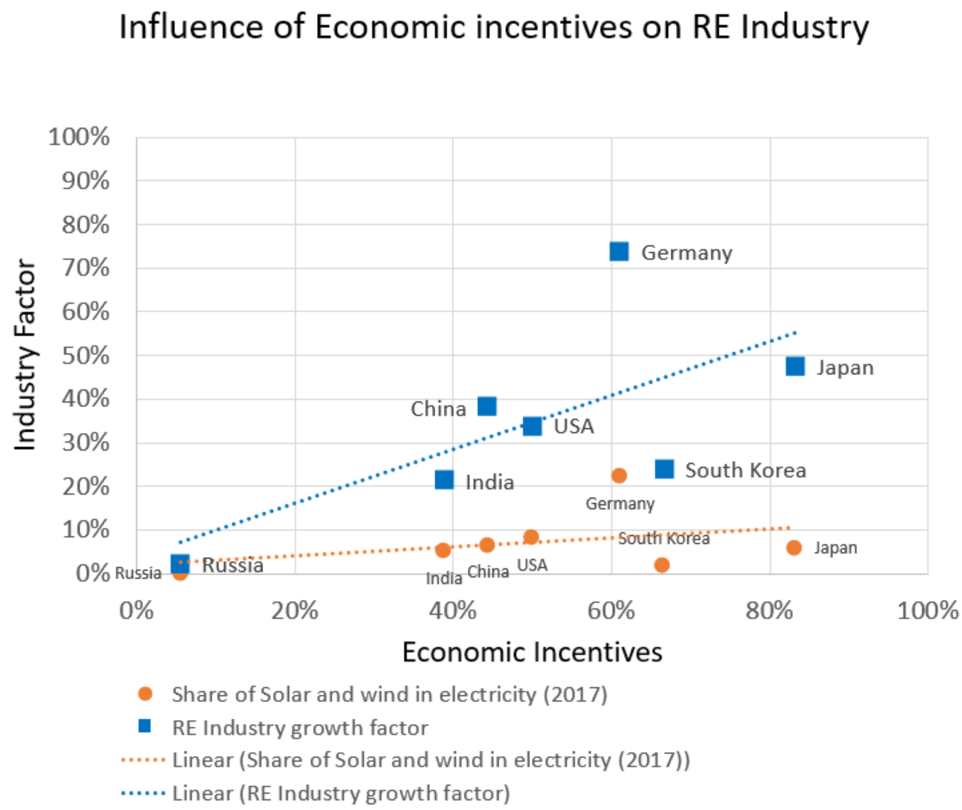


Fig. 4.20 Impact of economic incentives on industry (Data Source: Enerdata (2018)

d) *Influence of technological preparedness on RE industry* :

Since, technological preparedness is one of the backbones of improving the penetration of renewable energy, and an important factor in influencing the RE business environment. It can be be safely assumed that a better technological preparedness level of country would lead to increased share of variable renewable energy in electricity, boosting further deployment of RE and increasing RE industrial activities. Or it can also be argued that increased industrial activity or accelerated deployment of VRE generators creates pressure to improve the technological preparedness.

This section explores the above discussed interaction in the concerned countries.

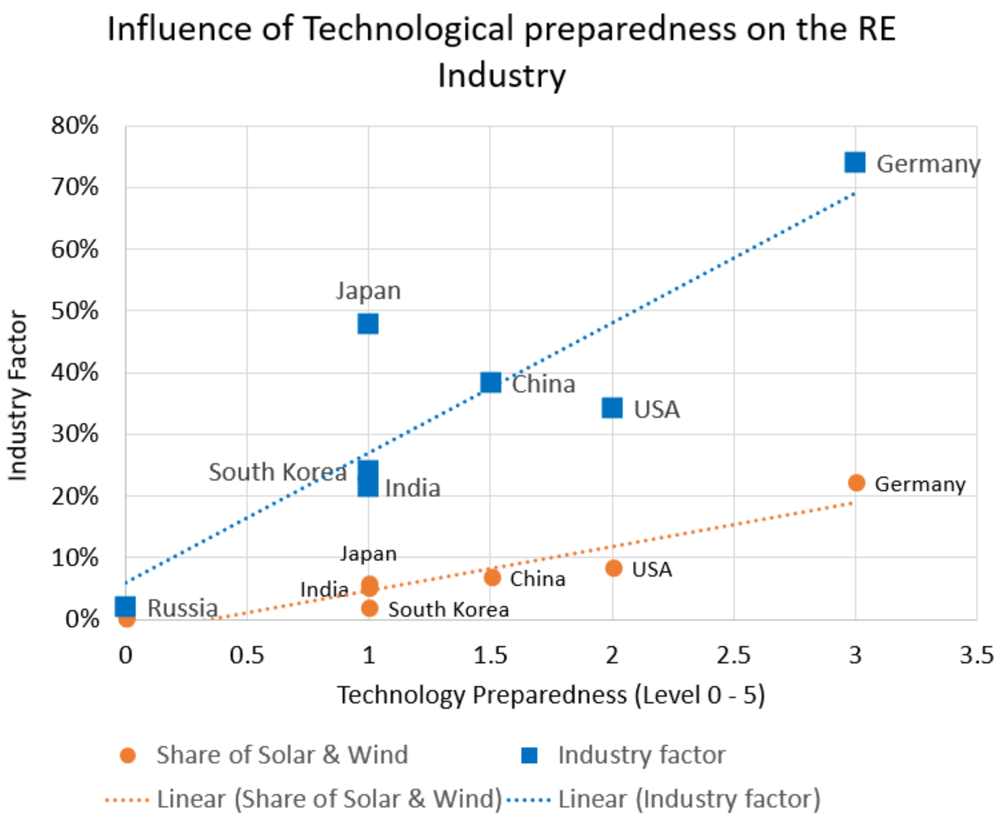


Fig. 4.21 Influence of Technological preparedness on RE industry

To make this comparison, results obtained in the Chapter 4.5 is translated into the technological preparedness score (in the range of 0 to 5) with the method explained in Chapter 3.5. Fig 4.21 presents the correlation between the technological preparedness and the RE Industry factor.

From the results, it can be observed that countries like Russia, South Korea, India, China, and Germany shows a very good linear relationship, while Japan, and USA shows positive and negative deviations, respectively, when the overall RE industry is observed with respect to the technological preparedness. Major positive deviation of Japan is observed due to very high share of RE, in new capacity installations in the last five years. And negative deviation of USA, is due to comparatively lower contribution of solar and wind in electricity, and also due to smaller contribution of the RE manufacturing industry.

However, out of the three segments of the RE industry, it the RE power generation industry which is assumed to be most strongly impacted by the technological factors and technological preparedness discussed in the Chapter 4.5.

So this relationship can be assessed through the figure 4.21, which also presents the variation of share of the solar and wind in electricity in 2017, with respect to the latest technological preparedness level of a country. The result shows very good influence of the technological preparedness of a country on the share of solar PV and wind power in electricity. Germany with the technological preparedness score of 3/5, shows highest penetration of renewable energy sourced electricity (RES-E). With the observed results it can be suggested that the USA is technically prepared for RES-E share of around 12%. Countries like China, Japan and India are very close to the average RES-E penetration levels and may be required to increase the technological preparedness by improving their position through the technological barrier hierarchy, in order to increase the RES-E share in the electricity. South Korea on the other hand is observed to be technologically prepared for RES-E shares up to 5%. For Russia very low level of technological preparedness also appears to be a strong limiting factor or one of the another major constraints in improving the share of solar PV and wind power.

Hence, the direct influence of technological preparedness on RES-E share in electricity or the renewable energy industry is clearly visible. This relationship although seems to be very linear as the penetration levels are quite low (less than 10% for all the countries considered, except Germany), but this may show non-linear relationship with increasing penetration level. However, this can be verified when these countries make advancements in the technological preparedness and as the RES-E penetration level of solar PV and wind power increases beyond 25%, or by including set of countries with the such or higher RES-E penetration levels.

Hence, it can be concluded that the results shows influence of the technological preparedness level on the RE Industry, however, the major influence is observed in the RE power generation industry. Furthermore, it can also be critically argued that instead of technological preparedness driving the increase in share of solar and wind in electricity, the increased share of variable renewable electricity or increased deployment of renewable energy drives the technological preparedness of a country. This argument is also true, as in the case of Germany which has higher share of VRE, the country has slowed down deployment of solar and wind power, focusing more on strengthening their electricity grid to handle target share of VRE. Or in other words, increased share of VRE is driving the technological preparedness. Hence, a good interaction among these two factors is highly desirable, which involves timely assessment of technological preparedness of a country to study the VRE share it can handle, and then further improve the technological preparedness for integrating higher share of variable solar and wind power.

e) *Influence of the RE policy environment on the RE industry:*

A strong influence of RE policy on the RE industry is desirable, as this would imply that the RE policies were successful in sending clear and consistent market signals, which garnered sufficient confidence in the market which further stimulated the required investments in capacity expansion and increase in the industrial activities. This would also suggest coordination between the implemented RE polices and RE industry impacted by them.

This section explores the above discussed interaction in the concerned countries.

Fig. 4.22 presents the influence of the RE policy environment on the RE industry. By observing the trend of the overall RE industry factor, it can be observed that in Germany, Japan, China, and USA, good interaction exists between between these two factors and RE industrial activities are found to increase with improvement in RE policy environment. Due to good interaction with RE policy scores of 97%, 76%, 70%, and 58%, RE industrial activities reached 74%, 48%, 38%, and 34% respectively.

It must be noted that the United States is in weak RE policy environment zone and shows low RE industrial growth. With this low value of RE policy environment, the country's RE policy is not strong to drive the RE industry alone. Hence, the RE industrial growth can be attributed to the combined influence of the economic incentives developed for these technologies in the United States.

Germany with conducive RE policy environment and due to strong influence on the RE industry, shows strong growth in all the three segments of the RE industry. Japan and China also showed strong interactions leading to a proportionate growth in the RE deployment, RE manufacturing and RE power generation industry.

However, it can be observed that Russia, South Korea, and India, showed negative deviations. Strong negative deviation of Russia suggests limitation of the methodology used to assess the RE policy environment, as although it is successful in representing RE policy environment of developed economies but fails to represent the true RE policy environment of countries like Russia, where the RE industry failed to take off, even when the RE policy environment is 65% for the country. In addition to the above presented reason, negative deviation of India suggests lack of sufficient interaction or influence of the RE policy on the RE industry of the country leading to the lower growth of the RE industry. RE policy in South Korea showed good interaction with the RE manufacturing industry (score 54%) , however, due to the small domestic industry, even with a good RE policy environment, the country had a very small scope for the growth of the RE deployment and RE generation industry.

Hence, it can be concluded that the RE policy environment of Germany, Japan, and China, were strong and with a good influence on the RE industry, were successful to drive the RE industry. India on the other hand, suffered from weak interaction of the RE policy on the RE industry. South Korea's small domestic government restricted the growth of RE industry, even with good RE policy environment, and Russia's RE industry failed to kick off due to insufficient understanding and implementation of the RE policy.

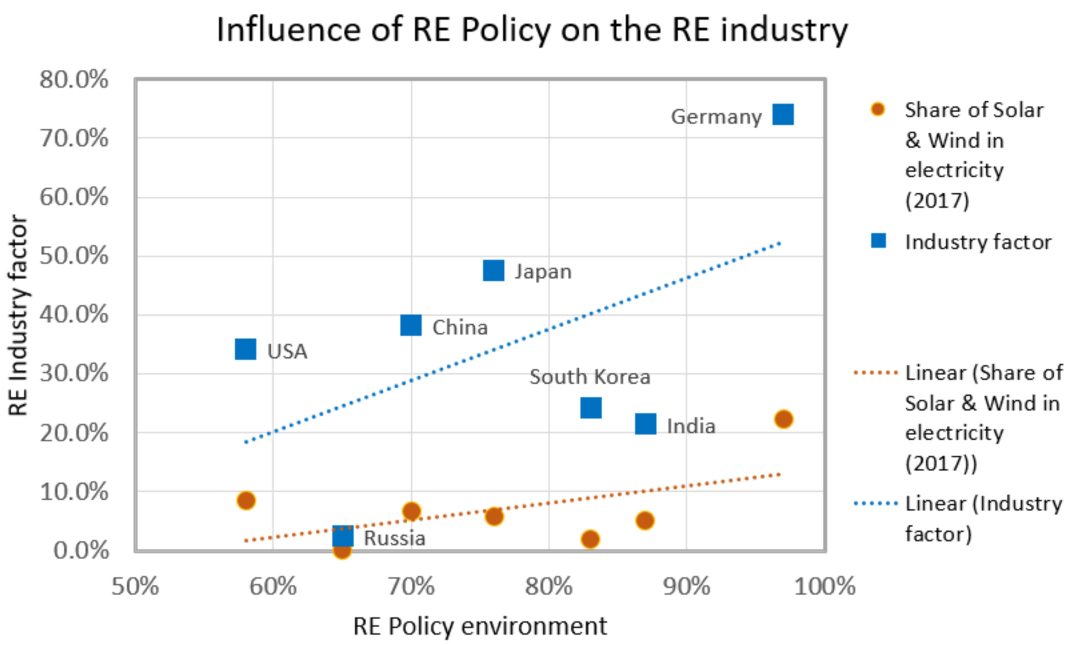


Fig. 4.22 Influence of RE Policy on the RE industry

f) *Interaction between the national political will and the RE industry:*

A strong influence of the national political will on the RE industry is desirable, as this suggests the strong confidence of industry on the country's government and on government's capability to create a suitable renewable energy market and finally achieve the national RE targets. A strong influence of the RE industry on the national political will would suggest the stronger market power held by the RE industry, however, a weaker influence suggests that the lobbying power of the conventional power industry has a stronger influence on the political decisions.

This section explores the above discussed interaction in the concerned countries.

Fig. 4.23 presents the influence of country's political will on the renewable energy industry. Although, the linear trend-line of overall RE Industrial factor shows increase in the growth of RE industry with increasing political will. However, the RE industry factor values appears distributed around the trend-line, hence, this interaction needs to analyzed very carefully.

From the plot, it can be observed that the RE industry factor in the United States, Japan, and Germany increases proportionally with increase in the political will. It must also be noted that these countries belong to the category of developed, high income countries. By their position above the trend-line, it can also be concluded that for Germany and Japan, there is a strong interaction between the political will and the RE industry. This can be observed by the strong growth of RE deployment and RE manufacturing industry in both of these countries. USA also shows strong potential of influence from the political will of the country, however, the political will of the country seems quite low.

South Korea and China, can be seen very close to the trend-line, however, the negative deviation can be attributed to the low share of solar and wind in electricity, in both of these countries, and to the low share of RE deployment share in new capacity installations in South Korea. Strong negative deviation of India is due to weaker growth in the all the three segments of the RE industry. It also suggests inconsistent political will or insufficient influence on the RE industry. Russia suffers from very weak political will and almost negligible growth in the RE industry. However, it must be noted that the high share of solar and wind in electricity, results from a long term commitment and political support, and short term political support would not have much influence on this industry.

Another interesting results were observed by plotting the trend of RE manufacturing industry share with respect to the country's political will. RE manufacturing industry showed very strong dependence on the political will of the country with only exception of India. This suggests that either the influence of the political will on RE manufacturing industry is weak in India, or the perceived political will or RE support by the RE manufacturing industry of India lies somewhere close to 20% (which is close to the

Renewable Purchase Obligation (RPO) planned by the country to increase the RES-E share to 21% by 2022 (Ministry of Power, 2018)).

Hence, based on results, the following conclusions can be drawn:

(a) In Germany and Japan, strong influence of the political will and political support is observed which supported the growth of RE Industry.

(b) The influence was found to be weak in India, or it refers to inconsistent political will.

(c) USA's RE industry showed strong potential to grow but the political support is weak.

(d) South Korea and China, are getting recent political support, but this would be required for a long period to make observable improvement in the RE generation industry.

(e) Russia's political will is found to be too weak to positively influence the RE industry or the influence of the conventional power industry on the government is too strong in Russia.

