Scope of cooperation between India & Germany in Renewables

with a focus on Opportunities in the Wind Sector in India

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Scope of cooperation between India & Germany in Renewables with a focus on Opportunities in the Wind Sector in India

By

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गच्छन् पिपिलिको याति योजनानां शतान्यपि ।

अगच्छन् वैनतेयः पदमेकं न गच्छति ॥

"A continuously moving ant might cover the distance of hundreds of kilometres, but the non-active Garuda* does not move even a single step further."

*(*The fastest moving bird, and king of birds in Indian mythology)*

DISCLAIMER

This study was conducted by the authors on behalf of the Consulate General of India, Hamburg, in an independent manner. Views expressed herein are those of the authors and do not necessarily represent the views of the Consulate General of India, Hamburg or any other agency or institution of the Government of India.

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KEY ABBREVIATIONS

BfN	German Federal Agency for Nature Conservation (*Bundesamt für Naturschutz*)
BMWi	German Federal Ministry of Economic Affaird and Energy (*Bundesministerium für Wirtschaft und Energie*)
BU	Billion units (1 BU = 1,000 MU; 1 unit = 1 kWh)
BWE	German Wind Energy Association (*Bundesverband WindEnergie e.V.*)
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority (Ministry of Power, Govt. of India)
cf.	Confer
EU	European Union
FDI	Foreign Direct Investments
FIT	Feed-in Tariffs
GDP	Gross Domestic Product
GW	Gigawatt (*equivalent to 1000 Megawatts*)
GWh	Gigawatt hours
IEA	International Energy Agency
INR	Indian National Rupees
IRENA	International Renewable Energy Agency
kWh	Kilowatt hours
LCOE	Levelised Cost of Energy
MNRE	Ministry of New and Renewable Energy, Govt. of India
MU	Million units (1 MU = 1,000,000 units; 1 unit = 1 kWh)
MW	Megawatt (*equivalent to 1000 Kilowatts*)
MWh	Megawatt hours
NIWE	National Institute of Wind Energy
R&D	Research and (experimental) Development

TECHNICAL NOTES

- The term "renewable energy", as per Encyclopaedia Britannica, refers to "usable energy derived from replenishable sources" and, unless specified otherwise, is meant within this study to include energy derived from the following sources: wind, solar, geothermal, biomass, biofuels, and small hydro not exceeding 25 MW capacity.
- The terms "wind power" and "wind energy" are used in this study interchangeably and refer to a "form of energy conversion in which turbines convert the kinetic energy of wind into mechanical or electrical energy that can be used for power. […] Modern commercial wind turbines produce electricity by using rotational energy to drive an electrical generator. They are made up of a blade or rotor and an enclosure called a nacelle that contains a drive train atop a tall tower" (Encyclopaedia Britannica).
- A megawatt (MW) refers to a unit of electric capacity or electric load and is equal to 1,000 kilowatts (kW). A megawatt-hour (MWh) refers to a unit of measure of electric energy. A MWh is 1,000 kilowatt-hours (kWh). An MWh is the amount of electricity generated by a one MW electric generator operating or producing electricity for one hour (State of New Jersey, 2019, UCS, n.d.).
- Capacity factor refers to "the actual energy output from a generating plant over a period of time, usually a year, as a fraction or percentage of the plant's capacity". For instance, if a 1-MW wind turbine has a capacity factor of 20% in a given year, it would lead to the following output: 1 MW × 365 days × 24 hours × 0.20 × = 1,752 MWh.
- Official fiscal years (FY) in India pertain to the period from April of a given calendar year to March of the following year. For instance, "FY 2017-18" refers to the period from April 2017 to March 2018. This pattern has been followed in the report regarding all official data for India, unless specified otherwise.
- All monetary values that were originally only available in Indian rupees (INR) have been converted to Euro or US Dollars based on average exchange rates for a given fiscal year as published by the Reserve Bank of India (RBI), unless specified otherwise.
- Monetary figures available in Indian denominations (such as "lakhs" and "crores") have been converted to international units (10 lakhs = 1 million; 100 crores = 1 billion) for the sake of better understanding for international readers.
- Where appropriate, figures have been rounded off to ensure a smooth flow in reading. This may at some places cause a minimal discrepancy in data.
- All figures in Dollar ($) refer to US Dollars, unless specified otherwise.
- Limitations of secondary data cited in this report have not been thematised for reasons of space and to ensure a better flow while reading. Readers are advised to refer to original sources if requiring precision about the data and its limitations.

भारत का प्रधान कौंसलावास

हैम्बर्ग

सत्यमेव जयते

CONSULATE GENERAL OF INDIA

HAMBURG

FOREWORD BY THE CONSUL GENERAL

The Government of India has recognized renewable energies (RE) as a top priority area and set itself four years ago a challenging goal of installing 175 gigawatt (GW) of RE capacity by 2022. The realization of this ambitious goal progressed so well that the Ministry of New and Renewable Energy (MNRE), in 2018, decided to revise the goal upwards. As per revised goals, India intends to install an RE base of 227 GW by 2022, out of which 67 GW concerns wind power capacity. By the end of 2018, the country had successfully installed 35 GW of wind power capacity.

However, India's wind power potential is estimated at over 300 GW and efforts must be made to utilize it, for the benefit of universal, 24x7 energy access to India's citizens and to meet their growing future needs in an environmentally sustainable way. Secondly, we must look for ways to continuously improve the utilization of existing utilities and to enhance resource efficiency.

Germany is a global lead market for wind power. Furthermore, to my great pleasure, the precinct of the Consulate General of India (CGI), Hamburg, is home to over 10,000 wind energy installations and 18,455 MW installed wind power capacity. The four federal states of Bremen, Hamburg, Lower Saxony, and Schleswig Holstein that constitute the consular jurisdiction of CGI Hamburg accounted for close to 35% of the total installed capacity in Germany in 2018.

Therefore, it is with immense pleasure that I present this report on "Scope of cooperation between India & Germany in Renewables with a focus on Opportunities in the Wind Sector in India". The study has been authored by Dr. Sadhana Tiwari and Dr. Rajnish Tiwari of Center for Frugal Innovation at Hamburg University of Technology (TUHH). The report intends to provide insights into recent developments and market opportunities for the benefit of Indian and German companies looking to expand or enhance their business with each other; as well as for other relevant stakeholders, e.g. industry associations, institutional bodies and policy makers from both sides.

I would like to thank the authors and TUHH for this fruitful collaboration in producing a highly informative study. My team and I look forward to many more productive collaborations in future. The publication of this report was made possible under the Market Expansion Activities Programme of Economic Diplomacy and States Division of the Ministry of External Affairs.

February 2019

Madan Lal Raigar
Consul General of India, Hamburg

PREFACE BY THE AUTHORS

Renewable energies have become increasingly crucial in today's world. The conventional and finite sources of energy, such as fossil fuels, are simply unsuitable to provide affordable access to energy to an increasing population in the long-run. It is against this backdrop that we have investigated the potential of wind energy in the context of Indo-German bilateral cooperation.

Based on our analysis of the renewable energies in general, and the wind energy sector in particular, in both countries, we observe that India and Germany are endowed with many complementary capabilities. The relevant stakeholders from the value chain of the wind power sector should join hands to benefit from an almost unique win-win-win constellation: the Indo-German cooperation in this field has the potential of becoming an attractive proposition commercially, technologically and environmentally for all parties concerned.

For this Indo-German proposition, we coin the term "IDEA" that stands for "Invest, Develop, Establish and Apply". As our recent research on behalf of Germany's Federal Ministry for Education and Research (BMBF) and the Austrian Council shows, we are living in a "frugal AGE", where the increasing depletion of natural resources necessitates a rethink of our consumption patterns, and without compromising on quality and technological advancement, we can strive for "Affordable, Green Excellence". This bilateral cooperation can bring up frugal innovations that would be highly demanded in a mature and cost-conscious industry across the globe. By building upon lead market capabilities of both nations, it is possible to contribute to the realization of sustainable development goals.

We hope, readers – especially those participating in the value chain of the wind energy sector – would find our study useful. We would like to take this opportunity to thank Mr. Madan Lal Raigar, Consul General of India in Hamburg, and Mr. Parminder Singh Bandechha, Commercial Officer, for initiating the idea of this study and enabling us at Center for Frugal Innovation at TUHH to, yet again, present our research to firms as well as to policy and decision makers in India, Germany and beyond.

We look forward to continued cooperation and collaboration with the Consulate General of India, Hamburg and other entrepreneurial and institutional actors. For, we are convinced that this collaboration contributes to the deepening of the bilateral relations in all spheres and is in mutual interest of both nations while supporting the greater good.

Hamburg, February 2019 Sadhana and Rajnish Tiwari

Center for
Frugal Innovation
TIM / TUHH

EXECUTIVE SUMMARY

In 2015, India set itself a very ambitious task of expanding its installed base of renewable energies by more than five times to 175 gigawatt (GW) within seven years (by 2022). It was envisioned that 60 GW would be contributed by wind power. In 2018, the objective was revised upwards to 227 GW in total and 67 GW for wind power. The country needed such challenging goals to ensure an early, universal, and 24x7 access to electricity for all citizens. However, India's per capita electricity consumption remains one of the lowest in the world. The young, aspiring and increasing population in a growing economy naturally engages in social and economic activities. As a result, the demand for electricity is increasing fast. Finally, there is a pressing need to switch from fossil fuels to renewable, replenishable and locally available resources for ensuring better energy security, reducing financial burden of energy imports, and – most crucially – for reducing carbon emissions to best protect the environment from a disastrous climate change.

