World Utility Summit

IMPACT OF ENVIRONMENTAL REGULATION ON UTILITY BUSINESS

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THEME

The theme for **World Utility Summit™** 2018 is "Utility of Utilities - The future of Utilities in the era of convergence". Significant changes are happening in the provision and consumption of energy services leading to convergence of factors that would alter the conventional definition of utility.

With more and more integration of the renewable energy into the grid, Utilities are embracing a multitude of technologies to manage the complexities for such a grid or supply. The adoption of smart grid technologies, SCADA systems, and data analytics in real time will enable Utilities to optimally manage the demand, supply and to make data driven decisions in real-time.

Future Utilities will embrace internet of things (IoT), machine learning, artificial intelligence and plethora of new technologies to deliver energy, and other services to ever more demanding applications and consumers. These developments will bring the much-needed transparency in the system resulting in better consumer engagement. With the help of digital and smart technologies, will transform Utilities in an unprecedented manner.

World Utility Summit™ 2018 which is spread over three days from 11-13 March, 2018 and provides common ground for electricity, water and gas utility personnel to discuss with Industries, Consultants, Service Providers, Researchers and Regulators and re-define the "Utility of Utilities" in the changing business environment.

THE SUMMIT WILL FOCUS ON THE FOLLOWING TOPICS

Empowering electricity, water and food security:

In view of the changing utility landscape, the need arises to re-define the "Utility of Utilities" focusing on ensuring electricity, food and water security. The global community is well aware of food, energy and water challenges, but has so far addressed them in isolation, within sectoral boundaries. A comprehensive approach to sectoral management, through enhanced communication, collaboration and coordination, is needed to ensure optimization that co-benefits and trade-offs are considered and the appropriate safeguards are put in place.

Harmonizing the regulatory frame work for Utilities:

Realizing that sector specific regulatory frameworks have evolved over the years for different utilities, the time has come to co-opt best practices across domains to the changing times. The main aim is to ensure transparency, safeguarding the quality and delivering cost effective services to consumers while taking into account the environmental impact and safeguarding interests of all stake holders.

Racing with technologies:

Utilities strive to catch up with technologies and many technologies driven projects are implemented to provide quality supply and services to consumers. Technology projects that are user centric rather than vendor driven see the success and acceptability in a faster phase. Understanding and discussing the various technological developments that are needed will benefit both the utilities and industries.

Impact of environmental regulation on Utility business:

The Paris Agreement by UNFCC in October 2016 which brings all nations into a common cause to undertake ambitious efforts to combat climate change and decarbonizing the economies. This will also enhance financial support to renewables. The developing countries will have minor concessions for some time. However, these changes will have significant implications to the utilities business.

Convergence of Utility Business:

Utilities and the allied industries need to re-look into their business models while world is geared up to implement the Paris Agreement. Many utilities are consolidating their business operations and significantly, electricity, water and gas utilities are transforming themselves from 'poles & wires', 'valves & pipes' and 'regulators & cylinders' companies to give value added services to consumers through convergence of service from technological front.

Transportation electrification, storage and renewable energy integration nexus:

This will have huge impact on electric utilities as the world moves towards electric transportation. The advancement of storage technologies will be a key enabler of transport electrification; this along with the induction of renewable energy systems will dramatically alter the human and material transportation in the near future.

MESSAGE FROM KNOWLEDGE PARTNER

A.K. Saxena
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Electricity is increasingly become crucial in the functioning of today's economies. In developing countries, social and political imperatives of providing 24x7 reliable and affordable electricity supply to all and meeting rapid growth in demand continue to govern the business of electricity utilities. In developed countries, electricity is playing an increasingly important role in decarbonising the energy systems. In the context of combatting climate change impacts, the environmental regulations as well as transitions on the demand and the supply side present key challenges as well as opportunities to the Utilities.

TERI is delighted to be a Knowledge Partner for the World Utilities Summit 2018 and present knowledge paper on impact of environmental regulations on the utility business model. We hope this would pave the way for further deliberations and development of road maps as relevant to different countries for smooth transition. Such a road map should ensure balancing the interest of utilities, developers and consumers.

Managing such transitions would undoubtedly call for increased dialogue between regulators and policy makers in multiple sectors, as well as with industry players. We are extremely happy to note that WUS 2018 provides a much needed platform for this kind of dialogue and hope that the knowledge paper can contribute to this debate in a significant manner.