(f) RE manufacturing industry showed very strong dependence on the political will of a country.

4.7 Comparative analysis of national RE business environment:

This section presents the final result, analysis and comparison of the RE business environment of China, USA, Germany, Japan, India, South Korea, and Russia, created as an cumulative effect of the external business-environmental factors like the political will for adoption of renewable energy, RE policy environment, economic incentives, technological preparedness, and the interactions among these factors, which are discussed in the previous sections.

Final results of the Renewable Energy Business Environment for solar PV and wind power in Germany, USA, China, India, South Korea, Japan, and Russia are depicted through radar charts in Fig 4.24, 4.27, 4.26, and 4.25.

The four dimensions in the radar chart represent the strength of each of the factors which are Political Will, RE Policy Environment, Economic Incentives and Technological preparedness. More spread of the plot towards any of these dimensions present a

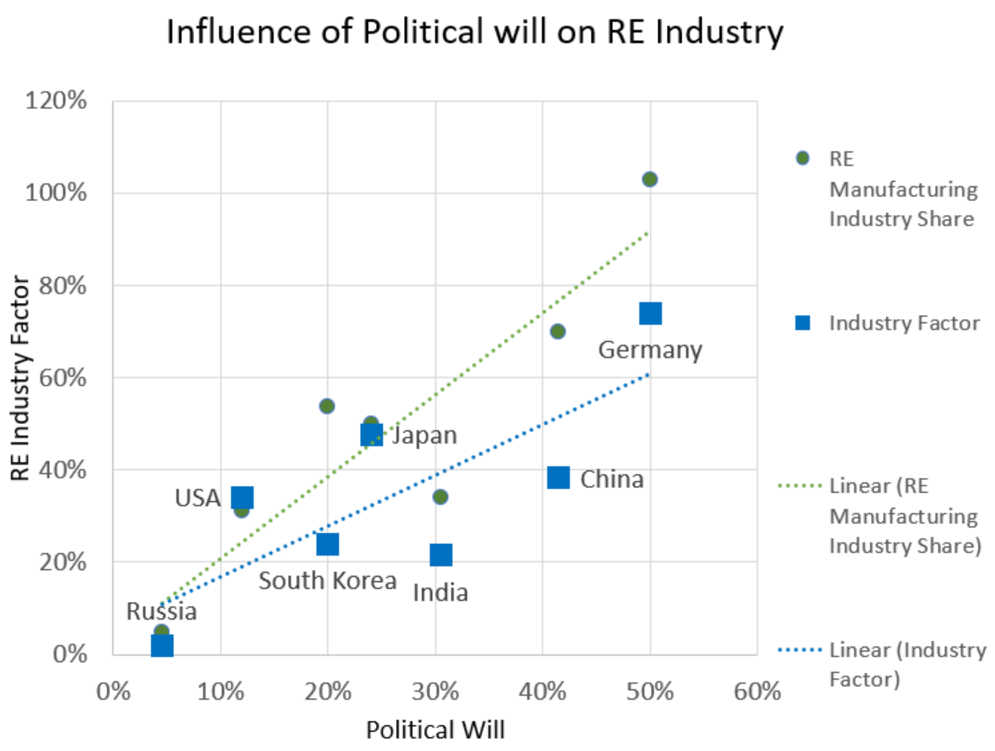


Fig. 4.23 Influence of political will on RE industry

stronger support to the RE business environment from that dimension. And larger plot area would suggest better suitability of the national renewable energy business environment to drive the growth of renewable energy and contribute in the energy transition.

Following observations can be made based on the results:

(a) First of all, it can be observed that RE Policy Environment score of all the countries are exceptionally high, which in most of the cases does not represent the true RE policy environment of a country. This is due to the limitations of the RISE indicators used in this research, which provides only comparative RE policy and framework scores based on best practices around the world, and it fails to measure the RE policy environment at an absolute level. This is because the best practices of one country, may not be a suitable or a best fit model for another country as well. Hence, based on the historical success in achieving the renewable energy targets, the values of the RE Policy environment are adjusted to include the net effectiveness of the RE policy environment to bring the energy transition. Methodology adopted to measure the adjusted RE policy environment value and results are mentioned in the Appendix C.

(b) Germany can be observed to have the largest radar area, with good plot spread in all the dimensions. This shows good support for the growth of renewable energy from all the four factors. This validates the strong interactions and influence of the political will, energy policy, economic factors and technological preparedness on the RE business environment. The greater spread of the plot towards the political will and policy impact suggests that the political will and policy support are the strong drivers of the German RE business environment which has led to creation of better economic incentives and technological preparedness for the adoption of solar PV and wind power in the existing electricity industry. Hence, the overall RE business environment of Germany is found to be most conducive among the selected countries. This result can also be confirmed by the highest RE industry growth factor score of Germany which was measured to be 74% (please refer table 4.8).

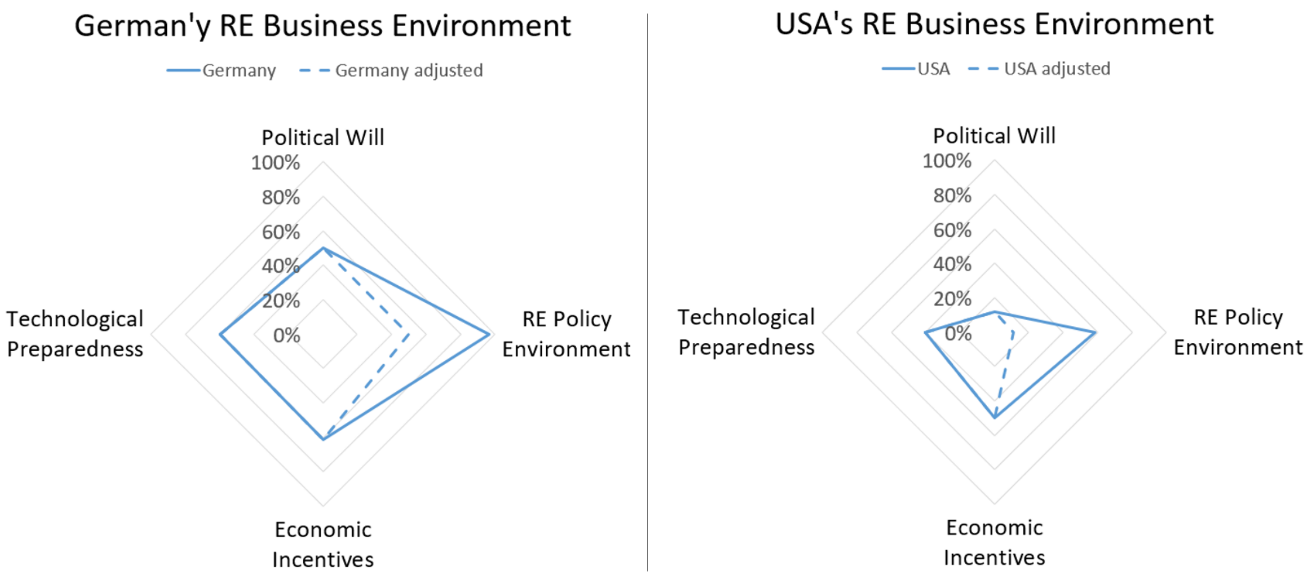


Fig. 4.24 Comparison of the RE business environment in Germany and the United States

(c) USA's plot spread is very distinct from other countries. If we look at the USA' RE business environment plot, with adjusted RE policy environment, the plot suggests stronger influence of economic incentives and technological factors in the growth of the renewable energy. In USA, it can be observed that the political will and the RE policy environment are not the main drivers of country's RE business environment. Furthermore, it was observed that the economic incentives are weakly influenced by the country's renewable energy policies, the plot suggests that the economic incentives are being driven by the technological improvements, which is supporting the RE business environment. Finally, the overall RE business environment of the United States does not look very conducive, this can also be confirmed by moderately low value of RE industry growth factor of USA, which is 34%.

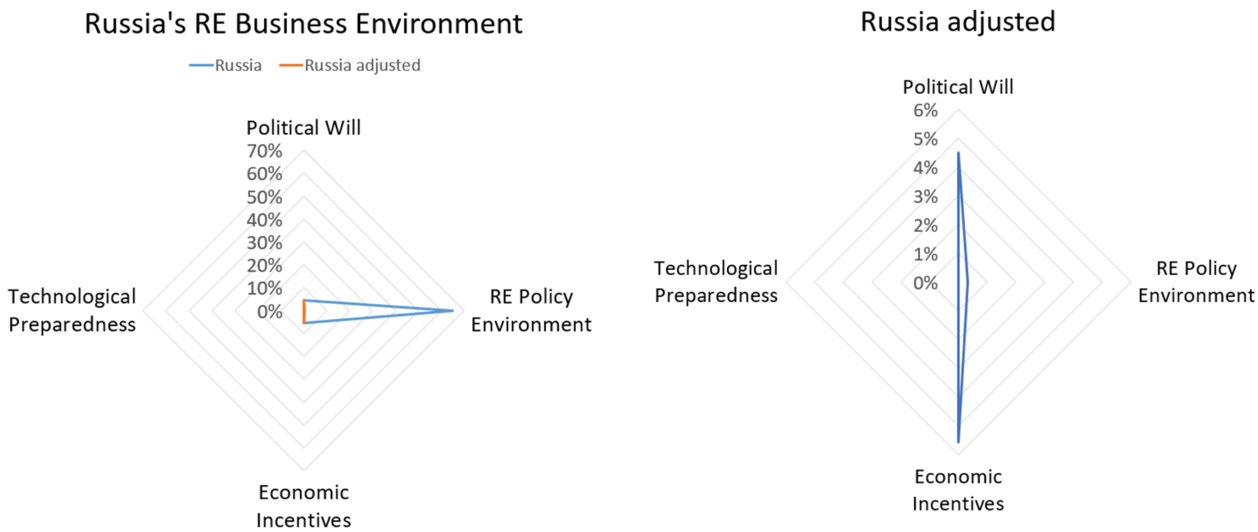
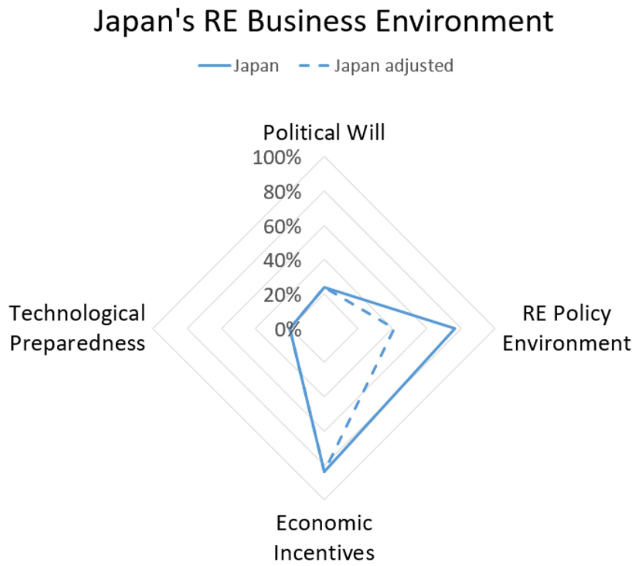


Fig. 4.25 Russian renewable energy business environment

(d) Russia: If we observe Russia's business environment plot, the RE policy environment looks exceptionally high. After adjusting the RE policy environment score for the actual results in the country, it can be observed that all the required essential driving factors of Russia are very weak, and hence, they could provide negligible support to build the Russian RE business environment. The primary driving factors such as the political will and technological preparedness are very weak on their own in Russia, and their influences on creating suitable RE energy policy and economic incentives for RE technologies are also very weak. Hence, weak driving factors and weak interactions have resulted in a very small plot area, and suggests very weak suitability of the growth of renewable energy in the given national electricity market. This can be confirmed by the lowest RE industry growth factor score of 2.5% for Russia.

Some contrast differences can be observed in the technological preparedness of Russia and USA. In Russia, due lack of any observable political support, technological preparedness of the country also failed to kick start. In the United States, the country had reasonable technological preparedness and although very small but 12% political support. So comparison of RE business environment of Russia and USA, suggests that the technological factor is not a prime mover and it would require political support and/or support from the industry, so that the technology can be developed in order to be able to create incentives and to be able to compete in the existing industry.



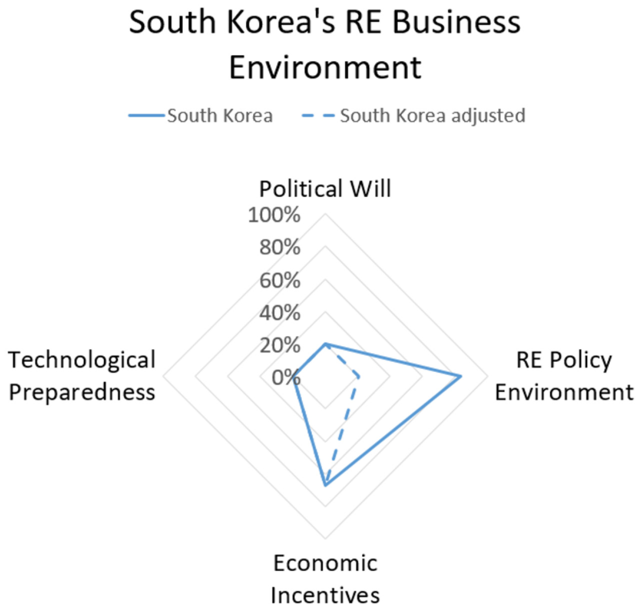


Fig. 4.26 Comparison of the RE business environment in Korea and Japan

(e) South Korean and Japanese plots suggest that these countries have developed good economic incentives due to the political and RE policy support to the renewable energy technologies. Further economic incentives in these countries are also influenced by the technological developments. The plot suggests that among all the factors, influence of the economic incentives on RE industry, would be the strongest in these two countries. However, the Japan's plot size appears to be of moderate size and quite small for South Korea, this suggests that the overall RE business environment of Japan is moderately conducive but weak for South Korea and growth of RE industry would also require stronger political will, policy support and technological preparedness for strengthening the renewable energy industry. RE industry growth factor measures Japan's growth at 48%, and 24% for South Korea.

(f) Radar plots for China and India suggest similar features of the RE business environment. However, it can be observed that China's RE business environment is quite better as compared to India, due to comparatively better political will, RE policy environment (adjusted) and technological preparedness, which have created comparatively better economic incentives in China, which suggests

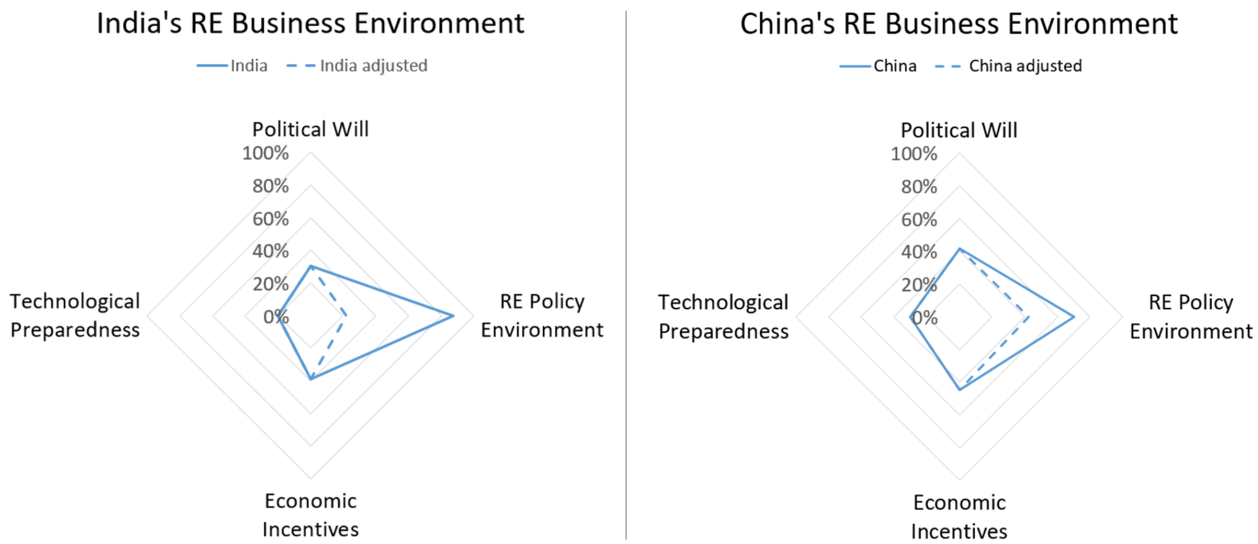


Fig. 4.27 Comparison of the RE business environment in India and China

comparatively better growth of the RE industry. However, when compared with Germany, smaller areas of China and India suggest that the driving factors of RE industry are comparatively much weaker in China and India. Furthermore, the plots also suggest that the influence of the economic incentives on RE industry in China and India are not as strong as in South Korea and Japan. Hence, the overall RE business environment of China and India appears to be in the moderate to weak region. To compare with RE industry growth factor, China scored 38% and India 21.5%.