Wind energy has emerged as a success story in India. Today, India is leading globally on the fourth position in terms of installed wind power capacity. As a mature and cost effective technology, wind power has rapidly gained market share. The resultant economies of scale have again helped lower the costs and allowed firms to intensify innovation activity. Nevertheless, a huge market potential remains untapped, even as capacity utilization in terms of actual power generation has substantial scope of improvement. Germany is a global lead market for wind power, and renewable energies in general. It has a proven base of technological prowess and it has co-shaped the development of this industry. However, a certain saturation is setting in, as good sites for onshore wind power become scarce.

There is a strong case for the two countries and their enterprises to cooperate in this sector. This case includes commercial, technological, humanitarian and environmental reasons. While there is a strong untapped potential in India and other global markets for affordable and excellent wind power solutions, technological cooperation can help in achieving affordable excellence ("frugal innovations"). Bilateral cooperation can help in realising the sustainable development goals (SDGs) in India and other developing economies of Asia, Africa and South America, in the process leading to a better life for millions, if not billions, of people. Finally, the environment and the biodiversity of our planet is at stake. Many of our non-human cohabitants are as severally, if not worse, affected by the human-intensified climate change, which potentially may threaten the existence of life itself on the planet if left unchecked.

This study proposes an "IDEA" framework for Indo-German bilateral cooperation in wind sector that encompasses all relevant stakeholder in the value chain. The acronym stands for "Invest, Develop, Establish and Apply". If implemented, this framework can help in creating affordable, green excellence with a win-win-win component for the countries involved, for human welfare, and for the environment.

1 Introduction

1.1 Study background

On 2nd October 2016, marking the occasion of 148th birth anniversary of Mahatma Gandhi, India ratified the Paris Agreement on Climate Change. With this symbolic move on the birth anniversary of the founding father of modern India and one of the early environmentalists of our times,[1] India officially and publically committed itself to environmental protection by reducing emission of the greenhouse gases. In the year before that, the Indian Government announced an ambitious plan to massively ramp-up its renewable energy targets to 175 gigawatts (GW) by 2022. The target envisions a renewable energy mix of 100 GW solar power, 60 GW wind power, 10 GW biomass power and 5 GW small hydro power (PwC, 2015). In June 2018, the Economic Times quoted Mr. R.K. Singh, Minister for New and Renewable Energies, as revising the target to even 227 GW (Saluja and Singh, 2018). The new targets, as per this report, consist (in rounded figures) of 114 GW solar power, 67 GW wind power, 6 GW small hydro, 11 GW biomass and 31 GW hybrid power from floating solar and offshore wind.

Both these developments can be understood in the context of one of the biggest dilemmas of our time: how to meet the rising energy demand while reducing carbon emissions (BP, 2019). The nation has been working on ensuring universal and 24x7 electricity supply across India to ensure inclusive and sustainable societal development (PwC, 2015). Frequent load-shedding and low-quality electricity supply often forces people to take recourse to "private, local, costly and dirty solutions such as diesel generators, which pose both health and environmental concerns" (Jain et al., 2015). The 1951 census showed that only 3,061 villages in India had access to electricity. This number increased to 478,966 by the end of FY 1990-91 (GOI-DOP, 1991). However, it was only in 2018 that "all 597,464 inhabited villages in the country" were connected to the grid (BBC, 2018). Nevertheless, around 31 million homes reportedly remain without access to electricity (D'Cunha, 2018). Energy deficit, especially in meeting peak demand, continues to exist too, albeit at a much smaller scale than in the previous decade.

Renewable energies can help "the nation achieve energy security in a sustainable, affordable and environmentally [*sic*] friendly way" (Suzlon, 2018: 6). The thrust on renewable energies has borne fruit: with 74 GW of installed renewable energy capacity as of Dec. 2018, the country has already made noteworthy advancement towards reaching these ambitious goals. Furthermore, with new investments worth $11 billion in renewable power and fuels (not including hydro over 50 MW) in 2017, India scored globally fourth, preceded only by China, the USA and Japan (REN21, 2018). Suzlon, India's market leader in wind energy, reports that "more than 60% of the new investments in the global power sector have been in renewables, and this momentum will continue for the next five to ten years in India too" (Suzlon, 2018: 6).

[1] See, e.g., Malhotra (2011) for Gandhi's engagement for the cause of the environment and sustainability.

Studies show that India has made substantial progress on renewable energies, ranking globally fourth in terms of installed renewable capacity, and wind energy has a dominant stake in the renewable energy mix in India. Nevertheless, studies also reveal two key shortcomings (see Figure 1). First, India's installed capacity in absolute numbers still vastly lacks behind that of China, the USA or Germany. Second, the per capita share of installed renewable energy capacities in India is extremely low (0.05 kW). For comparison, Germany's per capita renewable capacity is 1.3 kW, while China's is 0.2 kW (Figure 1).

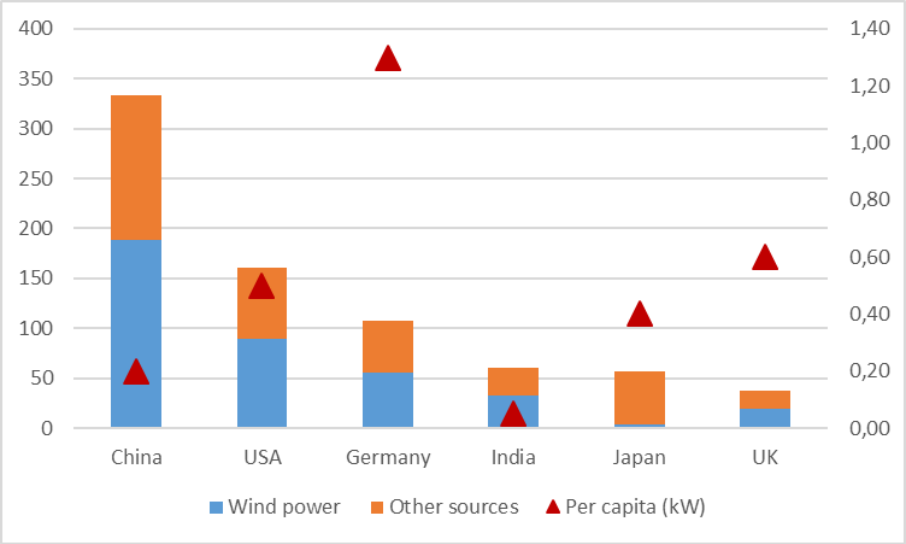

Figure 1: World's leading nations in renewable power capacity (2017)[2]

On a positive note, Figure 1 also reveals the immense potential that lies before India, if Germany is taken as a benchmark. Wind energy can play a key role in unlocking this potential. Recent studies by the National Institute of Wind Energy (NIWE, 2019) have pegged India's potential in wind power at 302 gigawatts achievable with wind turbines that are installed at 100 metres above ground level (AGL).[3] The estimated potential, thus, by far exceeds even the updated target for 2022 and points to immense possibilities.

1.2 Objectives

A core objective of the present study is to explore and identify the large-scale and yet-untapped opportunities for Indo-German bilateral collaboration in the area of wind energy. The desk research-based study provides sectoral overview and (mid-term) growth prospects for the wind sector in both countries. An analysis of inherent strengths and weaknesses, as well as of opportunities and threats present in this sector is conducted to recognize potential synergies and recommend measures to best utilize them. An added emphasis is laid on the prospective role of affordability-driven frugal innovations that can ensure green excellence in

[2] Source: own illustration based on REN21 (2018) data

[3] A PwC (2015: 3) report even stated that "[r]ecent studies suggest that wind potential of 40-65 times higher is possible with new scale and technologies".

India, and possibly benefit both India and Germany as lead markets in renewable energies in general, and in wind energy in particular.

1.3 Structure

This study is structured along the following lines: after a brief introduction to the study background and the objectives in section 1, the reader is introduced to the wind energy sector, its scope, value chain, and relevant global developments. Section 2 contains a brief overview of the power sector in India, including the role that renewable energies play in it. This section also contains information about expected future developments that are likely to have deterministic effects on the prospects of wind energy in the county. Section 4 is devoted to the wind energy sector in India and contains information regarding capacities, trends, opportunities, and challenges. An analysis of the German wind energy sector, along similar lines, is undertaken in section 5. The scope of a mutually beneficial bilateral partnership between India and Germany is investigated in section 6. A summarizing discussion in section 7 concludes the report.

2 Wind energy and global developments

2.1 Sectoral scope and value chain

The wind energy sector is concerned with generation of electricity by utilizing the domestically available and replenishable potential of wind, which can be integrated in an electricity grid, or be alternatively directly delivered off-grid for local use to end-consumers.[4] The value chain of the wind energy sector involves development of the required wind turbines and components, their manufacturing and installation at the site of the wind farm, integration in the grid system, and finally the operation and maintenance of the plant (see Figure 2).

Figure 2: Value chain in the wind energy sector[5]

Wind turbines often have "more than 8,000 individual components, and about 90% of the value is captured in three main component groups: blades and hubs, towers, and nacelles" (CEMAC, 2016). Therefore, the value chain of the wind energy sector involves, apart from manufacturers of wind turbines and owners/operators of wind farms, also stakeholders from many different socio-economic spheres. Examples include suppliers and manufacturers of components, project developers, specialist lawyers, experts and appraisers, regulatory bodies, financial institutions, logistics providers, construction companies, providers of maintenance

[4] For elaborative discussions, see, e.g., Ellenbogen et al. (2012), Mathew (2006), or Redlinger et al. (2002).
[5] Source: own illustration, adapted from a generalized model of value chains for clean energies technologies proposed by CEMAC (2017).

services and storage technologies, electricity traders, grid operators and energy providers (cf. BWE, 2018).