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Global Climate Change and Energy Transition

The electric utilities sector is a crucial part of economies worldwide, with electricity making up 18.3% of global final energy consumption in 2016, up from just 8.8% in 1971. With the trends of digitization, urbanization, and economic development, the importance of electricity will only grow with the passage of time. However, the electric utilities sector is also responsible for a number of significant impacts on the global and local environment.

Most prominent among these impacts in the policy debates of recent years is global climate change. The electric utilities sector is responsible for some 40% of global emissions of energy-related carbon dioxide (CO_2) in 2015, and some 25% of global greenhouse gas emissions (GHGs). This, in turn, has led to increased policy scrutiny on the electric utilities sector, both at national and international level. In 2015, the Paris Agreement on climate change was signed and it entered into force in record time in November 2016. As a global framework agreement, it does not directly regulate the electric utilities sector (or any other, for that matter). However, countries in their national undertakings under the framework agreement (so-called Nationally Determined Contributions, or NDCs) have placed significant emphasis on targets and policies targeting the electricity sector. Model-based estimates suggest that implementation of NDCs would lead to a reduction of the carbon intensity of electricity by 40% by 2030 relative to today's level, while by 2030 the low emissions share of electricity generation would increase by more than 10 percentage points from 30% to 41%.

However, the NDCs are only the international translation as of 2015 of a dynamically evolving domestic policy context at national level. Thus, assessment of adequacy and appropriateness of transition pathways actually being pursued in a country also calls for a proper appreciation of the dynamically evolving domestic policy context. Here, the signs also point to increasing momentum behind transition in national electricity sectors. China is in the midst of establishing a nation-wide carbon market and implementing electricity market reform, whilst its target of 20% non-fossil fuel energy in primary energy by 2030 would imply a share above 45% in electricity. The Government of India has given a strong push to renewable energy with the objective of 175 GW by 2022, which would lead to a share of variable renewable energy of 20-22% of electricity production.

Other Environmental Impacts

In addition to climate change, the electric utilities sector is responsible for a number of other important environmental impacts. It is one of the major sources of generation of sulfur-dioxide emissions (one-third of the global total), 14% of nitrogen-oxides, and 5% of total particulate matter 2.5 (PM 2.5). Smog due to local air pollution has been a significant driver for change in environmental regulations for the power sector particularly in China and India. The water-energy-food nexus is also gaining increasing attention among policy-makers and corporate strategists. The land footprint of power generation technologies, in particular renewable energy technologies, is also a significant environmental impact, affecting communities, agriculture, ecosystems, economic use, and amenity or scenic value of land. The communities which are dependent on land and marginalized may suffer significantly due to change in land use. The existing fleet of coal powered power stations use significant amount of water; water efficiency is another aspect that needs to be incorporated by utilities businesses.

In summary, the electric utilities sector will continue to grow to meet growing energy demand, and as the world transitions towards increasing preference for electricity as an energy carrier. However, it is worth noting that the lion's share of incremental demand growth will take place in often densely populated emerging countries, suffering from already severe constraints of land, air, and water availability and quality (e.g. China, India, MENA region). The electric utilities sector will face increasing pressure from policy-makers, regulators, investors, and citizens to minimize its environmental impacts. The result of these pressures will be a transition in energy mixes, markets, and corporate strategies.

Context-Specific Transition Pathways

The electric utilities sector is subject to a number of other forces that are shaping the sector in significant and fast-moving ways. Most prominent among these is technology innovation. The cost declines in RE have been impressive, with levelized costs of wind and solar declining 67% and 86%, respectively, over the last 8 years, while battery costs have declined at a compound annual rate of 20% per year since 2010. These technology trends are difficult to disassociate from environmental policies and regulation – the demand pull given to wind first and then to solar in the 2000s and early 2010s led rather than followed the dramatic cost declines that have been seen in both technologies. Moreover, technological innovation is also occurring outside of the energy sector as such, in particular with the digitization of all segments of the energy value chain. This will open up new challenges and opportunities for policy-makers and utilities.

The electric utilities sector is thus likely to undergo significant change in the decades to come. The exact form of this transition pathway will depend on context-specific factors, including the existing electricity mix, the rate of demand growth, the current regulatory and market structure, as well as diverse social and policy imperatives. Here there are important differences between developed and developing countries, with the latter tending to have regulatory and market models based more on vertical integration and regulated price discovery rather than competitive liberalized and unbundled wholesale and retail markets as exist in developed countries. Developing countries also have faster demand growth, and less diversified, more fossil-heavy supply mixes.