Chapter 5

Discussions

Now, as the results of this research are known, and the designed methodology is implemented and tested, this chapter analyzes the quality of the research work by discussing the strengths, limitations, and scope for improvement. This chapter is developed based on the self-assessment by the author, critical review by the thesis supervisor, and by peer review.

This chapter first critically analyses the assessment of this research work in section 5.1 by looking into the selected parameters, methodology, and reflection on results in section 5.2. Then, this chapter presents a comparison of the methodology, results, and analysis with the existing and similar research works in section 5.3. Section 5.4 briefly presents the error analysis of interactions discussed in section 4.6.

5.1 Critical analysis of the research

This section would discuss the strengths, limitations, and scope for improvements in the implemented parameters, methodology, and results.

1. Political Will

   Strength: This is the first research that has tried to capture and quantify the political willingness and support for renewable energy. The selected parameters for measurement, which were national renewable energy targets and road-map for the energy transition, were able to map and measure the political will to a reasonable extent. The indicators and the methodology adopted to measure the political will were successful in creating a single framework that can be used and implemented to measure the political will of any country on an absolute scale and compare them for further analysis.

   Limitations: (a) Adopting a standard definition of renewable energy is the first challenge. This is because the meaning and interpretation of renewable energy change from country to country and this makes a one-to-one comparison of renewable energy targets difficult. For example, India and Russia do not include hydro-power more than 25MW within the renewable energy targets, whereas hydro-power form the part of renewable energy targets in other countries. Similarly, some countries include other renewable sources such as the hydrogen power, biomass under renewable energy targets, whereas others do not include them. So it is quite challenging to adopt the same definition for every country, and this is one of the limitations of the parameter selected to measure the political will.

(b) Secondly, although this research considers the overall renewable energy targets to measure the political will for solar and wind power, these renewable energy targets include all the sources which are regarded renewable by a specific country. This approach is adopted because, in many countries, it is difficult to find the share of solar and wind power in the national energy targets. Furthermore, the national targets for energy transition are not designed to favor any specific technology.

(c) Thirdly, a mismatch between the calculated and perceived political will by the industry, was observed, as in India. This is because although the political will of a country is important, it is essential to have a consistent political will for an extended period. This is another limitation of the research, where the development or trend in the national political will of a country, could not be covered in this research.

Scope for improvement: In addition to the observed strengths and limitations in measuring the political will, inclusion of historical national annual budget allocations (for R&D development, product introduction, and deployment) and/or allocated budget for future investments, could have corroborated or further strengthened the quantification of political will, as this provides the information on a country's willingness to spend to achieve the renewable energy targets. The budget parameter does not form a part of this research due to the lack of clear information on future investment plans, and due to the lack of historical budget allocation data for the concerned countries.

2. Renewable Energy Policy Environment and RISE indicators

   Strength: This research has adopted RISE indicators by the World Bank to measure the renewable energy policy environment or the renewable energy policy and framework environment. Adopting the RISE indicators helped this research, as these indicators are well established, easy to understand, map, compare and rank the RE policy and frameworks of countries around the world. But the most significant advantage of these indicators is that these are globally acceptable.

Limitations: The following limitations of RISE indicators were observed in this research.

(a) RISE indicators only provide a comparative measurement of RE policy and regulatory framework but do not provide a quantitative mapping on an absolute scale.

(b) RISE indicators and rankings assume that the set of policies which are suitable for one country would also be useful for other countries. RISE's approach of one size fit for all may not be applicable, and best practices of one country may not be the best solution for other countries as well (Urpelainen, 2018). Urpelainen (2018) also suggest that RISE ignores the ground realities which are essential in the formulation of RE policies.

(c) RISE indicators do not include ground-level developments to adjust or correct the RE policy and framework environment scores. For example, the indicators ultimately failed to represent the real RE policy environment of countries, as in Russia.

(d) RISE indicators measure the presence of RE policies and regulations but do not provide proper mapping about how good or effective are these policies and regulations.

(e) The countries were estimated to have the same RE policy environment for onshore wind power, off-shore wind power and solar PV, which in reality cannot be the same. This failure occurred due to the limitations of the RE policy environmental factor, which does not measure the RE policy environment separately for different RE technologies.

Scope for improvement: Although RISE indicators provide a globally accepted methodology to compare the RE policy and framework environment, it can be improved by incorporating correction factor to include the ground realities of a country, efficiency in policy design and implementation, and their effectiveness in meeting the targets.

3. Economic Incentives

   Strengths: The methodology and parameters used to measure the economic incentives were found to be very useful in covering major aspects of the economic incentive in renewable power generation, by including the grid parity, competitiveness with the existing fossil fuel-generated electricity and remunerations for renewable electricity. This methodology is very scalable and can be used for any country to measure the economic incentives for renewable energy.

   Limitations and scope for improvement: Although the adopted methodology measures the economic incentives in a broad range, the selected parameters and methodology does not incorporate the effects of policy mechanism and instruments which influence the investment cost of renewable energy projects in the form of subsidy programs (for example residential, building, government offices, hybrid-installations), capital subsidies, tax credits on investments, income tax credits, and other economic benefits from green certificates. Economic incentives due to the presence of these policies mentioned above also play an essential role in deciding the economic competitiveness of solar and wind power projects, their profitability, and creating a suitable renewable energy business environment, and hence, can be included for a more comprehensive analysis.

4. Technological Preparedness

   Strength: This research presented a very preliminary but a broad framework to measure and compare the technological preparedness of a country to improve the share of solar PV and wind power in electricity. The presented technological preparedness hierarchy can be used by countries to understand their current level in technological preparedness, and this hierarchy provides a broad direction in which a country can proceed to improve the technological environment and preparedness for a higher share of renewable energy.

   Limitations and scope for improvement:

   (a) As already suggested, the developed hierarchy levels are very preliminary. No direct one-to-one correlation can be established between a particular level of technological preparedness hierarchy and a range of renewable electricity share, that a country's power system can handle.

   (b) The designed hierarchy framework can help identify the problems that need to be solved to improve the technological preparedness, but it not designed in a way to suggest specific solutions to achieve that.

   (c) It is further limited in scope and does not cover the technological development of solar PV and wind power itself, which was observed to be a critical component in their development in Russia.

5. Industrial Factor

   Strength: The adopted parameters and the overall framework of Industrial factor were quite successful in measuring and mapping the growth of all the three segments of the renewable energy industry (a) RE deployment industry, (b) RE power generation industry, and (c) RE manufacturing industry. The framework was found to be useful and relevant in explaining the growth of the RE industry. This framework helps to measure, rank, and compare the growth of national renewable energy industries at an absolute level, without facing any comparative biases. The framework can be extended to an extended set of countries to map the growth of their national RE industry.

This framework can be further extended to map the global RE industry growth by incorporating weight factors for each country based on their share in global power consumption.

Limitations and scope for improvement: The adopted methodology and parameters do not incorporate the availability of skilled labour, which would have presented interesting results and interactions.

6. Overall factor selection:

   Although the selected factors were quite successful in creating a broad generic framework to map renewable business environment, the factor selection may be argued upon, regarding their comprehensiveness and capacity to represent the actual renewable energy business environment. Furthermore, this framework does not include country-specific factors which may be very important for a country but not for others, for example, abundant availability of cheap domestic fossil fuels as in Russia, lack of availability of land, or natural resources, extremely weak or degrading socioeconomic status, presence of natural or social threats etc.

7. Placement of national renewable energy business environments in the global RE business environment:

   The adopted methodology may suggest that the national renewable energy business environment is an isolated system, as the influences from the international factors do not form a direct part of the research framework. However, all the factors considered in the current research are influenced either directly or indirectly by the international factors. Hence, the representation of national renewable energy (RE) business environment as a connected part of the global RE business environment would be a better portrayal of the actual renewable energy business environment.

8. Gottschamer and Zhang (2016) have discussed interactions within the policy dimension and have presented more comprehensive theoretical interactions among various factors affecting the implementation of RE projects. These interactions, however, do not form a part of this research due to the involved complexity and time constraint.

9. Although the designed methodology is capable of explaining the development of RE business environment over time, the research work does not present the development of the selected factors and their interactions over time, and hence, appears to be a quite

static model. Such detailed analysis is possible by considering each country separately and studying the developments over time in much further detail.

10. The research work could have been improved by including the analysis of "intensity of influence" between different factors. Calculating the intensity of influence would require time-series comparison of parameters for individual countries, which would give a better idea of correlation of factors because the intensity of correlation may vary for different countries. Hence, data set of more countries and the factor values through a more extended period, can be used to calculate variable coefficients representing the intensity of influence by employing Fixed Effects Vector Decomposition (FEVD) model.

11. The research results suggest that the technological factor is not a prime mover and requires political and policy support and support from the industry. Hence, the inclusion of interactions with the research and development (R&D) of renewable energy technologies (RETs) as a separate factor would have made the research more comprehensive. However, the current research does include the R&D development as a part of technology up-scaling, cost reduction and eventual reduction in the Levelized cost of electricity (LCOE) by RETs, which is covered with the economic factor.

12. Due to time constraints, this research work does not include other relevant economic factors such as the flow of the investment, availability of capital, ease of investment, investor's perception, break-even period, return on investment, risk factors, the sufficiency of incentives. Inclusion of these factors may help in making a very in-depth comprehensive analysis of RE business environment of a particular country.

    Hence, the designed framework to assess the renewable energy business environment, has much scope for improvement, in terms of comprehensiveness and in-depth. The designed framework can also be adopted into a computer algorithm and can be programmed to estimate the RE business environment of any country. However, the presented framework in the current form was also found to be very helpful in assessing and mapping the renewable energy business environment of the concerned countries.

5.2 Reflection on results

- The RE business environment methodology suggests a direct or indirect influence of the political will on most of the factors of the renewable energy business environment. The comparative results with all the 7 countries suggested that the political will has a potential to have a powerful influence on the renewable energy industry and energy policy of a country, and further this influence gets reflected on the technological development and preparedness, and the economic incentives created for the renewable energy technologies, through the national energy policy. Germany through strong political support for renewable energy, was able to design and implement effective renewable energy policy, which supported the growth of renewable energy technologies, brought the costs down for solar PV and onshore wind power, and created good economic incentives for RETs, making them competitive in the electricity industry and hence, was successful in creating suitable opportunities for the growth of RETs. Hence, Germany was successful in creating synergy, by working on all factors and by successfully maintaining the interactions among them, which created a conducive business environment for the growth of renewable energy. Russia on the other extreme, with weak political support for the renewable energy, and lack of positive interactions among the different factors, was not successful in designing and implementing effective renewable energy policy, which can create sufficient economic incentives or technological preparedness of the country, for supporting the growth of renewable energy.

Furthermore, inherent market failure mandates the government intervention, to support the growth and adoption of new renewable energy technologies, by creating mechanisms for sufficient economic incentives, till the technologies reach the maturity level to compete in the electricity market.

- The renewable energy (RE) policy of a country emerged as a strong political tool which has the potential to directly influence the economic incentives and growth of the renewable energy industry. The results suggested added influence of the RE policy on the technological growth of RETs. In contrast with the weak and ineffective renewable energy policy of Russia; Japan and South Korea were quite successful in designing and implementation of renewable energy policy which had a strong positive influence on the multiple factors. Japan and South Korea's special policy focus on solar PV, on-shore wind and off-shore wind power, created good economic incentives in the last few years for the adoption of RETs and growth of the RE industry. Along with supporting the growth of solar PV and on-shore wind power, their effective policies are also boosting the deployment and technological development of off-shore wind industry.
- The three level analysis for calculating economic incentives was found to be quite useful in understanding the role and importance of multiple factors involved in creating

the economic incentives for renewable energy. High electricity prices in Japan and Germany, made the renewable energy an economical choice for electricity users, leading to increased demand, and growth of the solar and wind power. Furthermore, lower rates of renewable energy sourced electricity (RES-E) LCOE rates in comparison to the electricity rates, specially for the onshore wind power, which is approaching lower limits of fossil power generation costs in USA, Japan and South Korea, created very good opportunity for the deployment of the technology. Similarly, competitive LCOE of offshore wind power in Japan and South Korea, is helping the deployment of offshore wind power in these countries. These drops in offshore wind power LCOE has resulted from the national political support with suitable policies for R&D and deployment of the technology. Onshore wind power has emerged as a winner due to advancements in technology, very competitive LCOE (except Russia), and political support, creating very good economic incentives for the power producers.

- From the view of manufacturing capacity, it was observed that China supports around 50% of the solar PV and 40% of the wind power global production capacity and demand. Further, the domestic production capacity of solar PV in USA, Japan, Germany and India are insufficient to meet their national demand. Furthermore, only Chinese solar manufacturing industry was successful to grow in a rate corresponding to the global demand. Hence, any changes in the Chinese demand, manufacturing industry, or international trade policies with other countries, would greatly impact the capacity of other countries to meet their domestic solar PV demand.

5.3 Comparison with existing research

This section presents a comparison of this research work with the existing research and literature. This section is divided into two parts: a) The first part presents the comparison with the existing literature on the methodology and then presents the novelty added by this research. b) The second part of this section presents the comparison of the results available with the existing literature, and new insights/understanding contributed by this research.

1. **Methodology**

   (a) Existing research: Fernando (2011), and Worthington and Britton (2009) have explained the theory of the business environment from an organizational point of view, comprising of the internal and external business environment impacting a business. Fig 2.1, summarizes the general framework to explain the business environment as presented by the above literature. These literature suggest that a business does not

operate in isolation. However, they are continuously influenced by the interactions with the business environment within which they operate. The internal environment is influenced by the factors which are internal to an organization or business. The external environment, on the other hand, represents the combination of the external micro and macro-business environmental factors, which are beyond the control of an organization or business, however, plays a vital role in the operations, future growth, and success/failure of a business.

(b) Limitations of the existing research or the research gap:

- Although, the existing literature explains the framework of a general business environment, the adapted theory and framework to explain the business environment of renewable energy is not available.
- Although the existing literature suggests the presence of interactions among the factors of a business environment, these interactions have not been explored and compiled to develop a generic framework.
- The existing literature does not suggest any methodology to measure and compare the renewable energy business environment of different countries.

(c) Novelty and contributions of this research

This research has attempted to bridge the existing research gap and provided a novel contribution in the following ways:

- This research has used the basic theory of the business environment, and have further developed the theory and a novel framework to map the national renewable energy business environment.
- This research has attempted to compile the complex interactions among the external business environmental factors which may have a strong potential to influence the RE business environment and has integrated them into a single framework, intending to reach a step closer to depict the actual complexity in portraying the RE business environment.
- This research work has introduced many new and existing parameters to measure the external business environmental factors, and the developed framework helps to map the RE business environment of a country in an absolute level and can also be used to conduct a comparative study. These are the most significant achievements of this research work.

- The developed framework is scalable, and hence, it may be further extended to map and compare the RE business environment of other countries not covered in this research.
- The framework can also be quite helpful in identifying the weak areas in the RE business environment of a country, which can be further strengthened.