The wind energy industry is "moving toward longer blades and taller towers that capture more energy from the wind as part of efforts to improve performance and reliability and reduce the cost of individual wind turbines and wind systems. Larger turbines enable access to stronger winds at higher elevations above the ground" (CEMAC, 2016). Somewhat related to this development, some experts have also raised environmental concerns that are associated with the wind energy. In a review article, Dai et al. (2015) have grouped these concerns into three categories: ecological effects, impact on humans, and climate-related issues. In their words, "[t]he primary environmental issues related to wind turbine usage include wildlife safety, bio-system disturbance, noise, visual pollution, electromagnetic interference, and local climate change" (Dai et al., 2015: 912). A recent study by the German Federal Agency for Nature Conservation (BfN) comes to the conclusion that such concerns are often valid. At the same time, it also said that their impact is manageable with considerate planning and technological advancement (BfN, 2019a). Moreover, these impacts must be seen in comparison with the impact of other conventional sources and not in isolation. Prof. Beate Jessel, president of BfN said while presenting her agency's Renewable Energies Report (BfN, 2019b):

> "The expansion of renewable energies is imperative for achieving climate protection goals and must also protect species and habitats from the consequences of climate change. The transformation of energy systems must take place in a way that is compatible with nature and the environment. Efficient use of the land and consideration of the respective landscape conditions play an important role in this."

2.2 Global developments in the wind energy sector

Within the group of renewable energies wind power has emerged as "the least-cost option for new power capacity in a large and growing number of countries" (REN21, 2018: 23). An EU study, published in 2014, had reportedly put the average cost of one MWh power with onshore wind at around €105, gas at €164, and coal at €233, whilst the costs of energy generated with nuclear power, offshore wind and solar energy all stood at roughly €125 per MWh (cf. Neslen, 2014). Levelised costs of energy (LCOE), that refer to "costs of new power generation without public intervention" (European Commission, 2014), have since then decreased further and are expected to continue doing so till 2030 (Ram et al., 2018). The Clean Energy Manufacturing Analysis Center at National Renewable Energy Laboratory at the U.S. Department of Energy, cites cost reduction and performance improvement as the driving forces behind the rapidly growing demand for wind turbine components, including nacelle, blades, and tower (CEMAC, 2017). This cost advantage has helped wind energy to achieve grid parity (Suzlon, 2018). With economies of scale and new technological developments, costs are expected to go further down by another 58% from current levels by 2050 (BNEF, 2018).

It is already more cost-effective to build wind (or photovoltaic) power plants than building ones for coal and gas. With technological progress and substantial reduction in the cost of

batteries it would be easier to ensure uninterrupted power supply "when the wind isn't blowing and the sun isn't shining" (BNEF, 2018). As a result, wind energy has become "mainstream, relevant and commercially viable" and has shaded its image of being alternate yet commercially unattractive source of energy dependent on government subsidies (Suzlon, 2018: 6). Wind energy is now perceived as "a mature and cost-competitive technology" (REN21, 2018: 109). The global wind energy sector has registered an impressive growth since the turn of the millennium. Installed capacity has increased with a compounded annual growth rate (CAGR) of >21% between 2001 and 2017, increasing the installed wind energy capacity from 23.9 GW to 539.1 GW in this period (see Figure 3). Despite occasional slowing down of the pace of new additions, the cumulative installed base has continued to grow without a single break.

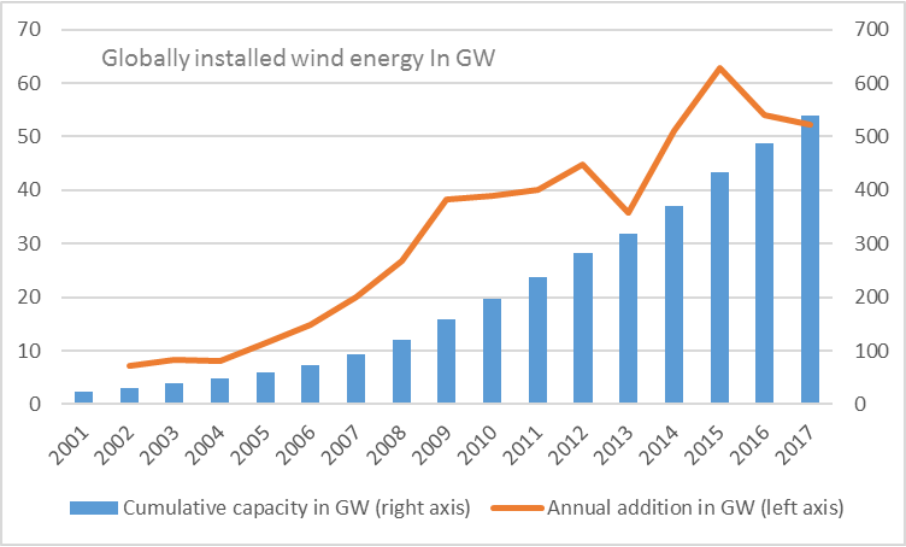

Figure 3: Global developments in the Wind energy sector (2001-2017)[6]

The wind energy sector has also emerged as a prolific creator of jobs. In 2017, it provided directly or indirectly a job to an estimated 1.15 million people (REN21, 2018).[7] The job creation went hand-in-hand with the industry growth and the number of jobs grew by a CAGR of almost 11%, from the base of 500,000 employees in 2009 (Statista, 2019c). China had the largest share of employment in the wind sector (44%), followed by Germany (14%) and the USA (9%). Together with India (5%) and UK (3%), the group of top-5 nations commanded a share of almost 76% in the global wind sector employment.

As of December 2017, China remained the undisputed market leader with a market share of (35%) in terms of the globally installed base of wind energy. Other key players include the USA (17%), Germany (10%), and India (6%). Together with Spain, the UK, France, Brazil, Canada and Italy, the group of top-10 accounts for 85% of the globally installed wind power. In the offshore segment, European nations account for 88% of globally installed capacity (IRENA,

[6] Source: own illustration based on Statista (2019b)
[7] The renewable energy sector, as a whole, was estimated to provide 8.8 million jobs worldwide (IRENA, 2018)

2018). Wind turbine manufacturing is heavily concentrated in China, the EU, India and the United States. However, there is a move towards greater localization for the production of components, such as blades, to reduce transport costs and cultivate price-sensitive markets (REN21, 2018).

3 Developments in India's power sector

3.1 Country's brief economic profile

Since starting on the path of economic liberalisation in 1991,[8] India has witnessed rapid economic growth. India's gross domestic product (GDP) in current prices has increased almost ten-fold from $275 billion to reach the mark of $2.7 trillion in 2018 (IMF, 2018). In this period, the country's population has also grown from 864 million to an estimated 1.3 billion in 2018. GDP per capita in nominal terms has grown from little over three hundred dollars per annum to more than two thousand dollars. In terms of purchasing power parity (PPP), GDP per capita is estimated to have grown from about $1,200 to approx. $7,800. Today, India is the fifth largest economy in the world after the USA, China, Japan and Germany. The International Monetary Fund (IMF) estimates that India's GDP would reach the mark of $4.3 trillion by 2023, further boosting the per capita disposable income.

In the post-liberalisation period, India's integration in the global trade has intensified considerably. While trade volume in FY 1990-91 stood at $42.2 billion (15.4% of GDP), it grew to $769 billion in FY 2017-18 (28.6% of GDP).[9] However, India's trade deficit has also increased massively, growing from a mere $1.5 billion to $162.2 billion. A large part of the trade deficit can be attributed to oil imports to meet the country's growing demand for mobility. In FY 1990-91, India's import bill for oil amounted to just above $6 billion, which more than doubled to $15.7 billion at the turn of the millennium (FY 2000-01). By the end of FY 2017-18, the oil imports had grown a further seven-fold to $108.7 billion. It is against this backdrop that India's push for domestically producible renewable energies has to be contextualised.

3.2 Key drivers of demand for energy

The relative share of people living below poverty line reduced by more than half to 22% since economic liberalisation was initiated (GOI-MOSPI, 2018). There is a process of urbanization and an enhanced ability to have discretionary spending on "non-essential" consumption (Bijapurkar, 2013, Ablett et al., 2007). One indicator for this economic growth and its impact on the societal/environmental life is the number of registered motor vehicles in the country,

[8] For a discussion on the causes, process and impact of economic liberalisation in India, see, e.g., Ahluwalia (2002), Kumar (1996), and Tiwari et al. (2011).

[9] Trade intensity has been counted on the basis of GDP in calendar years 1991 and 2018 (IMF, 2018). Trade data has been taken from RBI (2018).

which has increased more than four-folds from about 55 million in 2001 to 230 million in 2016 (GOI-MRTH, 2018), see Table 1 (on next page).

Similarly, the number of railways passengers has registered an enormous increase. The Indian Railways ferried 8.1 billion passengers in FY 2016-17, almost two-thirds more than at the turn of the century. The average distance travelled by passengers has also increased. For example, the average distance travelled by non-suburban passengers has increased from 187 KMs to 283 KMs in this time, signifying enhanced mobility (GOI-MR, 2018). The Railways were still using more diesel locomotives (6,023) than electric locomotives (5,399), as of FY 2016-17, and there will be an increasing need for electrification to cope with the demand for both intra- and intercity mobility that can reduce carbon emission and lessen financial burden.

Such trends are expected to further intensify with the growing economic activity and movement of the young population. Enabling environment-friendly and affordable mobility, e.g. in the form of electric vehicles that can reduce the consumption of fossil fuels and also enhance India's energy security would be crucial in a world that is faced with depleting natural resources and might get increasingly volatile due to geopolitical developments.