The result is that the particular transition pathways followed by different electric utilities will differ depending on the geographies in which they are active. Figure E1 conceptualizes the changes that are likely to occur in the electric utilities sector. While these changes are likely to be conditioned by local context, they are also structured by commonalities, such as the physical constraints to operating a power system with a high share of variable renewable energy and the increasing competitiveness of renewables across many geographies.

Main Transitions Expected in the Electric Utilities Sector

Supply Mix and Wholesale Markets

The structural trend in supply mixes and wholesale markets appears to be the increasing importance of variable renewable energy. By 2030, a number of jurisdictions are expected to have renewable energy shares of 40% and above of supply, with variable renewables making up more than 20%. This evolution will be driven by the increasing economic competitiveness of variable RE, as well as environment-related policies. As a result, there will be a number of different impacts on wholesale markets, while acknowledging that different jurisdictions' wholesale markets are structured quite differently. In liberalized and deregulated wholesale markets, the injection of zero marginal cost variable renewables has led to, and will increasingly lead to, a decline in wholesale market prices, and in certain cases increased price volatility. In wholesale markets, such as China and India, with regulated prices this impact will be different. In some cases, in particular where incremental demand growth is low or has shifted downward from trend, this price impact is combined with a reduction in load factors (for example, in Europe or China). As a consequence of the increased penetration of variable renewables, there will be increased emphasis placed on the importance of flexible operation and dispatch, as well as investment in new flexible resources. Different countries will face different flexibility

Figure E1: context- specific transition pathways for the electric utilities sector

Source: TERI

challenges, given their different electricity mixes and demand profiles. The importance of flexibility is likely to drive a shift in regulated wholesale markets, which currently provide little incentive for efficient and flexible dispatch.

Distribution and Customer Interface

The structural trend in the distribution segment is the emergence of distributed energy resources, including distributed generation, in particular renewables, batteries, and demand-side response and management. It is here, as well, that the exogenous trend of technology innovation in digitalization will likely have the biggest impact. From the environmental perspective, the promotion of distributed renewables, energy efficiency, and demand-side management will be important policy priorities. In future, there is a possibility of increasing shares of system variability and flexibility being located at the distribution level. This will come alongside the increased penetration of variable renewables at the transmission level, increasing the variability on the supply side. As a consequence, there will be a need for much greater coordination between transmission system operators (TSOs) and distribution system operators (DSOs), in order to ensure the safe and secure operation of the grid. Rather than being seen as a commodity, electricity and other forms of energy are increasingly being seen in terms of the services provided through the consumption of energy: mobility, heating, lighting, and so on. In future, it can be expected that this trend will intensify. New ICT technologies will increase the scope for the 'smart' management of end-use demands, which in turn will require the active involvement of market players to install, monitor, and market the services rendered by smart and connected end-use equipment.

Conclusion

It can be expected that the utility of tomorrow will have a significantly different role and market than is the case today. Environmental regulations and technology innovation are driving a shift in the electricity sector. The role of utilities will diversify from the provider of a bulk commodity to the provider of services, including flexibility and balancing, demand-side response and management, and energy efficiency and new end-use services such as EV charging. These evolutions in business models are likely to open up new avenues for a more environmentally-friendly electricity sector. This, in turn, makes it important that environmental policy-makers and regulators take note of the broad-based transition which the utilities sector is undergoing.

The preceding discussion leads to a number of questions, the answers to which need to be deliberated among all the constituencies including the policy-makers:

1. How can the transition in the electricity sector be accelerated such that climate change goals can be achieved?
2. What key policies are required in order to drive the transition to a more environmentally friendly electric utilities sector?
3. What policies could foster a transition in utility business models in line with the changes emerging in the sector?
4. How to ensure that this transition is made with a minimum of disruption to the key players in the sector?
5. How should wholesale markets be reshaped in view of the increasing penetration of zero-marginal cost renewables?
6. What are possible pathways for electricity market reform in view of a high share of renewables in developing countries which have not yet undergone a high degree of liberalization?
7. From an economic and institutional perspective, how to ensure the coordination between the transmission and distribution levels in view of the emergence of distributed energy resources?