2. **Results**

- Competitiveness of renewable energy

  (a) Existing research: IRENA maintains the database and conducts the power generation cost analysis for renewable energy technologies. Fig. 5.1 presents the LCOE ranges for renewable energy and fossil electricity, and weighted averaged LCOEs for China, India, OECD countries, and in the rest of the part of the world for years 2016 and 2017.

  (b) Novelty of this research: This research adds novelty by a conducting more detailed economic analysis for renewable power generation by using (a) grid parity, (b) RE power generation cost comparison with fossil electricity, and (c) RES-E prices in comparison with respective LCOEs (applicable in the year 2016-2017) .

  Results from the section 4.3 is summarized in the Fig. 5.2. Results as presented in the Fig. 5.2 is more informative, because in addition to the power generation cost comparison, it takes electricity price ranges and RES-E prices applicable in the countries, into consideration.

  In China, onshore wind power generation has achieved grid parity and with applicable feed-in-tariff in the country, economic incentives increases to a very good level. Solar and offshore wind power have not achieved grid parity in China, which reduces their economic incentives. Further, lack of feed-in-tariff scheme for offshore wind power reduces the economic incentives to zero.

  In the United States, the economic incentives of onshore wind power is reasonably good, due to the grid parity achieved by the technology and the generation cost being competitive with the fossil electricity. However, solar PV and offshore wind power fails to reach the level of good economic incentives, as the technologies have not achieved the grid parity and does not enjoy any incentives for RE power generation.

  In Japan, economic incentives for solar PV and onshore wind power are very good, and fairly good for offshore wind power, due to expensive fossil electricity

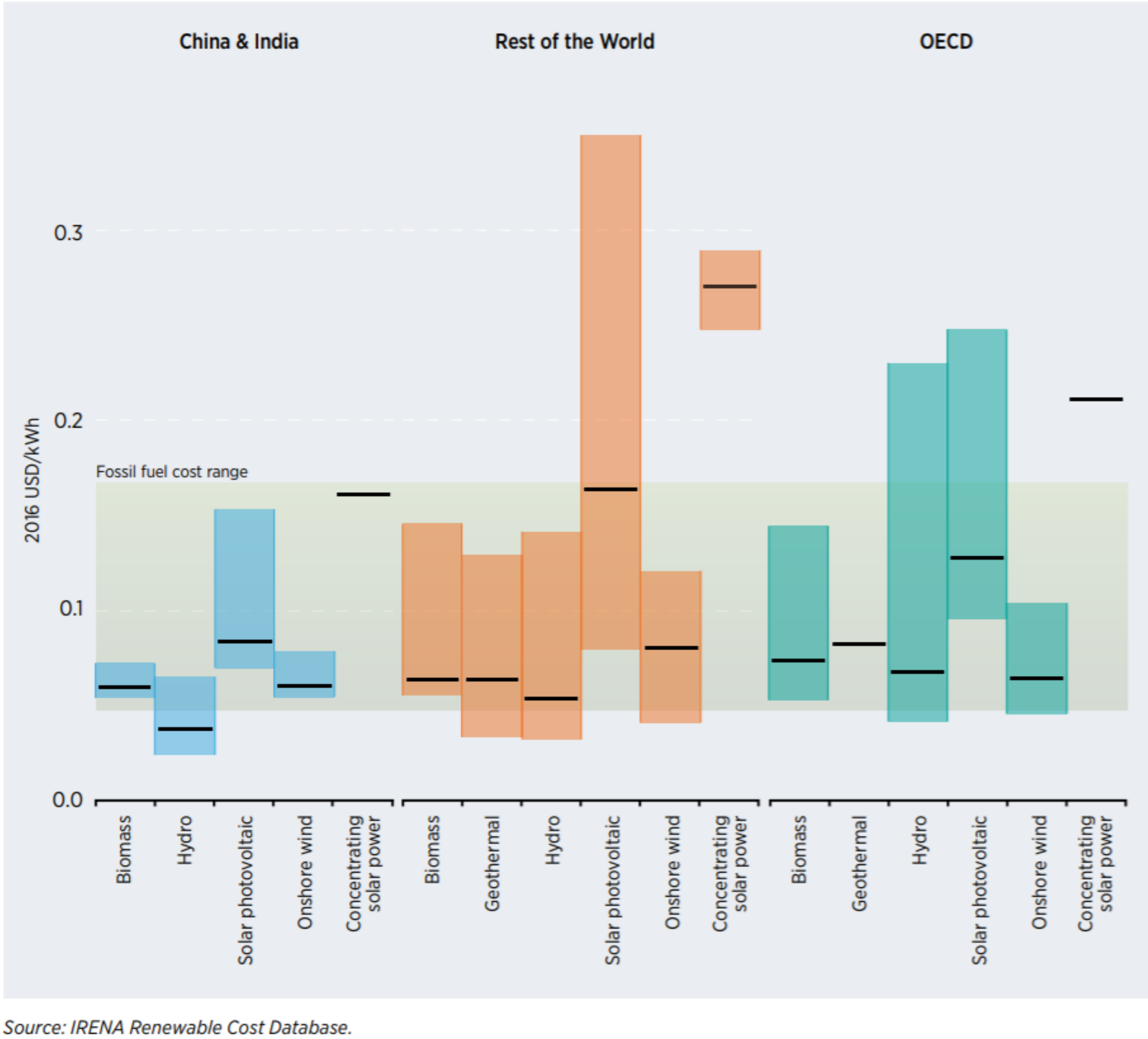


Fig. 5.1 LCOE ranges for RE and fossil generation, and weighted averages for 2016 & 2017
Source: IRENA (2018*c*)

generation cost, higher electricity prices and due to the applicable feed-in-tariff scheme for all the three technologies.

Germany has fairly good economic incentives for solar PV and onshore wind power, but insufficient economic incentives for offshore wind power. Economic incentives for these RE technologies reduced due to replacement of feed-in-tariff scheme with auction system.

In India only onshore wind power has fairly good economic incentives, and insufficient economic incentives for solar PV and offshore wind power. Russia has insufficient economic incentives for all the three technologies.

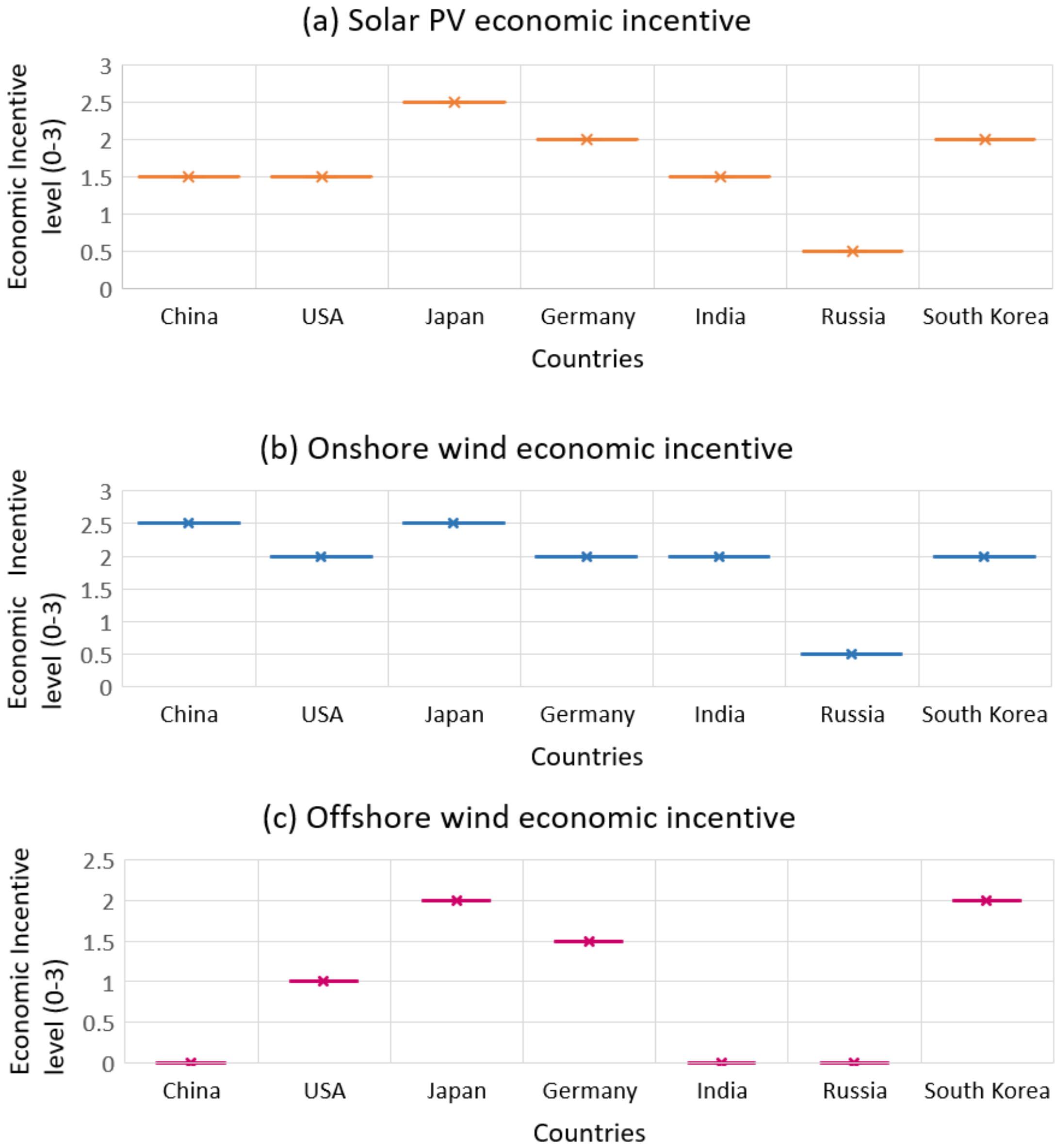


Fig. 5.2 Economic incentives for solar PV, onshore wind and offshore wind power in 2016-2017

South Korea has fairly good economic incentives for all the three technologies, due to expensive fossil electricity generation cost, expensive grid electricity, and applicable fixed price scheme with RPS scheme.

- Influence of politics on renewable energy industry:

  (a) Existing research: Existing research works like Renn and Paul (2016), Hake et al. (2015), Cadoret and Padovano (2016), and Marques et al. (2010), have

studied the influence of politics on the renewable energy industry in the context of Germany and other European Union (EU) countries. Involvement with the EU, and presence of target based RE consumption directives, were found to be strong drivers of renewable energy deployment in these countries.

(b) Novelty of this research: This research measured the political will of Germany (50%) along with other countries like China (41.5%), USA (12%), India (31%), Japan (24%), South Korea (20%), and Russia (4.5%), in section 4.1. These results give a reasonably good idea of the political will of these countries to adopt renewable energy technologies for the energy transition by 2030.

This research further explored into the influence of political will on RE industry in section 4.6 (f), and concluded that (i) the strong political will and political support enjoyed by Germany and Japan, led to the growth of RE industry, (ii) inconsistent political will in India led to a weaker influence in the RE industry, (iii) USA's RE industry showed strong potential for growth but suffers due to weak political support, (iv) South Korea and China are receiving political support for RE power generation in the recent years, and would require long term support for large scale transition of the power generation industry, (v) Russia's political will was found to be too weak to positively influence the RE industry, and (vi) RE manufacturing industry showed very strong dependence on the political will of a country.

- Growth in renewable energy industry:

  (a) Existing research: Lund (2009) studied the expansion of the renewable energy industry in 20 countries (mostly EU countries) including solar PV and wind power in Germany, China, USA, and Japan. Based on the 2005-2006 data, the study found that the solar PV industry may grow by depending on either the import or the export market. Germany, although with sizeable domestic PV industry, showed more than 50% import dependence. Whereas, countries like China and Japan, were found to have a larger export share as compared to the domestic industry. In the case of the wind industry, large and stable domestic market led to increased export share. IRENA and REN21, as many other organizations release annual reports on annual (and total) deployed capacity and the share of solar PV and wind power in electricity, to track the growth in RE industry, which are presented in the fig. 4.8, 4.9, and 4.10 of section 4.4.

  (b) Novelty of this research: This research adds value to the existing literature by studying all the three segments of the RE industry: (a) RE deployment industry, (b) RE power generation industry, and (c) RE manufacturing industry. Although

the available reports by IRENA or REN21, provides data on annual new RE installed capacities, this research adds to this information by finding the share of average RE capacity deployment in the average new capacity installations in table 4.6. This gives a perspective on the share of new capacity deployment industry captured by the RE industry as shown in the fig. 5.3. It can be seen that although, China seems to deploy huge RE power generation capacities, in comparison with the domestic power industry, the average share of new RE capacity installations is only 38%. For other countries it was found to be USA (63%), Japan (87%), Germany (97%), India (25%), Russia (3%), and South Korea (17%).

Similarly, this research presented the capacity of the RE manufacturing industry to meet the new power capacity demand in 2017 and found the following results China (70%), USA (31%), Japan (50%), Germany (103%), India (34%), Russia (5%), and South Korea (54%), as calculated in table 4.7.

Based on the above three RE industry segments, this research calculates the overall RE industry growth factor, with results as, China (38%), USA (34%), Japan (48%), Germany (74%), India (22%), Russia (2.5%), and South Korea (24%), which gives a fairly good idea of the growth in the RE industries of these countries.

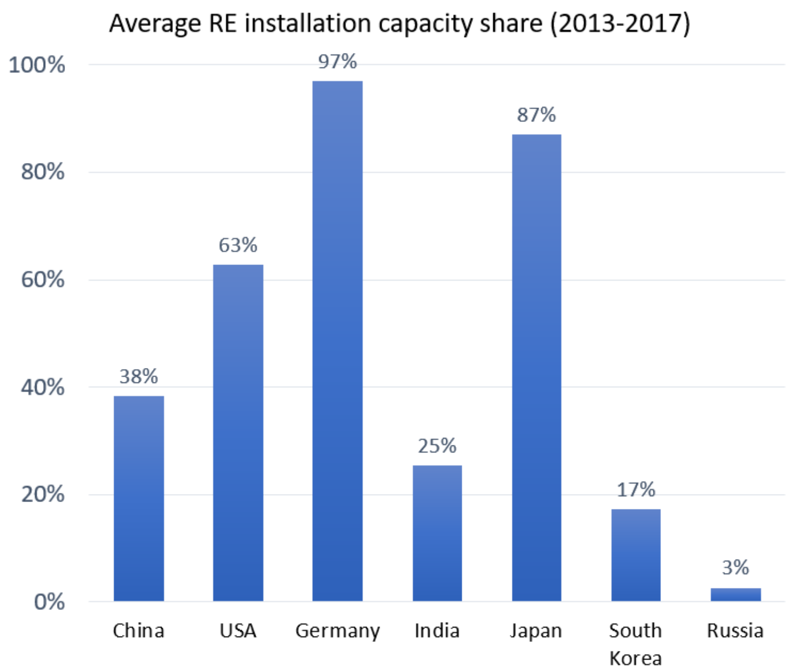


Fig. 5.3 Average share of RE installation in the average total new installed capacities (2013-2017)

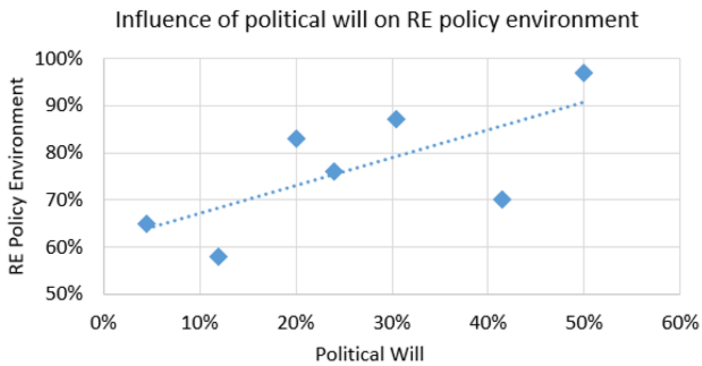
- Mapping overall renewable energy development:

  (a) Existing research: REN21 releases the *Global Status Report* annually, which provides detailed quality information on various aspects of the development of renewable energy, covering the global overview, RE policy overview, trends in the market and industry, distributed RE power generation for improving energy access, flow in investment, integration of energy systems and available enabling technologies, and renewable energy sourcing by corporate. World Bank group publishes the "The Regulatory Indicators for Sustainable Energy (RISE)" report/values, to track the growth in suitability of policy environment for adoption of renewable energy, which is also presented in the section 4.2. RISE compares the policy environment for renewable renewable energy and ranks the concerned countries in the order of conduciveness for RE as Germany (97%), India (87%), South Korea (83%), Japan (76%), China (70%), Russia (65%), and USA (58%) for the year 2017. Where, the RE policy environment of Russia and USA were found to be non-conducive.