Category	1951	1991	2001	2011	2016
Total vehicles (nos., million)	0.3	21.4	55.0	141.8	230.0
• 2-wheelers	8.8%	66.4%	70.1%	71.8%	73.5%
• Cars, jeeps & taxis	52.0%	13.8%	12.8%	13.6%	13.1%
• Buses	11.1%	1.5%	1.2%	1.1%	0.8%
• Goods vehicles	26.8%	6.3%	5.4%	5.0%	4.6%
• Other vehicles	1.3%	11.9%	10.5%	8.5%	8.1%

Table 1: Growth in the number of registered vehicles (1951-2016)[10]

3.3 Installed capacity and the role of renewable energies

At the end of January 2019, India had a total installed base of 349 GW electricity generation. In terms of regional distribution, the Western region (33.7%), the Southern region (30.1%), and the Northern region (26.4%) accounted for the bulk of the energy generation in the country, followed by the Eastern region (9.6%), the North-East (1.2%) and the Islands (52.6 MW).[11] It is interesting to note that the Northern and Eastern regions do not have installed capacities in proportion to their share of population, does not lead in energy generation. The

[10] Source: own illustration based on Road Transport Year Book 2015-16 (GOI-MRTH, 2018). The category "Other vehicles" includes tractors, three wheelers and other miscellaneous vehicles not classified separately.
[11] The composition of the respective regions is as per CEA classification and strictly geographical (Appendix A).

Eastern region with a large coastline seems to have under-utilized its potential for wind energy. This imbalance necessitates significant inter-regional and inter-state transmissions.

Nearly 74 GW, or about 21% of the total installed capacity (349 GW), could be attributed to renewable energy sources including small hydro not exceeding 25 MW power (GOI-CEA, 2019), see Figure 4.[12] In terms of the regional differences in the installed base of renewable energies, it is interesting to note that the Southern region contributes almost half of the installed capacity (49%), followed by the Western region (30%), and the Northern region (19%). The Eastern region, despite its large coastal area, accounts for only 1.8% of the installed renewable energy capacity. The share of the North-East and the Islands is almost negligible.

An analysis of the ownership pattern in the power generation sector in India reveals an interesting feature. While installed capacity of conventional energy is almost equally distributed between the state government, central government and private sector enterprises, the renewable energy sector is almost exclusively dominated by private sector firms (95%).

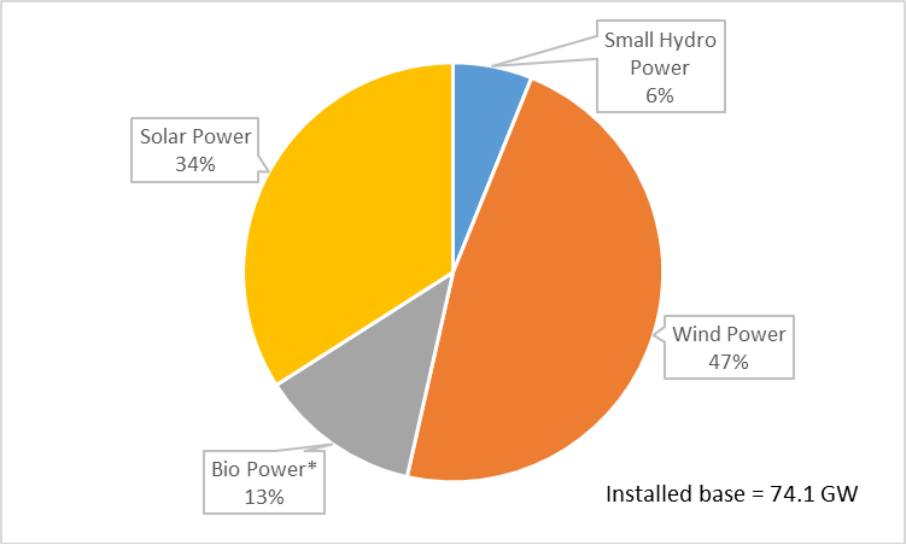

Figure 4: Sources of renewable energy in India, as on Dec. 31, 2018[13]

3.4 Actual power generation

At the of end of FY 2017-18, total power generation in India stood at 1,212 billion units (BU) (GOI-MP, 2018). It grew with a CAGR of 5.8% between FY 2009-10 and FY 2017-18. By the end of October 2018, power deficit in the country has decreased to 5 BU, with a CAGR of over 27%, from 84 BU in FY 2009-10. Crucially, India's capacity to meet the peak demand (177 GW as of Oct. 2018) has also increased in a similar fashion, and the deficit to meet peak demand stood at 0.8%, in contrast to 12.7% (of 119 GW) just 10 years ago (GOI-MP, 2018). The share of

[12] The installed base of renewable energies as on December 31, 2018

[13] Source: own illustration, based on GOI-CEA (2019) data. Bio power consisted of Biomass 9,076 MW and power generated from urban & industrial waste (138 MW).

renewable sources in the total power generation has grown steadily, rising from 62 BU, or 5.6% of total generation in FY 2014-15, to 102 BU, or 7.8% of total generation in FY 2017-18 (GOI-CEA, 2018a). While total electricity generation grew by a CAGR of 5.6%, generation by conventional sources grew slower by 4.8%. On the other hand, generation by renewable sources grew much faster by 18.2% in this period.

Nevertheless, the figures also reveal a core challenge for India that seems to lie in the ability to convert the installed capacity of renewable energies into actual power generation. Despite the impressive growth in power generation by renewable means (CAGR >18%), the fact remains that their contribution to actual power generation remains relatively low at below 8%, despite having a share of over 21% in the installed capacity. According to Central Electricity Authority (CEA), grid integration that can "tackle the variability/intermittency of generation" from renewable sources remains a high priority item for better utilization of renewable energy potential in the country (GOI-CEA, 2018a: 29).

3.5 Expected developments in energy demand

India has announced plans to support and promote electrical vehicles (EVs), which includes the vast fleet of two-wheelers in the country (REN21, 2018: 58). Government had even proposed to stop selling of combustion-based vehicles by 2030. It is supporting bulk procurement for its own fleet of vehicles of about 500,000 cars. India is expected to reach an 11% market share in global sales of EVs by 2030, not including two- and three wheelers (OECD and IEA, 2018). This development, coupled with the electrification of public transport including in the Railways will increase demand for electricity significantly.

According to International Energy Agency (IEA) data, India's per capita electricity consumption has grown from 0.27 MWh in 1990 to 0.92 MWh in 2016 (IEA, 2019). However, in international comparison it is still at a significantly lower level, see Table 2.

Year	India	China	Germany	USA
2016	0.92	4.28	6.96	12.83

Table 2: Per capita electricity consumption in selected countries (in MWh)[14]

Per capita consumption of electricity is, to a certain extent, positively correlated with the level of economic development. Therefore, it is a reasonable assumption that India with its young and growing population, largely unsaturated markets and the (resultant) intensifying economic activity, will witness a progressively higher level of per capita electricity consumption in the years to come that will go hand-in-hand with the rising prosperity and improvements in the standards of living.

[14] Source: own illustration based on (IEA, 2019) data

3.6 Investment overview

Data by REN21 (2018) show an exponentially growing volume of investments in the renewable energy sector (power and fuels) in India. In 2017, 4% all new global investments in renewable energies were made there. The cumulative volume of investments has reached almost $97 billion between 2007 and 2017 (CAGR: 31.2%), see Figure 5.

Statistical data released by the Department for Promotion of Industry and International Trade (DPIIT) in February 2019 show that the country received FDI worth $7.1 billion in the field of "non-conventional energy" in the period between April 2007 and September 2018 (GOI-DPIIT, 2019).[15] This amounted to about 1.8% of all FDI inflows into India in this period. At the same time, companies such as Suzlon have engaged in outward FDI and established presence in many countries, including in Denmark, Germany, and the Netherlands (Tiwari, 2014).

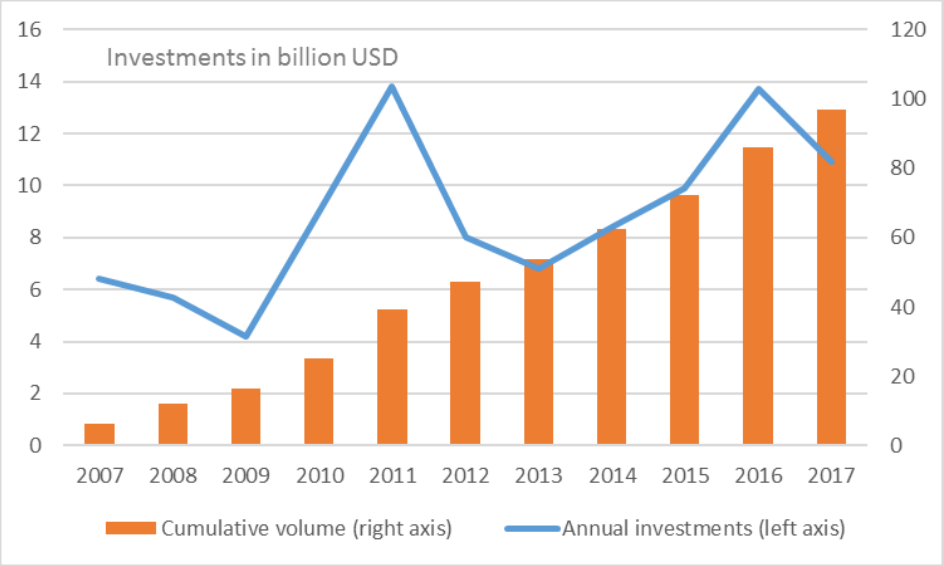

Figure 5: Investments in India's renewable energy sector (2007-2017)[16]