1. INTRODUCTION: RATIONALE AND SCOPE

Electricity is a crucial energy carrier for modern economies and is increasingly important in the context of the emerging digital transformation of the global economy. As an illustration of the growing importance of electricity as an energy carrier, it is worth noting that electricity's share of the world's total final energy consumption (FEC) grew from 8.8% in 1971 to 18.3% in 2016 (Enerdata, 2017). The ongoing, large-scale trends of an expanding middle class, digitalization, and urbanization will only increase the importance of electricity.

At the same time, production of electricity is the source of significant environmental externalities. The electricity sector was responsible for 41.9% of global CO_2 emissions from fossil fuel combustion in 2015 (IEA, CO2 Emissions From Fuel Combustion Highlights 2017, 2017a). The power sector is also a major contributor to local air pollution. In India, for example, the power sector is responsible for some 53% of sulphur dioxide (SO_2) emissions and 44% of CO_2 emissions from fossil fuel combustion (IEA, 2016a; Enerdata, 2017). Other notable externalities of the power sector include the use of water resources to produce steam, provide cooling, and serve other functions; discharges of wastewater into water bodies, including "thermal pollution";[1] generation of solid waste, which may include hazardous waste; and land use for fuel production and power generation. These, in turn, can have significant health impacts on humans, as well as affected ecosystems. It should be noted that externalities pertain not only to fossil-fuel based power generation, but also from renewable power generation (e.g. land footprint from solar and wind, hazardous waste products from solar panel production and recycling, etc.).

The electricity sector is, thus, at the heart of policy efforts to mitigate climate change and address other environmental externalities. Moreover, the electricity sector has lower costs for GHG emissions reductions relative to other sectors, as noted by the Intergovernmental Panel on Climate Change (IPCC) (Bruckner, Bashmakov, & Mulugetta, 2014). In addition, the electrification of end-use consumption is a cost-effective means to significantly reduce emissions in end-use sectors. Decarbonization of electricity production and the electrification of end-uses are, thus, two of the three pillars of the transition to low-carbon energy systems, alongside the improvement in energy productivity.

For these reasons, environment-related norms and policies are expected to be major strategic factors for the electricity utilities sector in the next 10–15 years.

At the same time, the electricity sector is undergoing significant transition, driven by two interacting waves of technology innovation, enumerated as follows:

- Innovation **in production, transmission, and consumption technologies.** For example, since 2008, the cost of solar PV has fallen by a factor of five and the cost of battery storage by two thirds (IEA, 2017c).
- Innovation in **enabling technologies,** in particular in data collection, processing, and connectivity for system management. Big data, machine learning, artificial intelligence, and automation promise to revolutionize the production, transport, and consumption of energy, especially in the electricity sector (IEA, 2017c).

The combination of technological and policy change is driving an emerging and uncertain shift in business models in the utilities sector. Different jurisdictions comprise different legacy structures, and it is thus expected that a variety of different business and regulatory models will evolve in coming years (NREL, 2015).

The objective of this background paper is to provide an overview and strategic analysis of the impact of environment-related regulation, policy, and market forces on the electricity utility sector.

The paper is structured as follows. Section 2 addresses the issue of the nexus between the utilities sector and climate change, and includes a discussion of the Paris Agreement. Section 3 provides an overview of environmental impacts of the utilities sector, other than climate change.

After an examination of different environmental impacts of the electric utilities sector, the following sections examine, in greater detail, the possible shift in electric utility business models arising from policy and technology change in relation to these environmental impacts. As noted earlier, changes to electric utility business models will depend on a variety of factors, notably the nature of policies used to deliver environmental benefits and the structure and regulation of the electric utility sector. For this reason, Section 4 provides an analytical framework for understanding change in the electric utilities sector. Section 5looks at potential changes in the upstream generation sector. Section 6 examines shifts in the downstream distribution sector.