  (b) Novelty of this research: This thesis adds novelty to the research by studying the renewable business environment in four dimensions which are political will, RE policy environment, economic incentives, and technological preparedness, which provides a broader picture of the RE business environment in these countries. The results obtained in section 4.7, also gives an idea about which of the above dimensions are stronger in a country's RE business environment and which dimensions need strengthening. The result suggested that Germany has the best RE business environment with well-balanced growth in all the dimensions. Germany is followed by Japan, due to very good economic incentives, but the political will of Japan was found to be weak. China was found to have the next best RE business environment, with a comparatively weaker technological preparedness which is restricting the increased share of RE in electricity. The United States comes next with good economic incentives but very weak political will and RE policy support. South Korea, have created reasonably good economic incentives due to the recent RE policy support but suffers due to weak political will for higher RE share. India ranks second last, as all the dimensions were found to be quite weak. Russia was found to be the last, with almost non-existent RE policy environment. These results were further verified by the current overall RE industrial growth factor which were found to be as follows: Germany (74%), Japan (48%), China (38%), USA (34%), South Korea (24%), India (22%), and Russia (2.5%), as calculated in the table 4.8.

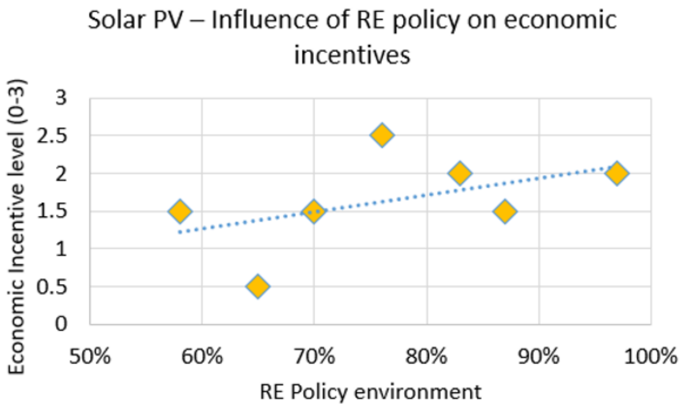
5.4 Error Analysis of the interactions

This section presents a summary of the error analysis, of the interactions discussed in section 4.6, based on the linear fit trend-line analysis using *the least squares* method described by Squires (2001). Equations used for the analysis are listed in the Appendix 4.



Slope	m	0.5908
Intercept	c	0.6117
Trendline eqn.	$y = 0.5908\,x + 0.6117$	
	R^2	0.4916
	S	0.0554
	Δm^2	0.0722
	ΔC^2	0.0065

Fig. 5.4 Influence of political will on RE policy

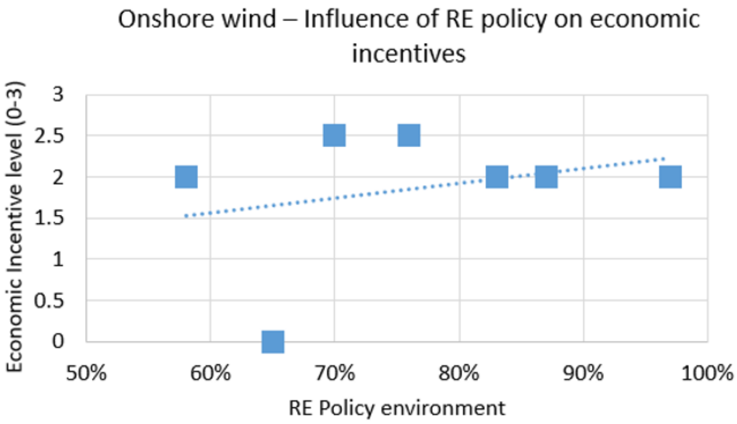


Slope	m	2.2417
Intercept	c	-0.0737
Trendline	$y = 2.2417\,x - 0.0737$	
	R^2	0.2323
	S	1.8095
	Δm^2	3.3211
	ΔC^2	1.9989

Fig. 5.5 Influence of the RE policy on the solar economic incentives

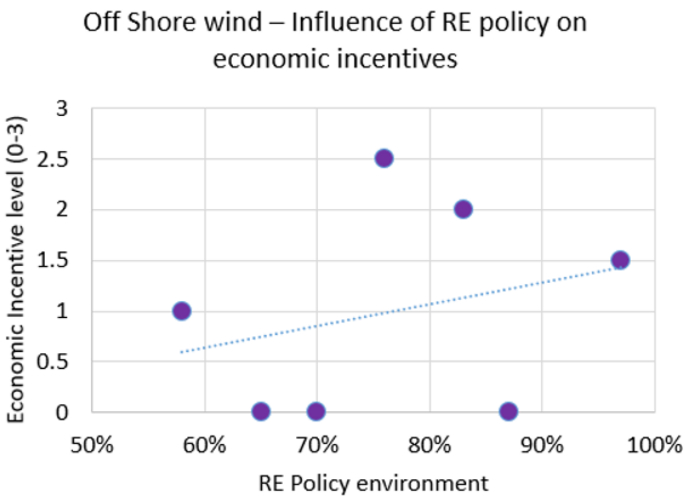
1. Fig 5.9 and fig 5.11, show highest values of R-square, suggesting a strong correlation of the technological preparedness and political will with the RE industry in the concerned countries.

2. Standard errors in slope and intercept are observed to be highest in the fig 5.7, 5.6, and fig 5.5, with the R-square values approaching zero, suggesting a weak correlation between the the RE policy scores and the technology-wise economic incentives created for offshore wind, onshore wind, and solar PV respectively.



Slope	m	1.7960
Intercept	c	0.4819
Trendline	$y = 1.796\,x + 0.4819$	
	R²	0.0807
	S	4.0056
	Δm^2	7.3517
	ΔC^2	4.4249

Fig. 5.6 Influence of the RE policy on the onshore economic incentives

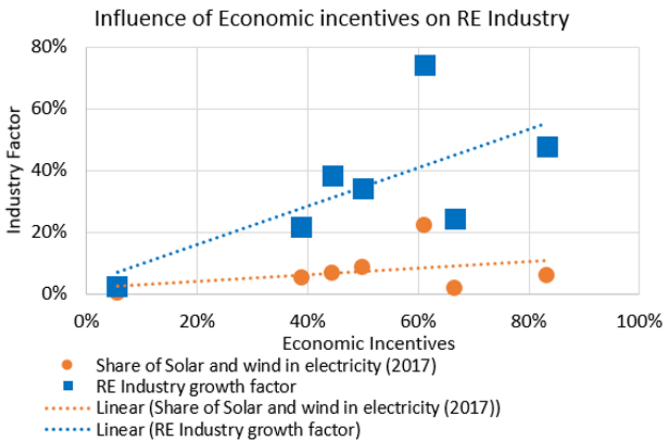


Slope	m	2.1565
Intercept	c	-0.6513
Trendline	$y = 2.1565\,x - 0.6513$	
	R²	0.0780
	S	5.9932
	Δm^2	10.9996
	ΔC^2	6.6205

Fig. 5.7 Influence of the RE policy on the offshore economic incentives

Furthermore, the slope of the trend-line (m = 2.24) in the fig 5.5 reduces to 0.96, if Russia is not included, and hence, reducing the significance of this interaction. Further, although the slope of the trend line in the fig 5.6 shows a positive slope of m = 1.8, the slope turns negative, if Russia is excluded, and hence, suggesting an inverse relationship.

3. Reasonable values of the R-square and low values of S, standard errors in slope and intercept in the fig 5.4, and fig 5.8 suggesting observable to weak correlation in fig 5.10, between the factors.



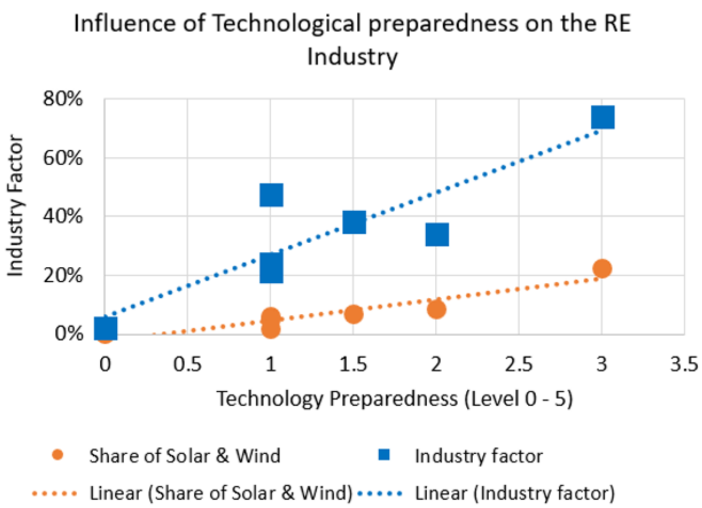
Linear (RE Industry growth factor)

Slope	m	0.6188
Intercept	c	0.0369
Trendline eqn. for Industry Factor	$y = 0.6188\,x + 0.0369$	
	R^2	0.4571
	S	0.1656
	Δm^2	0.0910
	ΔC^2	0.0275

Linear (Share of Solar and wind in electricity (2017)

Slope	m	0.1032
Intercept	c	0.0204
Trendline eqn. for share of solar & wind in electricity	$y = 0.1032\,x + 0.0204$	
	R^2	0.1238
	S	0.0274
	Δm^2	0.0151
	ΔC^2	0.0045

Fig. 5.8 Influence of the economic incentives on the RE industry



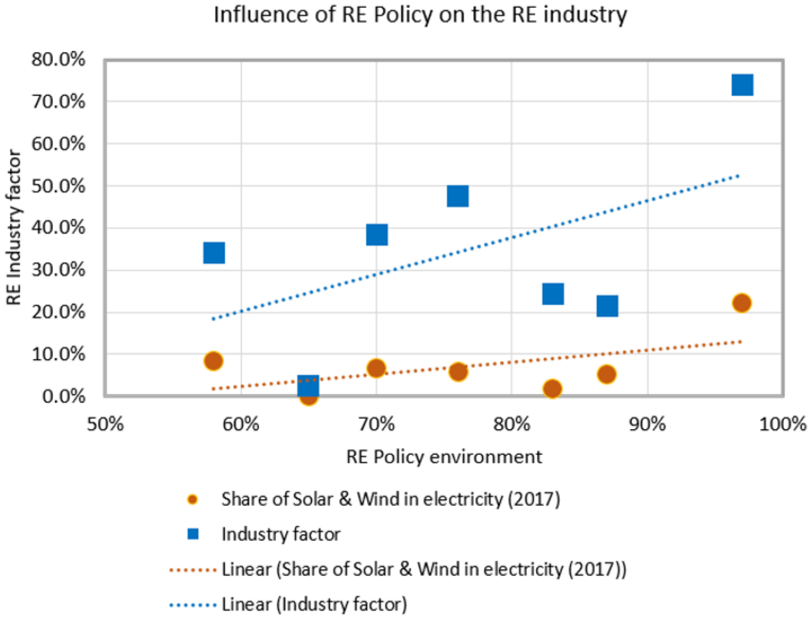
Linear (Industry factor)

Slope	m	0.2111
Intercept	c	0.0587
Trendline	$y = 0.2111\,x + 0.0587$	
	R^2	0.7732
	S	0.0700
	Δm^2	0.0001
	ΔC^2	0.0026

Linear (Share of Solar & Wind)

Slope	m	0.0713
Intercept	c	-0.0248
Trendline	$y = 0.0713\,x - 0.0248$	
	R^2	0.8701
	S	0.0041
	Δm^2	0.0002
	ΔC^2	0.0004

Fig. 5.9 Influence of the technological preparedness on the RE industry



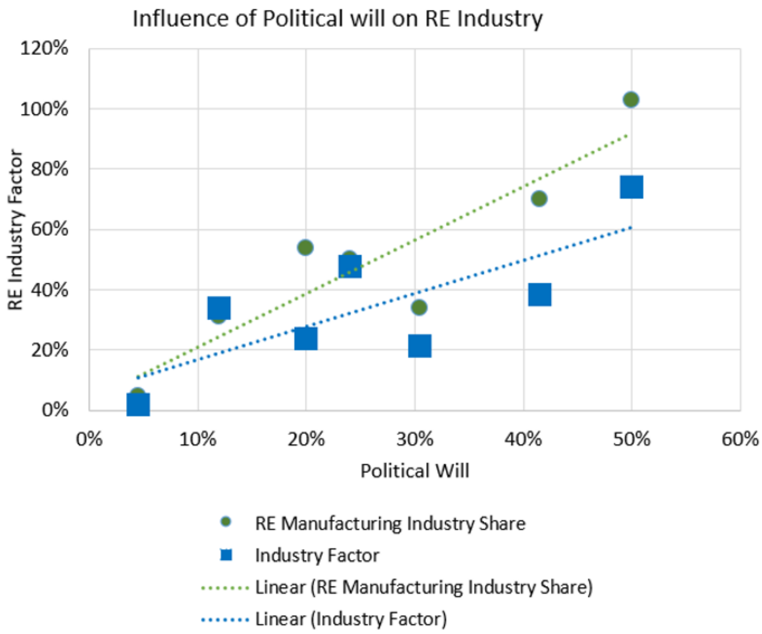
Linear (Industry factor)

Slope	m	0.8726
Intercept	c	-0.3219
Trendline	$y = 0.8726\,x - 0.3219$	
	R^2	0.2719
	S	0.2222
	Δm^2	0.4077
	ΔC^2	0.0324

Linear (Share of Solar & Wind in electricity (2017))

Slope	m	0.2898
Intercept	c	-0.1500
Trendline	$y = 0.2898\,x - 0.1500$	
	R^2	0.2912
	S	0.0223
	Δm^2	0.0409
	ΔC^2	0.0246

Fig. 5.10 Influence of the RE policy on the RE industry



Linear (Industry Factor)

Slope	m	1.1012
Intercept	c	0.0581
Trendline	$y = 1.1012\,x + 0.0581$	
	R^2	0.6026
	S	0.1227
	Δm^2	0.1599
	ΔC^2	0.0144

Linear (RE Manufacturing Industry Share)

Slope	m	1.7712
Intercept	c	0.0329
Trendline	$y = 1.7712\,x + 0.0329$	
	R^2	0.8218
	S	0.1044
	Δm^2	0.1361
	ΔC^2	0.0122

Fig. 5.11 Influence of political will on the RE industry

Chapter 6

Solutions and recommendations to improve the current RE business environment

Now, as the status of the renewable energy business environment in the concerned countries are estimated and analyzed (in chapter 4), limitations of the research are discussed (in section 5.1), results are reflected upon and compared with the existing research, the next step is to provide recommendations to improve the status of RE business environment. Hence, this chapter provides a list of recommendations [1] to improve the business environment for renewable energy in the top 7 emitting countries in the order of the USA, India, Germany, China, Japan, South Korea and Russia, followed by the common recommendations to strengthen the interactions among factors:

1. **The USA:** The United States was found to have insufficient economic incentives, weak technological preparedness, good potential to influence the RE policy environment through political will, and further enhance economic incentives through proper RE policies. Hence, the RE business environment of the United States was not found to be sufficiently conducive, specially due to very weak political will, non-supportive RE policy environment, and lack of sufficient interactions among the RE business environment factors which may improved in the following ways:

    - The country's RE business environment can be significantly improved by adopting a legal and binding renewable energy deployment and consumption plan, in

[1] All policy-level changes suggested in this chapter are recommended to be adopted only after going through an appropriate research process.

line with the IPCC's recommendations, applicable at the federal level, and by implementing a road-map or action plan to achieve these targets.