4 Wind energy sector in India

4.1 Sectoral overview & growth prospects

India belongs to early adopters of wind energy, with the country initiating wind power projects in the early 1990s (Jethani, 2017). Today, India ranks globally fourth in terms of installed wind power capacity behind China, the USA, and Germany. According to Indian Wind Turbine Manufacturers Association (IWTMA), there are 23 wind turbine manufacturers operating in the country producing more than 60 different models (Tanti, 2018). Apart from domestic players, such as Suzlon, there are many noted global players active in the Indian market. Examples of such global players include, Vestas, Siemens Gamesa and GE. According to REN21

[15] For time-series data, see "FDI Fact Sheets" of the Department for Industrial Policy and Promotion (DIPP)
[16] Source: authors' analysis and illustration based on REN21 (2018) data

(2018: 115), "European turbine makers – including Vestas, Nordex and Senvion – have invested in India, drawn by rapid growth. Siemens Gamesa opened its third blade factory in India […]". Reportedly, there are more than 4,000 SMEs in India producing wind turbine components across the value chain (Suzlon, 2018). The wind energy sector was estimated to employ about 60,500 people in India as of 2017 (REN21, 2018: 46).[17]

The "Make in India" initiative of the Govt. of India, as per IWTMA estimates, has attracted 43 manufacturing units to India and enabled investments worth Rs. 250 billion (approx. $4 billion). Apart from private sector efforts at product & technology development, India has also established R&D centres to support wind energy (Tanti, 2018). Today, the country has a strong domestic manufacturing base that can support 75-80% local content and is a global market leader in affordable solutions in wind power (REN21, 2018, Bhagwat and Tiwari, 2017). Costs have gone down in the range of Rs. 2-3 (approx. 3 Euro cents) per unit (Ramesh, 2018). The government has sought to promote renewable energies and system operators are required "to evacuate the available solar and wind power" on priority basis and treat them as a "must-run station" except in safety-related emergencies.

4.2 Installed wind power capacity

The installed wind capacity in India has grown exponentially since the turn of the century: from 220 MW in 2000 to over 35 GW at the end of 2018 (CAGR: >36%), see Figure 6. The annual addition of new capacities has been especially impressive between 2013 and 2017, before taking a dive in 2018 in the wake of global developments in the industry and in the wake of policy reforms affecting feed-in tariffs. However, experts and firms believe it to be a temporary setback and remain enthusiastic about future (cf. Suzlon, 2018, BP, 2019).

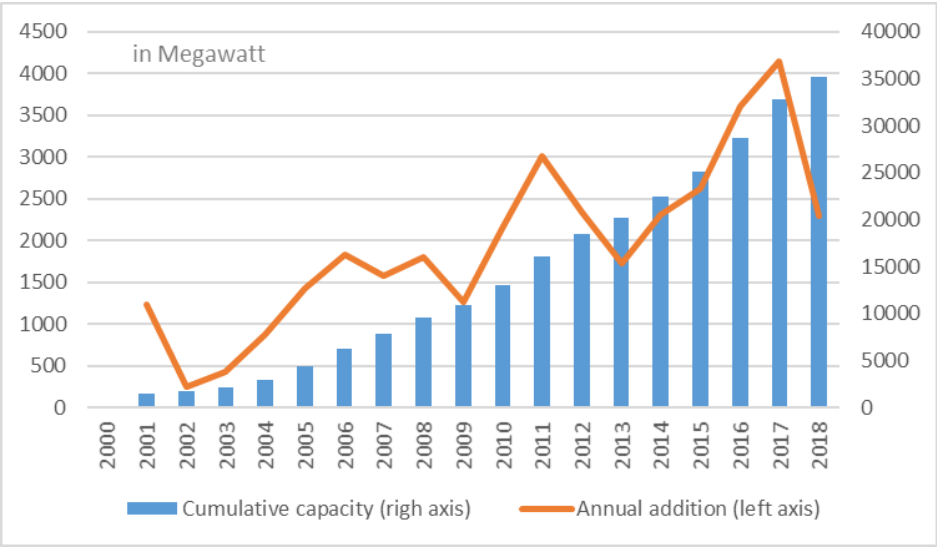

Figure 6: Growth in India's installed base of Wind power (2000-2018)[18]

[17] GWEC (2016) puts the number at even 400,000.

[18] Source: own illustration based on Jethani (2017), GOI-CEA (2019) and Statista (2019a)

4.3 Trends in wind power generation

Turning to actual electricity generation by wind power one can see a similar development. Since FY 2014-15, India's generation of wind power has increased from 34 BU to 53 BU, growing by a CAGR of 16% (see Figure 7). Generation of wind power in the first 9 months of FY 2018-19 (April to December) stood at 53 BU, which already surpassed the power generation by wind power in the preceding fiscal year. Measured against the corresponding period in the previous fiscal year, generation of wind power increased by 16.9% (GOI-CEA, 2018b).

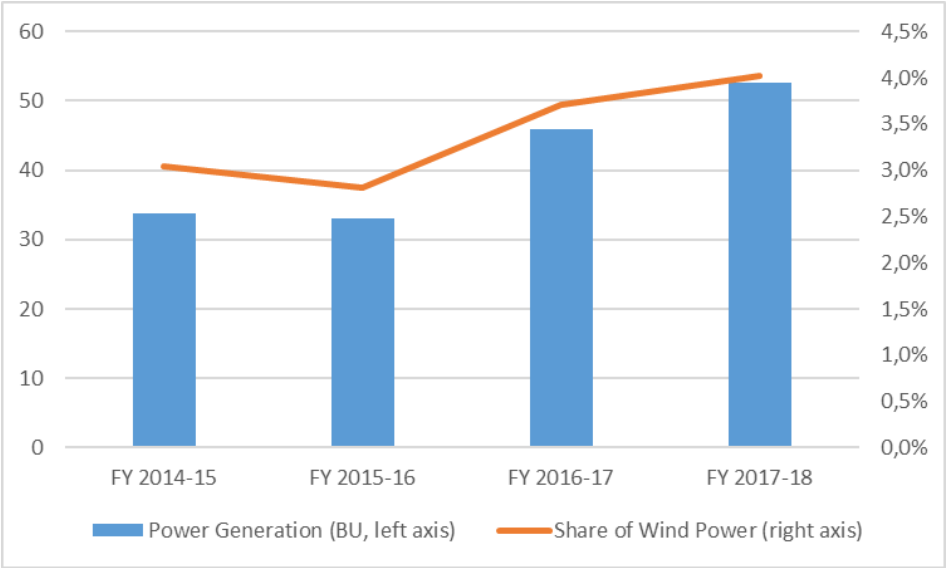

Figure 7: Wind power generation in India, FY 2014-15 to FY 2017-18[19]

In this period, the share of wind power in total electricity generation has also increased from 3% to 4%. Nevertheless, it continues to remain significantly under its relative share of 10% in the installed capacity. Wind power remains the predominant source of renewable power in India consistently commanding a share of over 50% (see Figure 7). In terms of geographic regions, the Southern region was the most important region accounting for 51% of all wind power production in the country between April and December 2018, followed by the Western region (32%), and the Northern region (10%). The Southern region could even increase its share by 2 percent points in comparison to the corresponding period in the previous year.

Table 3 shows the most important states for wind power production. Top-5 states are Tamil Nadu, Gujarat, Karnataka, Andhra Pradesh, and Maharashtra. The two other noteworthy states are Rajasthan and Madhya Pradesh, which had a market share of 9.9% and 7.5% in the first 9 months of FY 2017-18, respectively. Both registered impressive growth in comparison to the corresponding period in the preceding year.

[19] Source: own analysis and illustration based on GOI-CEA (2018a) data

No.	State	2018*	2017*	Growth	Share (2018*)	Share (2017*)
1	Tamil Nadu	11,658.37	11,063.32	5.4%	21.9%	24.3%
2	Gujarat	8,917.67	8,048.53	10.8%	16.8%	17.7%
3	Karnataka	8,306.70	6,348.43	30.8%	15.6%	14.0%
4	Andhra Pradesh	7,592.68	5,319.99	42.7%	14.3%	11.7%
5	Maharashtra	6,736.36	5,933.12	13.5%	12.7%	13.0%
-	All others	675.31	464.82	45.3%	1.3%	1.0%
-	Total	53,124.09	45,478.90	16.8%	100%	100%

Table 3: Wind power generation in India in MW (from April to December)[20]

4.4 Untapped wind power potential

Studies by India's National Institute of Wind Energy (NIWE) have revealed considerable untapped potential for wind energy in India.

No.	State	Rank I (wasteland)	Rank II (cultivable land)	Rank III (forest land)	Total
1	Gujarat	52,288	32,038	106	84,431
2	Karnataka	15,202	39,803	852	55,857
3	Maharashtra	31,155	13,747	492	45,394
4	Andhra Pradesh	22,525	20,538	1165	44,229
5	Tamil Nadu	11,251	22,153	395	33,800
6	Rajasthan	15,415	3,343	13	18,770
7	Madhya Pradesh	2,216	8,259	9	10,484
8	Telangana	887	3,348	9	4,244
9	Odisha	1,666	1,267	160	3,093
10	Kerala	333	1,103	264	1,700
-	Others	82	144	24	250
-	Total	153,020	145,743	3,489	302,251

Table 4: Wind power potential at 100 meters above ground level[21]

[20] Source: own analysis based on GOI-CEA (2018b) data. All figures relate only to the first 9 months of the FY.
[21] Source: own illustration based on NIWE (2019). For detailed methodological information, please refer to http://niwe.res.in/department_wra_100m%20agl.php.

In addition, NIWE's investigations, based on over 800 wind monitoring stationed across India (Jethani, 2017), show that the country has an indicative installable potential of 49 GW with wind turbines at 50 meters above ground level (AGL), and of 103 GW at 100 meters AGL. Table 4 shows installable wind power potential in India at 100 meters AGL. Seven states possess wind power potential of 10 GW and above. Also states, such as Odisha and Kerala, that so far have not been at the forefront of wind power generation, seem to have promising prospects and can be attractive investment destinations for domestic and foreign firms. Interesting to note is that some states, most importantly Gujarat, Maharashtra, Andhra Pradesh and Rajasthan, have high untapped potential in the "Rank I" category that denotes wind power potential using wasteland. This may open up new opportunities for setting up wind farms.