- Secondly, as the United States does not have a history of incentivizing RE power generation through feed-in policies, however, the country has less opposition for RPS scheme, as 29 states and Washington, D.C., have already implemented the mandatory RPS policy and targets, which have achieved very good success in meeting the annual targets (Barbose, 2017). Hence, the remaining 21 out of 50 states may also follow the same trend. Furthermore, the states with ongoing RPS scheme, may look into setting more ambitious RPS targets.
- From the technological preparedness point of view, the USA would need to improve the interconnection between the transmission grids and provide better transmission capacity. This will promote deployment of RE power generation capacity in locations with better renewable power generation sources, and improved interconnection between transmission grids will improve transmission capacity to high load regions and minimize fluctuations of RE power generation, by integrating RE power generation in a larger geographical area. To achieve this objective of increasing the grid inter-connectivity, transmission capacity, and availability of infrastructure for the development of RE generation sources, a combined effort through planning and timely investments would be required from the federal government, state governments, transmission & distrubution companies, and the potential utility scale RE power generators. This can be achieved by providing infrastructure for commercial development of RE power resources in the form of solar PV and wind parks.
- Since, the existing RE power generators in the United States does not enjoy priority dispatch or preferential RE power generation support, the exiting RE producers may look into incorporating energy storage and increasing the RE power share in the peak load hours, while competing in the wholesale electricity market. Increased energy storage capacity would also help to reduce loading on the existing transmision and distrubution lines, by improved dispatch planning of the generated power.
- State governments in cooperation with the transmission & distribution companies, may develop grid connected pumped-hydro storage capacities, in the states with available hydro resources. Utility scale solar PV and wind power generators would be the major beneficiaries of such projects, hence, they can play a leading role in developing the political support and through participation in investments.

- The independent renewable power generators can benefit from the available net metering scheme and may sell the generated electricity at the wholesale electricity rates. Utility scale RE power generators can specially benefit from the low onshore wind power LCOE in the United States and may easily compete with the conventional electricity generators. However, as discussed above, this would need the required power dispatch infrastructure.
- State governments with willingness to improve RE share may also incorporate other policy such as the priority dispatch, to allow RE generators to act as base load power suppliers, while utilizing the rest conventional power generators for balancing services. This would improve the RE policy environment in these states and also the share of RE in electricity.
- RE equipment manufacturers may look to into increasing their manufacturing and production capacity in the United States, as the current domestic RE equipment manufacturing industry can cater to only 31% of the country's overall new power generation capacity demand, this industry has a lot of scope for development and to drive the RE cost down.
- Industrial and commercial heavy electricity consumers can benefit from the low generation cost of solar PV and wind power (instead of the expensive electricity from the grid), by the direct purchase of RE electricity from RE power generators or by purchasing Renewable Energy Certificate (RECs) in the applicable states, or by in-house RE power generation and hence, promoting the RE power generation and deployment.
- Furthermore, the RE policy environment of USA may be strengthened in the following ways: (a) creating a nation wide legal framework for renewable energy, (b) by implementing fiscal incentives to support RE power generation, (c) by providing scheme for inflation corrected tariff contracts to large scale RE projects, (d) implementing rules for allowing seamless VRE power balancing and exchange, and (e) by implementing nationwide carbon pricing, monitoring and reporting mechanism.

2. **India:** Renewable energy business environment of India is not sufficiently conducive due to weak political will, ineffective policy support, in-sufficient economic incentives, very low technological preparedness, and also weak influence of the political will on RE policy environment, inability of RE policies to generate sufficient economic incentives, and further weak interactions among the factors. Hence, the RE business environment of India may be improved in the following ways:

- Inconsistent political will in India led to a weaker influence of the political will on the RE industry. Although, India has declared a target RE share of 40% by 2030, the Government of India needs to provide a detailed national road-map with annual targets to achieve this long-term target, along with state-level targets and road-maps in line with the national target. This is important to remove inconsistencies, give a clear market signal, and confidence to the investors and stakeholders about the direction and quantum of the future renewable energy industry.
- India need to strenghten the political influence through clear and effective policy design and implementation, by considering the ground market realities (subsidized coal & electricity, high RE LCOE, available manufacturing capacity, technological preparedness for RE integration, sufficiency of the economic incentives of PPAs, project delays etc.). India scores a high RISE score on RE policies, but low on effectiveness on achieving targets, signalling ineffective policy design and implementation. Influence of RE policy on RE industry was found to be very weak in India, suggesting the RE industry is not able to utilize the existing RE policies effectively as the RE policy is not able to meet the needs of the RE industry, and hence, the policies need to be designed and implemented based on the ground realities.
- Economic barrier for RE deployment was found to be quite strong in India and the RE policies were not effective in creating sufficient economic incentives. In India, it is difficult for RE power to compete with the conventional power and achieve grid parity, due to the subsidized coal and electricity. This reduces the economic incentives for solar and wind power, and makes it difficult to rise as a profitable power generation option for independent power producers when compared with the conventional power. Furthermore, subsidized electricity prices does not leave much economic incentives for small distributed RE deployment. One possible solution to the above problem would be to gradually transfer the coal subsidies for RE installations and power generation, to boost the RE industry.
- India has adopted the reverse e-auction process for utility scale RE projects, by replacing the earlier feed-in-tariff scheme. Due to heavy competition, the prices drop to impractical levels and further reducing the economic incentives. To solve this problem, the auction process need to incorporate project based fixed lowest tariff, based on the existing market to safeguard the minimum required economic incentives, to allow the project execution without financial disputes and delays. This can be achieved by the government intervention in the tender processes

through suitable policies. Furthermore, Indian government can re-introduce feed-in-tariffs for small distributed RE power generation.

- Current utility-scale RE projects are part of fixed long-term power purchase agreements (PPAs), however, these existing PPAs need to be respected by the respective state/privately-owned power purchasing and distribution companies to ensure long term economic incentives to RE power generators and to reduce risk on investments.
- Although, priority dispatch is applicable in the country, due to the lack of accurate forecasting and scheduling mechanism, the RE power undergoes heavy curtailment. Hence, Indian government in collaboration with the meteorological department, need to implement high quality solar and wind power forecasting, and scheduling mechanisms to enforce the RE priority dispatch and utilize the current coal fleet for power scheduling and balancing. State governments of India and the utility companies also need to look into employing energy storage capacities and/or energy conversion options for excess RE generated power.
- Indian government may incentivize domestic production of wind turbines and solar PV (and balance of plant components), through suitable tax and investment benefits, while promoting the scaling up of wind turbine capacities to bring the RE LCOE down.

3. **Germany:** Although, Germany has a well balanced and good RE business environment, with strong RE policy support and good economic incentives, and strong interaction among the supporting factors, the country's RE business environment may be improved in the following ways:

    - As Germany has a strong influence of the political will on the RE policies and eventual influence on the RE industry, adoption of a more ambitious RES-E targets may further boost the RE business environment in the country.
    - However, the major challenge which the country is facing is the technological preparedness for higher share of intermittent RE in electricity. The existing RE power generators can help in minimizing uncontrolled power injection to the grid by incorporating energy storage facilities. This will allow the RE industry to increase the RE deployment and improve the share of RE in electricity.
    - However, as the RE power generators enjoy priority dispatch, they do not have short-term direct financial incentives for investing in storage capacities, and the responsibility for enhancing energy storage capacity passes on to the power

transmission service providers. To resolve this, the German government in cooperation with transmission and distribution companies, and utility scale RE power generators, may look into increasing the grid connected energy storage. This may be achieved by exploring pumped hydro resources and new energy storage technologies.

- The German government in cooperation with research institutes, may look into improving the weather forecasting, and implement incremental stricter norms for the day-ahead RE power generation estimation, and allowing efficient power balancing.
- Independent RE power producers can benefit from the low solar PV and onshore wind power LCOE in the country and compete in the wholesale electricity market. Commercial and domestic electricity consumers may also benefit from the distributed RE power generation or by direct purchase of RE electricity.
- Furthermore, Germany in cooperation with the neighbouring countries may improve national and international grid inter-connection capacities to improve exchange of intermittent excess RE power.
- To further maximize the deployment and integration of solar and wind power to the existing power system, other energy dependent sectors may develop provisions for energy conversion capacities or increased integration for direct consumption RE electricity.

4. **China:** The overall RE business environment in China was found to be moderate and balanced. Although, China does not seem to have a good RISE RE policy score, the policy design and implementation were found to be effective in achieving the national targets. Good interactions were observed among the various factors, however, there is a lot of scope for improvement in China's RE business environment, which may be achieved in the following ways:

   - The first step would be to adopt a more ambitious RE target for the country's future energy mix, for example the Chinese government may adopt the targets as proposed by the China's renewable energy outlook by CNREC (2018) as 72% of RES-E share by 2035 and around 88% by 2050. Due to the presence of a strong political influence, this has a strong potential to drive the country's RE business environment.
   - RE power generation industry in China is getting recent political support, and to obtain a considerable development in this industry, a long term and consistent

political support would be required while increasing the annual share of RE deployment (currently low share in new RE power deployment 38%).

- To improve China's RE business environment, it would be required to strengthen the country's technological preparedness for high share integration of intermittent renewable energy. As already discussed in the results section, in addition to the market based solutions, China needs to improve transmission capacity from RE power generation centres (northern and northwestern China) to the major load centres (central and eastern China), and further reduce renewable energy curtailment. Lack of sufficient transmission capacity is impacting the further deployment of wind power. Furthermore, China needs to improve adaptation to flexible power generation using the thermal power plant fleet with minimum dispatch guarantees.
- Although, China's solar PV LCOE is one of the lowest among other countries, still it is expensive than domestic conventional power. Wind power is also towards the higher end of fossil LCOE. This reduces the the economic incentives for solar and wind power. To improve this, China's domestic RE industry need further technological and process innovation to bring the overall project cost down.
- China's wind turbine manufacturing sector has a good opportunity to increase the domestic manufacturing capacity to supply the domestic new wind power deployment demand created by the feed-in-tariff scheme.
- The government of China may extend feed-in-tariff support to offshore wind power to boost the industry and to introduce deployment in the eastern coast, near to the major demand centres.
- To improve the RE policy environment as of 2017, China may take the following steps: (a) making the information of future planned schedule of RE project auctions public, inclusion of pre-qualification for bidders' selection, indexing tariffs for inflation or an international currency, (b) providing security to small producers through fixed/inflation corrected tariff contracts, (c) by increasing the counterparty risk by improving creditworthiness of RE projects, by making the financial statements of public utility generators and retail seller public, (d) improving grid integration of VRE electricity through real time dispatch operations, implementing rules for allowing seamless VRE power balancing and exchange, and (e) improving the planning of RE expansion, by including investment as a part of RE target plan, mechanisms for reporting the progress and adjusting

the deployment plan, by conducting geo-spatial planning for RE commercial development.

5. **Japan:** Japan has a good influence of political will on RE policy environment, and RE policies were successful in creating good economic incentives for solar PV, onshore wind and offshore wind power, and achieving the national targets. These good economic incentives increased the RE share in new power capacity deployment to very good level, but low target RES-E share and insufficient technological preparedness are the main challenges in improving the country's RE business environment and limiting the faster growth. These may be improved in the following ways:

    - The government of Japan may adopt a more ambitious RES-E target share which is currently 22-24% by 2030. Due to the presence of a strong political influence on the other factors and good interactions among other factors, this would drive the overall RE business environment of the country.
    - High electricity charges due to the applicable cess in per unit of consumed electricity, and very good feed-in-tariff levels available for all the three new RE technologies, the economic incentives for these technologies are very good and LCOE of the solar, on shore and offshore have achieved grid parity. Industrial, commercial, and domestic consumers may utilize the good economic incentives for in-house production of RE electricity.
    - Although, Japan plans to improve the east-west grid inter-connectivity to 2.1 GW by FY2020, eastern network has a generation capacity of 130 GW and the western network around 160 GW, and hence, the inter-connectivity between these grid networks are insufficient and need accelerated inter-connectivity expansion for exchange of power and load sharing between different region. This would improve the technological preparedness of China for high share integration of RE.
    - Hokkaido and Tohoku regions, with majority of wind resources (in the northern areas) need to improve transmission capacity to the load centres.
    - Being an island country, the electricity grid of Japan is secluded from the neighboring countries, this creates challenges for integrating power generation and load in a large geographical area and further severing the problem due to intermittency of the generated solar and wind power. To resolve this, Japan may look into integrating grid connected energy storage options and improve the energy security, which is a major concern for the country.

- Even with a very good RE policies and economic incentives, Japan's wind power deployment is very low due to very low wind power target share (1.7% by 2030), hence, the country may look into increasing the wind power target share, and increase wind power contribution. Due to presence of coastline all through out the country, offshore wind power may provide major energy security to Japan.
- Further to improve the RE policy environment, Japan may introduce the following changes: (a) clear grid codes for variable RE integration, (b) clear rules for cost allocation of network charges (transmission & distribution system), (c) introduce provisions for renewable power to provide ancillary services and power balancing, (d) introduce provisions for real time dispatch operations, (f) allow priority grid access and dispatch of RE power, and (g) introduce provisions to compensate for delay in providing power dispatch infrastructure.

6. **South Korea:** South Korea's RE business environments is quite weak, mainly because of very weak political support for higher share of renewable energy, leading to RE policies which can only support the national targets. Due to policy loopholes and very weak technological preparedness for integrating higher RE share, the RE industry is facing major challenges in South Korea. To overcome these challenges and to improve the country's RE business environment, the following steps may be taken:

    - Although, South Korea has a good influence of political will on RE policy environment, to boost the RE business environment, the country needs a more ambitious RE target than the existing 10.5% overall RES-E share by 2022 and 20% by 2030. Due to weak economic incentives for solar and wind power, the only driving force for creating a market for solar and wind power are the mandatory RPS targets. Hence, South Korea needs to increase the market size by adopting higher annual RPS targets. The country also needs a consistent and long term political support to increase the share of solar and wind power in electricity from the 2017 level of 1.9%.
    - Due to costly domestic electricity, and solar and onshore wind power being competitive with the domestic electricity prices, the RE electricity may supply the demand. However, to enable this the government need to create provisions for direct purchase of electricity from sources other than the respective utility.
    - Although South Korea promotes self consumption of the generated RE power, net-metering at the retail electricity rate may increase distributed RE power generation.

- To improve the technological preparedness and promote wind power deployment, South Korea may identify and allocate major wind resource areas for commercial development with additional power transmission capacity to the areas like the uninhabited mountainous areas in the east coast, southeastern coast, and Jeju island. This would reduce the major environmental clearance delay and delays in delivering the required infrastructure for power dispatch.
- As sufficient land is not available in the inhabited areas for large utility scale solar PV, South Korea may look into developing large scale water based solar parks close to the main demand centres.
- Further, to provide clean electricity to 500 out of 3000 islands inhabited islands, which are currently dependent on diesel generated electricity, the South Korean government may provide special relaxation (for example subsidy) and/or provisions like feed-in-tariff for promoting distributed RE power generation and improving energy security.
- Further to improve the RE policy environment South Korea may adopt the following improvements: (a) provide provisions for renewable energy projects to participate in ancillary services and power balancing, (b) integrated high quality forecasting for RE power dispatch, (c) provide provisions to compensate for delay in providing power dispatch infrastructure, and (d) provide provisions for compensation due to VRE power curtailment.

7. **Russia:** Russia's RE business environment was found to be exceptionally poor for the development of renewable energy. The primary driving factors such as the political will, economic incentives, and technological preparedness were found to be very weak to drive any influence on other factors of the RE business environment, leading to almost absence of interaction among these factors and RE industry overall growth factor was found to be only 2.5%. Hence, to improve the RE business environment in Russia, the following steps may be taken:

   - Due to availability of abundant cheap fossil resources and strong lobbying by the conventional fossil based industry, it is quite challenging for Russia to develop strong political support for the renewable energy. However, this can be improved if the influence of the RE industry on the Russian government may be improved. This can be achieved by showcasing potential job opportunities created by the RE deployment, power generation, and RE manufacturing industry. Further, more job opportunities and an increase in energy security has the potential to drive the economic growth of a country, which may induce political support for renewable energy.

- Although Russia has a very small RES-E target of 4.5% by 2024, the country is not able to achieve the target. To improve this, Russia (Russian government through Administrator of the Trading System (ATS) (Smeets, 2017)) may ensure timely release of solar and wind power project tenders, and ensure timely completion of projects. Further, Russia may allow carry-over of annual target RE deployment (through required policy changes), which is currently not applicable. Achieving the existing targets may allow the government to adopt a more ambitious renewable energy target.
- Russia may look into developing domestic solar PV and wind turbine manufacturing capacities to cater to the global market, reduce the manufacturing cost (by learning by doing) and RE project LCOE, improve the economic competitiveness of solar and wind power, and drive the national RE business environment. To enable this the Russian government may incentivize and support domestic RE equipment manufacturing capacity expansion.
- Russia (Russian government through required policy changes) may reduce the local content restriction (which is currently 70% for solar projects and 65% for wind power (Smeets, 2017)) in the RE projects to allow the manufacturing/deployment industry to keep up with the requirements and allowing suitable time frame to achieve the required development and reducing the total RE project capital investments.
- To improve the economic incentives for grid connected renewable energy generators through CRESS scheme, Russia may reduce the lower capacity limit of 5 MW and introduce inflation corrected compensation to the existing 12% ROI (return on investment) to reduce the investment risk. Furthermore, the government of Russia may increase the ROI, to improve the economic incentives for solar and wind power.
- To allow the growth of decentralized retail RE power generation, Russian government may remove the upper total maximum capacity limit of 1 GW, and introduce fixed (inflation corrected) tariff rates for pre-defined long term fixed period. This would provide the energy security and cheaper green electricity to the dispersed, distributed population of Russia. To gradually replace the diesel based generation in these areas, integrated solar/wind power generation model with the existing diesel power generators may be promoted.

- To improve the technological preparedness for RE deployment, Russian government in collaboration with the meteorological department, may provide high quality solar irradiance and wind resource database.
- Due to extremely distributed geography of Russia, it is a huge challenge to connect all the inhabited regions with one national grid, hence, Russia may focus on strengthening the distributed electricity grid and allowing international power exchange with the neighbouring countries by expanding inter-national grid connectivity, to improve the technological preparedness for the deployment of renewable energy. This may be achieved with the international collaboration with the neighboring countries.
- Further to improve the RE policy environment, Russia may incorporate the following changes : (a) implementing a RE energy target through transparent methodology, making investment a part of renewable expansion plan, by making the resource map of solar/wind power available in the country, in line with the best practices around the world, (b) by providing required incentives and support, and safeguarding RE projects by making provision of compensating for delayed power dispatch infrastructure, and VRE power curtailment, (c) improving the auctions by including pre-qualification for bidders, and tracking auctions/bids for delay, by creating provisions for grid connectivity to small producers, (d) by improving network connection through grid codes for VRE electricity, by carrying out regular grid flexibility studies, and by integrating high quality RE forecasting, and (e) by implementing mechanisms for carbon pricing.

8. The following steps would be recommended to strengthen the interactions among factors:

    - *The influence of the political will on the RE industry* may be improved by enhancing the clarity and transparency of the government plans and vision for the future energy mix, in terms of concrete action plans, and by improving the accessibility to these information to the RE industry which is missing in China, India, and Russia, but observed in Germany and South Korea. The proven track records by the government in terms of achieving the previous RE targets garner the confidence of the RE industry in the country's government, which is missing in Russia. Further, the government's experience in designing and effective implementation of RE policy to steer the RE business environment is vital to strengthen this interaction as observed in Germany and recently in Japan and South Korea, but missing in India and Russia.

- *The influence of the technological preparedness on the RE industry* is already substantial due to the inherent technological dependence of the high share deployment and integration of variable renewable energy. However, the coordination between the interaction of the technological preparedness and the political will on the RE industry may be improved by the integrated planning of the target RE deployment and the technological preparedness of the country as observed in Germany.
- *The influence of the economic incentives on the RE industry* is the most challenging interaction to be improved due to the presence of the market failures in terms of subsidized fossil electricity, positive externalities of the RE not included in the transaction charges, involvement of public good (level of atmospheric GHG), high barriers for the adoption and integration of new power generation technologies, lobbying by the conventional fossil-based power industry. All these challenges need to be resolved to strengthen this interaction and allowing the market forces and economic incentives to drive the RE industry. A little improvement may be achieved by providing a level playing field to the RE by subsidizing the RE investment cost, removing subsidies to the fossil electricity or implementation of the emission cap and trade system. Schemes like guaranteed grid connectivity and priority dispatch help to overcome the initial deployment and integration challenges (as observed in Germany), along with timely payment of the electricity tariff and improving accessibility to the economic incentives reduces the risk on investment with improved chances of economic incentives reaching the RE power generators.
- *The influence of the RE policy on the RE industry* may be strengthened by designing policies which are clear and consistent, which may give clear market signals. The policies need to be designed by considering the ground realities of the national market, considering the requirements and challenges faced b the RE industry, by following appropriate research process to assess the situation, possible approaches, and their consequences, and not by following the set of policies (best practices) adopted by other countries without appropriate research. The policies may be designed iteratively based on the results and their effectiveness in terms of obtaining the desired policy targets. RISE indicators are incapable of answering the above questions.
- *Influence of RE policy on the economic incentives* is the weakest interaction observed in this research. This may be improved by designing technology-specific RE policies and economic incentives based on the concurrent level of the

technological development in a country, which may provide right incentives to overcome the investment cost and may be able to compete with the subsidized or conventional power generation sources. Above suggestions are compiled from the steps taken by South Korea and Japan.

- *Influence of the political will on the RE policy* may be improved by strengthening the influence of the RE industry on a country's government. The RE industry may be provided with appropriate channel to communicate the concurrent challenges, policy requirements and thereby improving the accountability of the government to timely design and implement suitable RE policies to achieve the desired renewable energy targets. This recommendation and other possible solutions to improve this interaction are beyond the scope of this research.
- Influence of the RE industry on the political will would be strengthened with the increasing share of RE industry as compared to the conventional power industry, with the increasing role and power to influence the political decisions and future energy mix. Positive feedback from the RE industry in terms of providing jobs and improving the economic status of a country would also boost this interaction.
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Chapter 7

Conclusion & Recommendations

The purpose of this research was to understand the business environment for the large scale deployment and consumption of solar PV and wind power, in the top-7 emitting countries, which are namely China, the United States of America, India, Russia, Japan, Germany, and South Korea. To achieve this Renewable Energy - Business Environment framework was designed by incorporating pertinent factors like the political will to adopt renewable energy, renewable energy (RE) policy environment, economic incentives for RE, technological preparedness for large-share integration of variable renewable electricity, renewable energy industrial growth, interactions among these factors, and their combined influence on the RE business environment.

Based on the results obtained and analysis done on the results, this chapter presents the conclusion of this thesis, by answering the main research question:

"How good is the business environment for renewable energy in the top-7 emitting countries?"

To answer the above mentioned research question, this section summarizes the business environment of each country in the order of China, USA, India, Russia, Japan, Germany, and South Korea, and additional insights obtained from the research, and then presents the final conclusion of this thesis, followed by the recommendations for future research in section 7.1.

- **China:** Although China has the largest renewable energy industry in the world when compared with the domestic power industry, the business environment of renewable energy in China was found to be of moderate level. Out of the countries considered for research, China ranked third with moderate growth in the RE industry, with a RE industry growth factor score of 38%.

China had moderate support from all the considered factors political will (42%), RE policy environment (70%), economic incentives (44%), and technological preparedness (30%). China's is required to adopt an ambitious RE target, provide consistent and long term political support, design more conducive RE policies, which can boost the economic incentives for renewable energy and further enhance the share of RE in new capacity installations (38%), and eventually increase the share of solar and wind power in electricity (6.8%). Besides, China needs to improve the technological preparedness by reducing the renewable power curtailment, and by providing sufficient dispatch capacity to the wind power generation centres. China's RE manufacturing industry was found to be in a moderately good state with a share of 70%. The influence of RE policy was observed to be good on the RE industry and economic incentives (although with moderately low economic incentives) with the RE industry. The influence of the RE policy on the creation of economic incentives is quite weak in China (especially for offshore wind power), which needs further strengthening to boost the growth of RE.

- **The USA:** The RE business environment of the United States was found to be at a moderately low level. The USA ranked fourth in the RE industry growth factor with a score of 34%.

  The USA's political will (12%) was found to be quite weak, resulting in an insufficient RE policy environment (58%). However, technological development and high electricity prices increased the economic incentives for RE (50%), which led to an increased share of RE in new capacity installations (63%). However, the solar and wind power generation industry (6.8%) and RE manufacturing industry (31%), need better market signals in the form of RE targets and deployment plans at the federal level, incentives for deployment and generation of RE. Hence, the RE business environment of the United States was found to be partially supported by the applicable mandatory RPS scheme (in 29 out of 50 states and Washington, D.C.), economic incentives due to expensive electricity prices, and by the low technological cost (onshore wind power). The major interactions among the above factors required to create a conducive RE business environment were found to very weak, for example, weak influence of RE policy on the creation of economic incentives, insufficient economic incentives leading to weak influence on the RE industry, and insufficient technological preparedness leading to insufficient support to the RE deployment and integration.

- **India:** The RE business environment in India was found to be at a low level. India ranked sixth in the RE industry growth factor, with a score of 21.5%.

Although India scored 31% in political will, the perceived political will by the industry was found to be around 21%, due to inherent inconsistencies. It was further reflected in the designed RE policy environment which although scored 87%, but when adjusted to ground conditions, it dropped down to 22%. Due to insufficient RE policy support, and subsidized fossil electricity, economic incentives were found to be moderately low (39%), which led to slow growth in all the segments of the RE industry, resulting in a low score of 21.5%. The influence of the RE policy environment on the creation of economic incentives was found to be weak and ranged from zero incentives (for offshore wind) to moderate incentives (for onshore power, and the average for solar PV). Weak economic incentives led to a weak influence on the growth of the RE industry. Weak technological preparedness and RE policy environment could not provide sufficient influence and support to the RE industry.

- **Russia:** The RE business environment in Russia was found to be in an extremely poor level. Russia ranked seventh in the RE industry growth factor, with a score of 2.5%.

  The factors which support RE business environment in other countries were found to be close to non-existent in Russia with the political will score of 5%, RE policy environment (65%) (adjusted 0.3%), economic incentives (6%) and technological preparedness (0%). The primary driving factors like the political will, economic incentives, and technological preparedness were found to be very weak (to non-existent) to drive any influence on the other factors of the RE business environment, leading to almost the absence of interactions among these factors and eventually negligible support to the renewable energy industry.

- **Japan:** The RE business environment in Japan was found to be at a moderate level. Japan ranked second in the RE industry growth factor, with a score of 48%.

  Although with the moderate political will of 24%, Japan was successful in creating a moderately good RE policy environment (76%), due to increased focus in R&D, low technology cost, and high electricity prices. As a result, Japan was successful in creating a consistent and good economic incentive (83%), which sharply boosted the RE deployment industry share (87%) and RE manufacturing industry (50%). However, Japan would need long term RE support to increase the share of solar and wind power in electricity from the current level of 5.9%. Japan has a good influence of the political will on the RE policy environment, and RE policies were successful in creating good economic incentives for solar PV, onshore wind, and offshore wind power, and achieving the national targets. The economic incentives increased the RE share in new power capacity deployment to a good level, but low target RES-E share and insufficient technological preparedness for integrating VRE were found to be the main challenges in improving the country's RE business environment.

- **Germany:** The RE business environment in Germany was found to be at a good level. Germany ranked first in the RE industry growth factor, with a score of 74%.

  Germany, with a political will of 50%, was successful in creating a very conducive RE policy environment (97%). Even after recent policy changes, Germany's economic incentives remained at 61%. The technological preparedness of the country is 60% supporting an increased share of RE. All these led to the robust growth of the RE industry with the RE deployment industry, capturing 87% market share, and the manufacturing industry evolving to be a major global supplier. Overall, Germany was successful in developing a conducive RE business environment, due to strong support from all the factors, and presence of good interactions among these factors, for example, good influence of the political will on the overall RE industry along with the RE manufacturing industry, excellent policy support helping the RE industry, and technological preparedness supporting the RE industry. Hence, Germany's RE business environment can further support the growth of RE industry (solar PV and onshore wind power), even without generation based support schemes (like feed-in-tariff), as the support from all the factors are quite strong, and interactions among these factors were found to be strong enough to drive the RE business environment. Offshore wind power, on the other hand, has not yet reached a level to overcome market challenges on its own, but still needs a further political and policy support, right economic incentives, and improved technological preparedness.

- **South Korea:** The RE business environment in South Korea was found to be at a low level. South Korea ranked fifth in the RE industry growth factor, with a score of 24.3%.

  RE business environment of South Korea is supported by the moderately good economic incentives (67%), a strong focus in R&D, technology development, and high electricity prices. However, South Korea was found to be an exceptional country, which is driving the development of all the solar PV, onshore and offshore wind power technologies, due to technology-specific RPS policy design. RE business environment of South Korea suffered from the low political will or the target share of RE in the energy mix, making the domestic RE industry very small, which led to low RE deployment share (17%), and a meagre share of solar and wind in electricity (1.9%). Due to improved technological experience, South Korea's manufacturing observed moderately good growth (54%). The influence of the political will on RE policy was found to be healthy, and RE policies were also successful in creating moderately good economic incentives. However, the economic incentives, RE policy, and technological preparedness were not able to successfully influence the RE industry, primarily due to the weak political will, which curtailed the renewable energy market.

Conclusion: Hence, the results validate the initial expectation and assumption, that in order to create a conducive renewable energy business environment, it is crucial to strengthen the factors of the RE business environment, and these factors must be able to influence (interact with) each other positively, and such healthy interactions create a conducive business environment for the growth of renewable energy, as observed in Germany. On the other hand, factors acting in isolation, weak influences and interactions among these factors add to the challenges in the growth of renewable energy, making RE diffusion quite challenging in the existing dominant fossil-powered electricity sector, as observed in Russia.

Technological preparedness and the political will were found to have the strongest influence on the renewable energy (RE) industry. Influence of the economic incentives on the overall growth of the RE industry is observed to be of comparatively secondary importance. Influence of the renewable energy policy on the RE industry is found to be quite weak, with the weakest correlation observed in the economic incentives created by the renewable energy policy. Secondary influence of the economic incentives on the growth of the RE industry is due to the inherent market failures in the power industry and the insufficiency of the market forces to drive the growth of the RE industry. The weak influence of the RE policy on economic incentives is due to the role played by the electricity prices and the fossil electricity cost in the country. Furthermore, the RISE indicators used to map the RE policy environment is found to be inefficient in reflecting the ground realities of the suitability of the RE policy, the effectiveness of RE policy in achieving the desired renewable energy deployment, and the capacity to measure the economic incentives for renewable energy.

Hence, the national political will with the available technological preparedness was primarily responsible for driving the RE business environment in Germany, China, India, Japan, and South Korea. In the absence of the national political will, the state political support in terms of the mandatory state RPS targets with the economic incentives created due to expensive electricity prices and fossil electricity drive the RE business environment in the United States. Almost absence of the political will and the lack of technological preparedness failed to create the RE business environment in Russia, which is further exacerbated by the availability of abundant and cheap fossil fuel and subsidized electricity.

The result suggested that Germany has the best RE business environment with well-balanced growth in all the dimensions. Japan comes next with good economic incentives, but the political will of Japan for high RE share need further strengthening. China was found to have the next best RE business environment, with a comparatively weaker technological preparedness which is restricting the increased share of RE in electricity. The United States comes next with good economic incentives but very weak political will and RE policy support. South Korea, have created reasonably good economic incentives due to the recent RE policy support but suffers due the to weak political will for higher RE share. India ranks second last, as all the dimensions were found to be quite weak. Russia was found to be the last, with almost non-existent RE policy environment.