4.5 Opportunities & challenges faced

The vast untapped potential of wind energy in the country, the still present electricity deficit, the emerging need for energy in a rapidly developing economy, and equally importantly the need to shift away from the conventional (thermal) sources of energy make India a long-term, attractive market for wind energy. The country has faced several challenges in fully utilizing the potential of its wind power. The share of installed capacity has so far not been correspondingly reflected in the actual power generation.

To achieve better utilization of its potential the country needs, on the one hand, new investments in ramping up its wind power generation capabilities, and on the other hand, it needs to ensure their optimal usage. For example, by better forecasting of real-time wind conditions and better grid integration. The country needs to optimize its wind power value chain. The focus must not remain limited to power generation but encompass power delivery to the end-user. Meeting this objective necessitates technological and business model innovations both at the supplier-side and at the front-end. Context-specific, frugal solutions (Tiwari and Bergmann, 2018, Agarwal et al., 2017) must be created that retain monetary affordability to both B2B and B2C customers in focus, while ensuring societal and environmental sustainability, and fit to the given infrastructure.[22]

5 Wind energy sector in Germany

5.1 Sectoral overview & growth prospects

> "Germany remains the leading market for wind energy in Europe, still a considerable margin ahead of Spain and the United Kingdom. […] In terms of technology, Germany remains the driver of innovations when it comes to turbine availability, producible quantities of electricity, forecast reliability, new maintenance concepts or questions of grid integration, as well as management of fluctuating generation and digital concepts such as virtual power stations."

[22] On challenges facing India's wind power industry also see Ahn and Graczyk (2012) and PwC (2015).

The above statement by Hermann Albers, president of the German Wind Energy Association (BWE, 2018: 5) illustrates the pioneer role of Germany in the global wind energy industry.

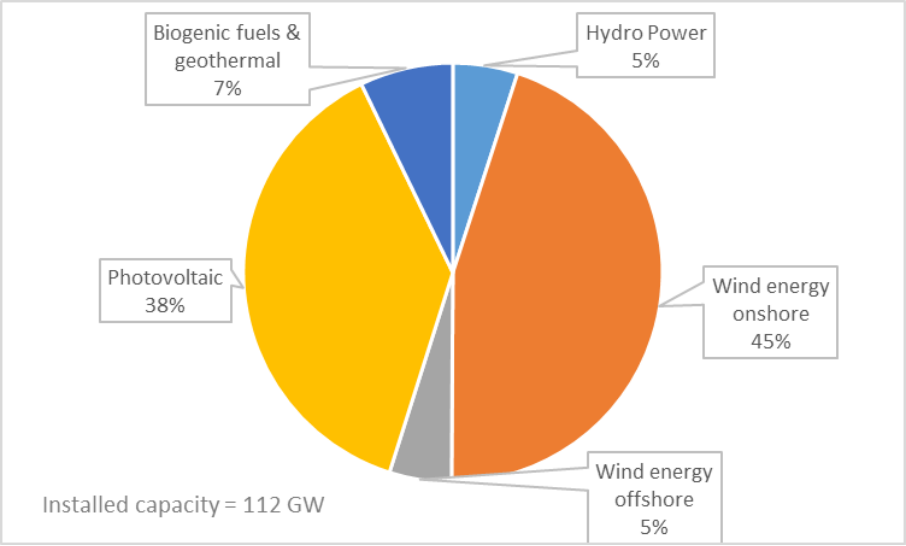

Figure 8: Installed renewable energy capacity in Germany, 2017[23]

Germany had an installed capacity of 112 GW in renewable energies in 2017 (BMWi, 2018c). This is a remarkably high percentage, as the renewables had a higher share (55%) than the conventional sources (45%) in the net installed electricity generation capacity of 203 GW (Fraunhofer ISE, 2018). As can be seen in Figure 8, wind energy constituted the single most important source of renewable energy in Germany, with a share of almost 50% in 2017, including 5% from offshore stations. Table 5 shows the regional distribution of the wind energy sector and the leading federal states for onshore wind power.

No.	Federal State	Installed capacity	Share (in %)	Installations (nos.)
1	Lower Saxony	11,165	21.1%	6.305
2	Brandenburg	7,081	13.4%	3.821
3	Schleswig Holstein	6,964	13.2%	3.661
4	North-Rhine Westphalia	5,773	10.9%	3.726
5	Saxony Anhalt	5,139	9.7%	2.862
-	All others	16,808	31.8%	8.838
-	Total	52,931	100.0%	29.213

Table 5: Top-5 federal states with installed onshore wind power capacity[24]

[23] Source: own illustration based on BMWi (2018c)
[24] Source: own illustration based on Wallasch et al. (2019)

An estimated 338,700 people worked in the renewable energy sector in Germany in 2016, out of which around half (160,100) are engaged in the wind energy sector including plant maintenance and operation work (BMWi, 2018c). Offshore wind energy sector employed 28,200 people. The rest worked in the onshore sector.

5.2 Renewable energy mix and capacity utilization

In 2017, Germany produced 216 BU electricity from renewable sources that amounted to 36% of total generation (BMWi, 2018c). Wind power (on- and offshore) contributed 106 BU, or close to 49% of the power generated by renewable sources. Overall, almost 18% of all electricity production in Germany in 2017 was covered by wind power. Figure 9 shows the renewable energy mix and its historical development in Germany. Wind power started here around 1990, but began to play a notable role in the renewable energy mix only around 2000, when it gained a share of 27% in electricity generation by renewable means. Over the years, its share has grown to 49%, including offshore wind power. The latter started to take off around 2009 and in the meantime already contributes more than 8% to wind power generation. Share of wind power in all electricity produced in Germany has grown from 1.7% in 2000 to 17.6% in 2017.

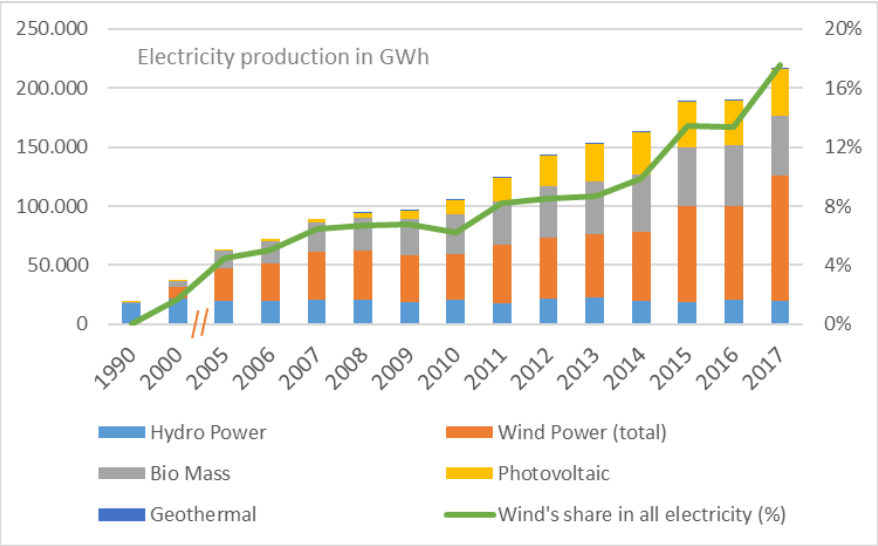

Figure 9: Renewable energy mix in Germany and the role of wind power

A very remarkable observation about wind power in Germany is that the country apparently has achieved a high efficiency and effectiveness in converting its installed capacity into actual generation of electricity. While the share of wind power (on- and offshore) in the net installed capacity in 2017 was 27.8%, it share in actual generation of electricity was 17.6%, which translates into a capacity utilization rate of 63.3%.[25]

[25] In contrast, wind energies had a share of 10.1% in India's total installed capacity in FY 2017-18, their contribution to total electricity generation was, however, only 4%, resulting in a capacity utilization rate of <40%.

5.3 Investment trends and economic returns

Between 2005 and 2017, Germany has seen investments worth €235 billion in building renewable energy installations. As Table 6 shows, wind energy installations attracted investments worth €76 billion and had a share of over 32% in total investments.

Year	Wind energy investments			Total investments	Share of wind energy (in %)
	Onshore	Offshore	Total		
2005	2.5	-	2.5	12.0	20.8%
2006	3.2	-	3.2	14.0	22.9%
2007	2.5	0.03	2.5	13.6	18.6%
2008	2.5	0.2	2.7	17.7	15.3%
2009	2.8	0.5	3.3	23.6	14.0%
2010	2.1	0.5	2.6	27.9	9.3%
2011	2.9	0.6	3.5	26.1	13.4%
2012	3.6	2.4	6.0	22.5	26.7%
2013	4.5	4.3	8.8	16.5	53.3%
2014	7.1	3.9	11.0	16.4	67.1%
2015	5.4	3.7	9.1	13.9	65.5%
2016	6.9	3.4	10.3	15.4	66.9%
2017	7.3	3.4	10.7	15.7	68.2%
Total	53.3	22.9	76.2	235.3	32.4%

Table 6: Investments in wind power installations in Germany (billion euros, 2005-2017)[26]

As Table 6 shows, wind energy investments have picked up after 2011, and today they corner the lion's share in all renewable energy installations with a market share of about two-thirds. Offshore wind energy investments have also picked up. Furthermore, data reveal an interesting negative correlation with solar energy investments; see Figure 10.