To conclude, the research fulfils the purpose by providing an overview and a broad understanding of the renewable energy business environment in the top-7 countries responsible for the highest GHG emissions. Although, the research revealed limitations in the methodology, factor selection, interactions, comprehensiveness and depth of the framework; concurrence with the observed growth in the RE industry validates the findings. Furthermore, in addition to contributing knowledge about the current status of the renewable energy business environment in these countries, which are continuously changing and evolving, especially in the recent years, this research contributed by developing a framework, which can map the RE business environment of a country in an absolute scale, and which may be further extended to a more extensive set of countries or for in-depth study any country of interest. Hence, this research provides an appropriate starting point and lays a basic framework to portray and further explore into the better understanding of the business environment of renewable energy to help the RE industry to identify the available opportunities, help the policymakers and stakeholders to take the required steps to improve the RE business environment.

7.1 Recommendations for future research

This research revealed various limitations, which were unavoidable due to the time limitations and also due to the complexity involved. However, the limitations opened multiple avenues and possibilities for improvement in future research. Based on the limitations observed, and insights gained from this research, this chapter presents a compilation of recommendations for future research:

- *Inclusion of a larger set of countries:* First of all, the developed framework to map the renewable energy business environment may be extended to a larger set of countries while dividing them into categories based on (a) the level of economic development, and (b) trend in annual electricity demand. Such research would give a fair comparison of efforts made by countries in the category of developed economies or developing economies to create a conducive renewable energy environment. Furthermore, the analysis considering the trend in electricity demand would reveal whether the new renewable energy deployment is due to the additional power demand, or the RE business environment is strong enough to replace the existing conventional power.

- *Time dependent analysis:* It would be quite interesting to see the time variations in the RE business environment of countries. Such a time-dependent analysis would give insights on the steps taken by various countries to strengthen the different factors and the interactions between them, and how the different actions led to either strengthening or weakening of the RE business environment. Such a detailed analysis is possible by considering each country separately and studying the developments over time in detail.

- *Statistical analysis for measuring the strength of interactions among factors:* As it was observed that the strength of interactions among factors varied from one country to the other, statistical tools may be implemented to quantify, test, and measure the strength of these interactions which would help to create a more accurate representation (by assigning weights to interactions) of the RE business environment of a country.

- *Improving comprehensiveness of factors:*

  Political will: Inclusion of historical national annual budget allocations (example for R&D, product introduction, and deployment) and/or allocated budget for future investments, may further strengthen the comprehensiveness and quantification of political will, as this would provide information on a country's willingness to spend to achieve the renewable energy targets.

  RE policy and regulatory framework environment: This factor may be improved by incorporating correction factor to the RISE indicators to include the ground realities of a country, efficiency in policy design and implementation, and their effectiveness in meeting the national targets.

  Economic incentives: This factor may be improved by incorporating the effects of policy mechanism and instruments which influence the investment cost of renewable energy projects in the form of subsidy programs (for residential, building, government offices, hybrid-installations etc.), capital subsidies, tax credits on investments, income tax credits, and other economic benefits from green certificates etc. Economic incentives due to the presence of these above-mentioned policies also play an important role in deciding the economic competitiveness of solar and wind power projects, their profitability, and creating a suitable renewable energy business environment, and hence, can be included for a more comprehensive analysis.

  Technological preparedness: This factor may be improved by (a) improving one-to-one correlation of the technological hierarchy level with the range of renewable electricity share a country's existing electric system can handle, (b) the framework may be improved with more details, so that it may be used to suggest direct solutions for improvement, and (c) level of technological development (of solar PV and wind power technology) may be incorporated for countries where the technology is in market introduction stage (or initial stages of introduction or deployment) or has not yet reached that level.

Industrial growth factor: This factor may be improved by incorporating the availability of skilled labor in the country.

- *Developing country-specific comprehensive framework:* To include the country-specific factors which may be very important for a country but not for others, for example, abundant availability of cheap domestic fossil fuels like in Russia, lack of availability of land in South Korea, or lack of natural resources, extremely weak or degrading socioeconomic status, presence of natural or social threats, etc., country-specific comprehensive RE business framework may be developed.
- *Adaptation to mathematical model and computer algorithm:* After developing country-wise RE business framework models which are both comprehensive, and capable of including the in-depth details and weighted interactions, the framework may be adapted to mathematical model and finally to computer algorithm, which may be used to estimate the variations the RE business environment, with changes in elements for example inclusion/exclusion of specific RE policy, RE tariff rates, electricity prices, tax rebates etc.

Hence, this research along with the field of renewable energy business environment offers a range of possibilities for future research, which may contribute towards a better understanding, improved solutions, and may eventually accelerate the energy transition.

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Appendix A

Electricity generation costs and prices

Table A.1 Conventional electricity cost and price table (in USD) (Data Source: refer text in section 4.3)

Country	Domestic Electricity (min)	Domestic Electricity (max)	Commercial (min)	Commercial (max)	Industrial (min)	Industrial (max)	Fossil Power (min)	Fossil power (max)
China	0.08	0.08	0.12	0.12	0.09	0.09	0.036	0.065
USA	0.13	0.39	0.11	0.27	0.07	0.27	0.0435	0.191
Japan	0.22	0.27	0.18	0.19	0.17	0.18	0.0435	0.191
Germany	0.32	0.32	0.15	0.18	0.05	0.05	0.04	0.15
India	0.04	0.11	0.061	0.097	0.064	0.097	0.029	0.084
Russia	0.03	0.042	0.07	0.0650	0.07	0.07	0.04	0.05
South Korea	0.075	0.23	0.043	0.16	0.042	0.16	0.0435	0.191

Table A.2 Renewable electricity cost and price table (in USD) (Data Source: refer text in section 4.3)

Country	LCOE Solar PV	LCOE Onshore	LCOE Offshore	FIT Solar (min)	FIT Solar (max)	FIT Onshore (min)	FIT Onshore (max)	FIT Off-shore
China	0.095	0.06	0.15	0.094	0.123	0.06	0.08	-
USA	0.13	0.05	0.24	-	-	-	-	-
Japan	0.166	0.06	0.15	0.161	0.232	0.169	0.169	0.321
Germany	0.144	0.053-0.096	0.15	-	-	-	-	-
India	0.09	0.07	0.15	-	-	-	-	-
Russia	0.5	0.25	0.285	0.456	0.1026	0.171	-	-
South Korea	0.09	0.06	0.15	-	-	-	-	-

Appendix B

Renewable Energy Policy and Framework scores

Table B.1 RE Policy Environment historical scores (Source: World Bank (n.d.))

Country	2011	2012	2013	2014	2015	2016	2017
China	34%	34%	35%	45%	63%	65%	70%
USA	53%	53%	54%	54%	57%	58%	58%
Japan	41%	49%	55%	62%	65%	76%	76%
Germany	71%	78%	83%	86%	90%	95%	97%
India	55%	67%	67%	78%	79%	84%	87%
Russia	35%	35%	48%	48%	57%	60%	65%
South Korea	46%	46%	44%	52%	63%	83%	83%

Appendix C

Adjusted RE Policy environment calculations

Adjusted RE Policy environment of a country would be calculated as per the formula below:

$$\text{Adjusted RE Environment} = \text{Political Will} \times \text{Policy Effectiveness} \tag{C.1}$$

Where,

$$\text{Policy Effectiveness} = \text{RE Target achieved} \div \text{National RE targets} \tag{C.2}$$

Table C.1 Policy effectiveness calculation

Country	RE Progress Planned	Progress achieved	Policy effectiveness	Political Will	Adjusted RE Policy Env.	Reference
China	105 GW solar, 210 GW wind (by 2020)	130 GW solar (2017), 188 GW wind (2017)	101%	41.5%	42%	(REN21, 2018), (International Energy Agency, 2018*b*)
USA	142TWh RES-E in 2017 through RPS	131 TWh	92%	12%	11%	(Barbose, 2018)
India	175 GW by 2022 (calculated interim target 105.25 GW by 2018)	74.8 GW by 2018	71.05%	30.5%	22%	(Government of India, 2019)
Russia	2.50% RES-E share by 2015	0.19% RES-E share by 2015	7.60%	4.5%	0.3%	(Ministry of Energy of the Russian Federation, 2010)
Japan	53 GW solar PV and 10 GW wind by 2030	49.5 GW Solar and 3.40 GW wind by 2017	170% (extrapolated based on current rate)	24%	41%	(International Energy Agency, 2018*a*), (IEA, 2017*b*)
Germany	Solar (2.5GWp/year), onshore Wind (2.8GW/year), offshore (6.5 GW by 2020)	Solar 1.7 GW (2017), Wind 6.76 GW (2017), offshore 5.41 GW by 2017	100%	50%	50%	(IEA, 2017*b*), (REN21, 2018)
South Korea	15.1 GW by 2017	15.8 GW by 2017	104%	20%	21%	(IEA, 2019)

This section presents the comparative retrospective policy analysis termed as the Policy effectiveness in the concerned countries based on the results observed in the terms of meeting the national renewable energy targets and the share of renewable energy in the electricity. It should be noted that most of the countries use these two terms viz. "share of renewable energy in the electricity" and "total installed capacity" interchangeably while setting the energy targets and while monitoring their growth. Although there are wide conceptual and practical differences between these two terms, these would be used interchangeably in this research based on the respective understanding of each countries.

The policy effectiveness of a country gives the confidence to the investors and all the stakeholders about the quantum of targets that would get converted into the actual market demand and supply. Fig. C.1 presents the results and calculation of retrospective policy effectiveness analysis of the concerned countries.

South Korea has been very effective in terms of designing RE policy and their implementation, for achieving their targets. According to the latest 2017 targets, South Korea had planned to install a total renewable capacity of 15.1 GW (including hydropower). However, as per IEA database, South Korea achieved a total renewable installed capacity of 15.8 GW by the end of the year (IEA, 2019). The planned target and the achieved renewable generation capacity are inclusive of hydro power. According to the Article 5 of the Act on the Promotion of the Deployment, Use and Diffusion of New and Renewable Energy, Korea launch plans for a period of more than 10 years. In 2014, Korea launched the 3rd Basic Plan for a period of 2014 to 2035 and exceeded their 2017 target. Hence, Policy effectiveness of South Korea is 104%.

Russia is doing quite good in hydro-power generation which contributed towards 16% of the total electricity generation. However, the Russian Federation Federal State Statistics Service (Rosstat) accounted that a maximum of 0.19% of the electricity generation in 2015 were sourced from renewable energy sources, as Russia does not account hydropower over 25MW as renewable generation (Lanshina et al., 2018). For the same year 2015, Russian national target was 2.5% of renewable share in the electricity (Ministry of Energy of the Russian Federation, 2010). Hence, Russia scored the Policy effectiveness rate of 7.6% and was rather unsuccessful with their policies and implementation.

India has entered the third phase of renewable energy expansion to reach a total installed capacity of 175GW by 2022, including 100 GW of solar PV and 60 GW of wind power. To achieve the target capacity, the required growth rate during 2014 to 2022 is 17.44 GW/year and a total installed capacity of 105.25 GW by the end of 2018. However, the achieved renewable capacity reached 74.786 GW by 2018 (Government of India, 2019). Hence, the Policy effectiveness rate of India is calculated to be 71.05%.

Germany scored 100% in the Policy effectiveness due to the very precise control over the annual installed capacity with effective implementation of the policies. With major political parties shifting their objectives towards renewable energy in the national energy debate, Germany launched “Energiewende” in 2011 (Gründinger, 2015). Currently Energiewende plays the most important role in laying the road map of country’s energy transition. Germany passed multiple PV Act (2010), PV Interim Act (2011), PV Act (2013), Renewable Energy Sources Act (2012), Renewable Energy Sources Act (2014) to control the growth of renewables, while The Federal Ministry for Economic Affairs and Energy (BMWi) monitored the status of energy transition (Gründinger, 2015). The later Renewable Energy Sources Act (EEG 2017) provides a fixed corridors for Solar energy (2.5 GWp/year), Onshore wind (2.8 GW/year from 2017 to 2019 and 2.9 GW/year from 2020 onwards), Offshore wind (total installed capacity of 6.5GW by 2020 and 15 GW by 2030), for annual growth of solar PV and wind power, and PV Interim Acts were used as policy measure to ensure the required growth (BMWi, 2016).

Japan has been very effective in implementing the renewable energy policies and scored 170% in Policy effectiveness. In July 2012, Japan implemented nation wide Feed-in-Tariff scheme after replacing RPS and making it mandatory for power purchasing companies to buy electricity from renewable sources at a fixed price for the contract period. Policy implementation was carried out by Ministry of Economy, Trade and Industry (METI) and Agency for Natural Resources and Energy (ANRE). In April 2017, the scheme was partially amended to ensure the project implementation, maintenance, inspection and appropriate decommissioning. Based on the Strategic Energy Plan (2014), The Government of Japan (GOJ) published the Long-term Energy Supply and Demand Outlook in 2015, and made the commitment of 7% solar and 1.7% wind by 2030, as part of their overall target of share of renewable energy in total electricity to be 22-24% by 2030 (METI, 2015). With the current growth rate (95 GW total Renewable capacity installed by 2017, 49.5 GW Solar PV DC against the target of 53 GW, Wind 3.4 GW against the target of 10 GW, and with the current average deployment rate of 8.6 GW/year (solar PV) and as the bidding process of 15.45 GW capacity already done in 2017 (4.46 GW land and 7.86 off shore) (IEA, 2017*b*)), Japan would meet the solar PV 2030 target share by 2021 and wind power 2030 capacity target in early 2020s (International Energy Agency, 2018*a*) (IEA, 2017*b*).

The United States scored around 92% in policy effectiveness. In order to meet the RPS target of 12% RE electricity sales by 2030, US needs to reach a total renewable energy electricity (RES-E) production of 15% of retail sales or around 56 GW of new renewable energy capacity (by 2013) to support RPS targets Barbose (2018). Most of the states met the interim annual RPS targets in previous years. The states for which the data is available, a total of 131 TWh of RES-E was generated in 2017 as compared to the total target of 142TWh [1] in these states, which was a success rate of around 92% Barbose (2018).

China is very efficient in terms of implementing their renewable energy policy and meeting their targets and hence, scores 101% in the Policy Effectiveness. The National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) are responsible for issuing and implementation of policies, regarding the power sector in China. In the 12th Five Year Plan China introduced first carbon intensity target and later issued the National Plan on Climate Change 2014-2020. China achieved 130 GW of solar capacity in 2017, as compared to the target of 105GW by 2020 (13th Five Year Plan) (International Energy Agency, 2018*b*) (Energy, 2016). According to the REN 21 2018, China has already achieved 188 GW of wind installed capacity in 2017 as compared to 210 GW target of 2020(REN21, 2018) (Energy, 2016).

[1] Although the total target, inclusive of all the U.S. states with mandatory RPS was 240TWh for 2017, the states for which data were not available, were not considered in the calculation

Appendix D

Least Square Method formulae

$$\text{mean } \bar{x} = \frac{1}{n}\,\Sigma x_i, \tag{D.1}$$

$$\bar{y} = \frac{1}{n}\,\Sigma y_i, \tag{D.2}$$

$$\text{slope } m = \frac{\Sigma(x_i - \bar{x})y_i}{\Sigma(x_i - \bar{x})^2} \tag{D.3}$$

$$\text{intercept } c = \bar{y} - m\bar{x}, \tag{D.4}$$

$$\text{equation of the trend-line } y = mx + c, \tag{D.5}$$

$$\text{deviation} = y_i - mx_i - c, \tag{D.6}$$

$$\text{Sum of deviations, } S = \Sigma(y_i - mx_i - c)^2, \tag{D.7}$$

$$D = \Sigma(x_i - \overline{x})^2, \tag{D.8}$$

Standard error in m, $(\Delta m)^2 \approx \frac{1}{D}\frac{\Sigma(d_i)^2}{n-2}$, Where n = number of data sets (D.9)

Standard error in c, $(\Delta c)^2 \approx (\frac{1}{n} + \frac{(\overline{x})^2}{D})\frac{\Sigma(d_i)^2}{n-2}$. (D.10)