Initially, investments in solar energy installations have dominated investments in renewable energy. They reached their zenith with an investment share of 74% in 2010 and have been on a downwards spiral since then. Conversely, wind energy investments have been, generally, on an upswing since 2011, and reached an investment share of 68% in 2017. According to BMWi (2018c: 29), this "growth was driven by the expansion of onshore wind energy installations".

[26] Source: own illustration based on BMWi (2018c) data

The decline in the solar energy sector is primarily attributed to falling installation prices "in 2011 and 2012 while new plants continued to be installed at an unchanged pace. Since 2013, however, prices have remained largely stable while the installation of new photovoltaics capacity has plummeted" (BMWi, 2018c: 29 pp).

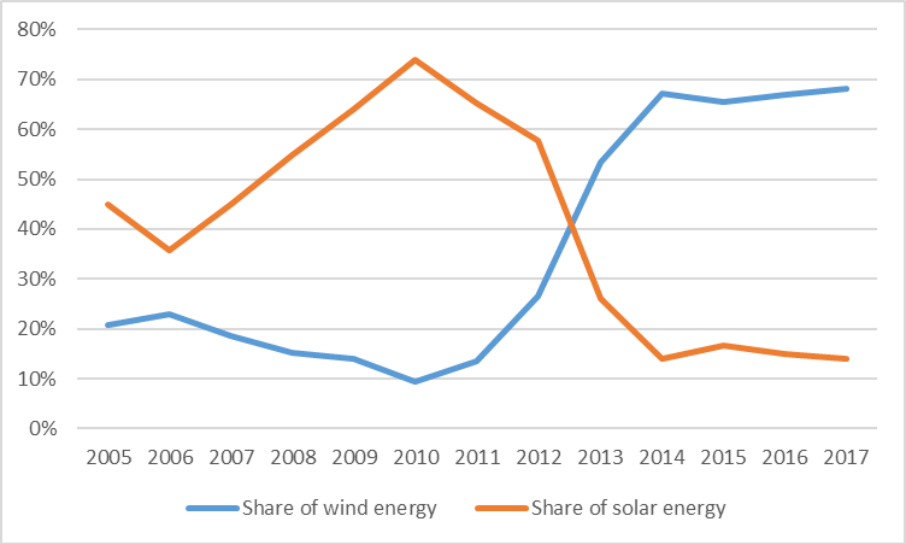

Figure 10: Investment patterns of wind and solar power installations, 2005-2017[27]

Data show that plant operations release economic stimulus and generate revenues for the suppliers of the plants. In 2017, the value of economic impetus from the operation of wind energy installations were estimated at €2.5 billion, up from €0.6 billion in 2005 (BMWi, 2018c).

5.4 Research and innovation

Germany's lead market position in the wind energy sector is based on the fundament of strong R&D and innovation activities that involves both private sector enterprises and universities & research institutions largely funded by the state. While R&D expenditures of leading firms such as Nordex (€220 million, 7.2% of annual sales) and Senvion (€68 million, 3.6% of sales) and their priority areas suggest large scale investments in future-oriented product and technology development, there is also a deep level of support from the public sector.[28] The Federal Government provided funding worth €3 billion for research in the field of renewable energies between 2006 and 2017 (BMWi, 2018a). The annual support progressively increased from €120 million in 2006 to €418 million in 2017. In addition, federal states also supported R&D in renewables with €2 billion between 2008 and 2016. Table 7 shows the thrust areas of research funding by the German Federal Government relating to energy conversion.

Table 7 shows that there has been a strong focus on wind farm development in research funding by the Federal Government, both in terms of the funding amount as well as in the

[27] Source: own illustration based on (BMWi, 2018c). Investments in solar energy have been grouped to include investments in photovoltaic and solar thermal energy.
[28] Figures relate to 2017 and are based on publically available information on firm websites

number of ongoing and new projects. Research on logistical and other value chain activities is also supported strongly, as are the environmental aspects related wind energy. In the meantime, the Federal Government has launched the 7th Energy Research Programme with a total funding of €6.4 billion for the period 2018-2022 with the purpose of "researching, developing, demonstrating and testing viable future technologies and concepts" (BMWi, 2018b).

Funding topic	Actual outlay 2012-2017 (million euros)	Number of projects in 2017		Funding appropriated in 2017 (million euros)
		ongoing	new	
Wind farm development	123.08	135	40	36.99
Onshore	10.15	13	7	1.79
Offshore	56.54	71	14	40.14
Wind physics and meteorology	13.89	20	4	1.02
Logistics, turbine installation, maintenance and operation	69.94	70	6	1.28
Environmental aspects of wind power and ecological accompanying research	13.57	19	2	3.72
Others	34.61	26	13	11.04
Total	321.78	354	86	95.97

Table 7: Thrust areas of wind power research funding (2012-2017)[29]

Wind power constitutes one of the core areas of the 7th Energy Research Programme. While energy yield was previously the primary area of research, it is now supplemented with additional considerations The programme seeks to develop suitable methods to utilize wind energy potential on complex terrain since market saturation is setting in at easily accessible and windy onshore sites. There is also a strong emphasis on affordability, which also includes integration of digital transformation that can provides investigative algorithms that can potentially render cost-expensive measuring masts redundant. Affordability turning into a core characteristic as margins are expected to continue falling (BMWi, 2018b: 39).

The research and innovation in Germany is increasingly turning towards what is characterized as frugal innovations in the emerging innovation management literature. Affordability, resource efficiency and appropriateness of the solution, apart from technological excellence, are turning into guiding principles. Funding is to be made available to develop micro grids that can work with small wind power plants enable access electricity that is "reliably and affordably generated locally". The policy sees "a need to develop small wind power plants that can work

[29] Source: own illustration based on BMWi (2018a) data

with comparatively low as well as turbulent and fluctuating wind flows" while taking care of "public needs such as the protection of nature and the environment, wildlife conservation and aviation needs" (BMWi, 2018b: 40). The research thrust can be increasingly aligned with the notion of "affordable green excellence" that characterizes frugal innovations (Tiwari et al., 2018). An indication of this can be found in this summarizing statement:

> "In the field of wind energy installation development, research seeks, for example, to reduce service life costs through more resource efficiency, the use of lightweight technologies and a holistic assessment of the installation design from the energy yield through the installation's service life to the removal/recycling of the components" (BMWi, 2018b: 62)

5.5 Opportunities and challenges faced

Wind power is a crucial driver of Germany's transition to renewable energy (Economic Times, 2019), and is expected to further enhance its market position with the help of innovative technologies and business models. Nevertheless, the country also "saw a sharp fall in the number of new onshore wind turbines installed last year [2018]" and industry groups were quoted as warning that "there was little prospect of a recovery without government help" (Economic Times, 2019). Market is seen as showing signs of weakness due to decreasing financial support from the state (Wallasch et al., 2019).

In addition, the transition to wind energy has faced opposition and criticism from local communities and environmental activists (Economic Times, 2019). The Ministry for Economic Affairs and Energy has recently stated that even though Germany "still has sufficient onshore and offshore space available to further expand its wind power. However, it is becoming harder to find windy onshore sites that are easy to develop." (BMWi, 2018b: 39).

6 Framework for a mutually beneficial bilateral partnership

6.1 Examples of existing bilateral collaboration

There are several instances of close bilateral cooperation between India and Germany, both in public sector and in private sector. For example, India's Ministry of New and Renewable Energy (MNRE), and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) have jointly initiated three major projects: the Green Energy Corridor (GEC) project, Access to Energy in Rural Areas (ACCESS) project and a project for Integration of Renewable Energies (I-RE) into the Indian electricity system (GOI-MNRE, 2018). The two countries have also jointly set-up an Indo-German Energy Forum that is based in New Delhi and has a mandate to promote "private sector activities and putting in place an enabling environment so as to further develop the market for power plant technologies, energy efficiency and renewable energies in India" (IGEF, 2019).

On the private sector front, there are several German companies active in India either on their own or through joint ventures. Examples include, but are not limited to, Nordex, Enercon, Siemens Gamesa, and Senvion. Similarly, India's Suzlon is active in Germany with two locations in Hamburg and Rostock. Suzlon is using Germany as a technology hub to learn from the lead market (Tiwari, 2014). On the other hand, German firms, such as Senvion, are also using India for conducting R&D work to create market-specific solutions. A company press release, issued on July 6, 2015, said, "Senvion is serving 26 markets to date, all with specific wind conditions, climates and grid requirements. The expansion of the Product Development division is therefore a necessary step when preparing to enter new markets and offering the highest quality of wind turbines with the best efficiency possible for every location" (Senvion, 2015).

6.2 Excursion: The Enercon case in brief

This section makes an excursion and discusses a case involving German wind turbine manufacturer Enercon. Some years ago, the case had created minor irritations in the popular perception of Indo-German bilateral cooperation. That the issue had more to do with overzealous media and misunderstandings between two business partners and less with the national policies as such has become clear in the meantime. The authors of the present report consider it useful and even necessary to thematise such issues in order to create better awareness amongst relevant stakeholders and to promote mutually fruitful collaboration.

In December 2010, German wind energy major, Enercon lost a court case in India's Intellectual Property Appellate Board (IPAB) related to use of patents by its Indian joint venture (JV) partner. In a claim that was widely reported by German and even international media (Ewing and Bajaj, 2011, Hein, 2011), it was alleged that the IPAB had revoked 12 Enercon patents on the ground that "India's national interest ought to be valued higher than the rights of an individual company to its technology".[30] That this claim was unsubstantiated and misleading has been pointed out by the German-Indian lawyer team of Podehl et al. (2018: 51), who after analysing the IPAB orders came to the following conclusion:

> "However, if one reads the IPAB's rulings carefully, it can be seen that there is no such reference at all to Indian national interests, let alone to their supremacy over the interests of a private foreign company. In the justification for the ruling, the declaration of annulment is exclusively based on 'lack of novelty' and 'lack of inventive step' and thus on criteria that are entirely common and legally correct under patent law. The parties have been in dispute for years and were referred to an arbitral tribunal by the Supreme Court in 2014."[31]

[30] Abridged translation from original German quote, "Indiens nationales Interesse sei höher zu bewerten als die Rechte eines einzelnen Unternehmens an seiner Technik", as reported by the reputed Frankfurter Allgemein Zeitung (FAZ) on Feb. 2, 2011, see Hein (2011).

[31] Abridged translation from the authors' German-language book quoted above: "Liest man allerdings die Entscheidungen des IPAB aufmerksam, so stellt man fest, das sich an keiner Stelle eine solche Bezugnahme auf nationale indische Interessen, geschweige denn auf deren Vorrang vor den Interessen eines privaten ausländischen Unternehmens findet. In den Entscheidungsgründen wird die Nichtigerklärung ausschließlich mit

At least one IPAB ruling concerning the revocation of Patent No: 199045 (IN/PCT/2001/1600/CHE) is in public domain.[32] An analysis of this ruling by IP lawyer Prashant Reddy,[33] came to a similar conclusion:

> "[…] it seems to be a fairly dispassionate order, grounded in patent law. The IPAB has found the impugned patent to be obvious in light of the prior art presented by the petitioner. […] the IPAB does not seem to have invoked the grounds of 'national interest' or 'public interest'. It is therefore extremely perplexing as to why exactly Enercon GmbH's lawyers are claiming that the matter was decided in 'national interest'" (Reddy T., 2011).

Moreover, on appeal, the Madras High Court actually set aside the IPAB order on technical grounds in 2013, ordering the IPAB to re-examine the "maintainability of petition filed by Indian partner and submit its decision within two months" (Babu, 2013).

In the meantime, Enercon has resumed India operations and is offering the largest wind turbines in India with a capacity of 3.5 MW (Ramesh, 2018), having reportedly secured a favourable order from the International Court of Arbitration. This incidence shows that the conflicts between business partners may result from their mutual misunderstandings and the law should be allowed to take its own course while accessing all legally available remedies under the law of the land, and under protection available to foreign investors as per bilateral and multilateral treaties. A good news is also that the protection of intellectual property (IP) has been improving in India. For example, the latest annual International Intellectual Property Index of the U.S. Chamber of Commerce's Global Innovation Policy Center, released on February 7, 2019, sees India's score (36 out of 50 surveyed nations) representing "the largest gain of any country measured on the Index, which covers over 90 percent of global gross domestic product". An accompanying press note (GIPC, 2019) praised:

> "[…] the government of India's incremental, consistent initiatives over time to improve the country's IP ecosystem, guided by the vision of the 2016 National IP Policy […]. The increase is a result of specific reforms, including its accession to the WIPO Internet Treaties, the agreement to initiate a Patent Prosecution Highway (PPH) with international offices, a dedicated set of IP incentives for small business, and administrative reforms to address the patent backlog. All of these enhance India's competitiveness in R&D-intensive industries. If India can surmount the serious challenges that remain, including with regard to patent eligibility and enforcement, it can build a robust innovation-led growth model for other countries to emulate"

"mangelnder Neuheit" und "mangelnder Erfindungshöhe" begründet und damit mit patentrechtlich üblichen und rechtlich korrekten Kriterien. Die Parteien streiten seit Jahren und sind 2014 vom Supreme Court an ein Schiedsgericht verwiesen worden" (Podehl et al., 2018: 51)

[32] https://spicyip.com/docs/IPAB-Chennai.pdf, retrieved last: Feb. 12, 2018. The IPAB website (www.ipabindia.org) iself also contains a search function for cases. This website was, however, consistently not reachable at the timing of writing this report in February 2019.

[33] Prashant Reddy also works as a Research Associate at the Applied Research Centre for Intellectual Assets and the Law in Asia (ARCIALA) at School of Law of Singapore Management University and has co-authored a book titled "Create, Copy, Disrupt: India's Intellectual Property Dilemmas" (Oxford University Press), that indicates his subject-matter expertise.

6.3 Mapping of opportunities in bilateral partnership

As the discussions in the previous sections have showed, India and Germany both belong to the leading global players in the wind energy sector. This sector in both countries has grown very impressively and both countries have been able to create a competitive industrial base in this field. At the same time, the specific market conditions and the business ecosystems provide them with complementary capabilities and strengths that can be very beneficial for both. We summarize some key factors in a framework for Indo-German bilateral cooperation in wind sector called "IDEA" (see Figure 11).

Figure 11: "IDEA" - A framework for Indo-German bilateral cooperation in wind sector

The term "IDEA" is an acronym for "**Invest, Develop, Establish and Apply**", as explained in the following:

Invest in the unsaturated market of India: the unsaturated market of India, with a still very low level of per capita electricity consumption, is set to grow exponentially. In fact, according to BP Energy Outlook, "[a]lmost all of the growth in power demand [in future] stems from developing economies, led by China and India" (BP, 2019: 53). India still has a vast, untapped potential in the wind energy sector. A global study conducted by REN21 to assess the feasibility of securing a 100% renewable energy and the associated challenges identified for India "a clear need for special assistance from developed countries, especially in relation to grid integration of wind and solar electricity, and operation and maintenance of renewable power generation" (REN21, 2017: 21). Thus, India offers an excellent potential for German firms that are faced with saturation in the domestic market due to the progressively decreasing number of suitable onshore sites. Their technological expertise, industry experience and endowment with resources provide them with a competitive advantage in the Indian market.

Develop solutions with high local responsiveness: For successfully cultivating the Indian market, German firms can benefit from developing market-specific solutions taking into consideration the given geographic and socio-economic factors. Collaborative efforts to develop frugal innovations ("affordable excellence") can lead to highly promising products.

Establish environmental sustainability of wind energy: Both countries can collaborate on establishing environmental sustainability of wind power. Wind energy has been found to have certain negative environmental impacts. Even if this impact is minimal or less in comparison to other conventional sources of energy, renewable energies must work with an added emphasis on protection of environment and biodiversity for long-term acceptance. India can learn from experiences gained by Germany and avoid repeating the same or similar mistakes, and to jointly develop policies, guidelines and technologies in this sphere for global usage.

Apply frugal solutions in the global markets: Frugal solutions, with their high emphasis on monetary, infrastructural and environmental affordability, are increasingly demanded in the wind power sector globally. Attempts to meet sustainable development goals (SDGs) in the developing economies of Asia, Africa and South America are on one hand humanitarian imperatives. However, on the other hand, they also offer commercial opportunities in the wind sector. At present, just ten nations (except for China, India and Brazil, all developed economies) dominate 85% of the installed global wind power capacity. In order to enhance access to energy in an environmental sustainably manner the world requires frugal solutions, e.g. in the form of "Distributed Renewables for Energy Access" (DREA) systems. These include mini-grids and off-grid solutions and might also involve "pay-as-you-go" business models (REN21, 2018: 24) . India is a known pioneer of frugal innovations and a lead market for affordable excellence (Herstatt and Tiwari, 2017). Just during 2016-17, more than 200 mini-grid systems were installed in India (REN21, 2018). The country has the lowest total investment costs for onshore wind power as measured in USD/kW, while countries in Africa, Central America and South America had some of the highest costs (REN21, 2018: 122 p.). This shows the potential for frugal innovations. Collaborative efforts at innovative frugal solutions could create win-win-win situations for (a) the countries involved, (b) for the human welfare and not the least for (c) the environment.

7 Concluding summary

This study set out with the objective of exploring and identifying the large-scale and yet-untapped opportunities for Indo-German bilateral collaboration in the area of wind energy. The investigation has shown clear-cut potential for such a fruitful and promising cooperation, which can serve both nations and the world at large, profitably. The key to this cooperation lies in the "IDEA" framework that builds upon a paradigm of "Invest, Develop, Establish and Apply". Renewables, and especially the wind energy sector, are highly cost-sensitive and at the same time critically important for the long-term societal welfare. The relevant stakeholders in both countries need to leverage their complementary strengths to create a frugal AGE, i.e. affordable, green excellence.

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APPENDIX A: REGIONAL COMPOSITION OF THE INSTALLED CAPACITY IN INDIA

Northern Region	Western Region	Southern Region	Eastern Region	North-Eastern Region	Islands
Delhi	Goa	Andhra Pradesh	Bihar	Assam	Andaman & Nicobar
Haryana	Daman & Diu	Telangana	Jharkhand	Arunachal Pradesh	Lakshadweep
Himachal Pradesh	Gujarat	Karnataka	West Bengal	Meghalaya	
Jammu & Kashmir	Madhya Pradesh	Kerala	Odisha	Tripura	
Punjab	Chhattisgarh	Tamil Nadu	Sikkim	Manipur	
Rajasthan	Maharashtra	Puducherry		Nagaland	
Uttar Pradesh	Dadra & Nagar Haveli			Mizoram	
Uttarakhand					
Chandigarh					

Table 8: Regional composition of the installed capacity in India, as on Jan. 31, 2019[34]

[34] Includes allocated shares of the respective states in joint and central sector utilities.

USEFUL CONTACTS

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GERMAN WIND ENERGY ASSOCIATION (BWE) Neustädtische Kirchstraße 6 10117 Berlin +49 30 212341 210 https://www.wind-energie.de/	**INDIAN WIND TURBINE MANUFACTURERS ASSOCIATION (IWTMA)** Transit House: C-1, 2nd Floor, Soami Nagar, New Delhi - 110 017 +91-11-41814-744/755 www.indianwindpower.com
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