[1] Water that is hotter than the original temperature of the water body

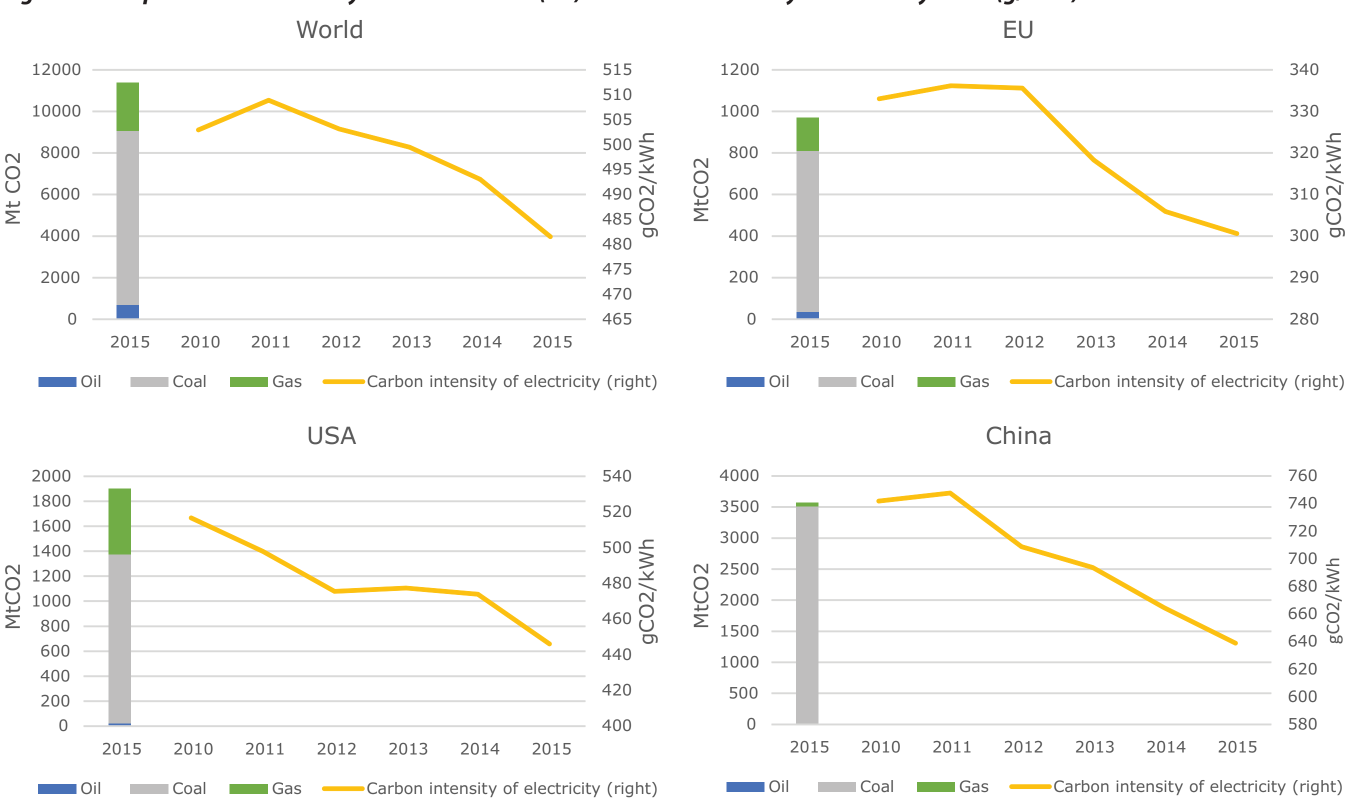
2. CLIMATE CHANGE AND THE ELECTRIC UTILITIES SECTOR

2.1 The Emissions Footprint of the Electricity Sector

Since 1980, the global electricity sector's emissions have increased from ~5.1 billion tons of CO_2 to ~11.5 billion tons in 2015, while its share of global CO_2 emissions from fuel combustion has increased from 29% to over 40% across the same period (Enerdata, 2017; IEA, 2017a). The electricity and heat production sector contributed 25% of global emissions of greenhouse gases (GHGs) in 2010 (IPCC, 2014). Coal combustion dominated, with a share of CO_2 from the electricity sector of 74.5% in 2015, gas was next with 19.2%, and oil was responsible for 5.9% (Figure 2).

As can be seen from Figure 1, different countries and regions have different electricity mixes and hence different shares of fuels in electricity sector emissions. However, a general trend of decarbonization of the power sector is evident, due to improved combustion efficiencies, fuel switching to lower emissions fuels, and the deployment of zero carbon sources of electricity, such as renewables.

Figure 2: Composition of electricity sector emissions (Mt) and carbon intensity of electricity trend (g/kWh)



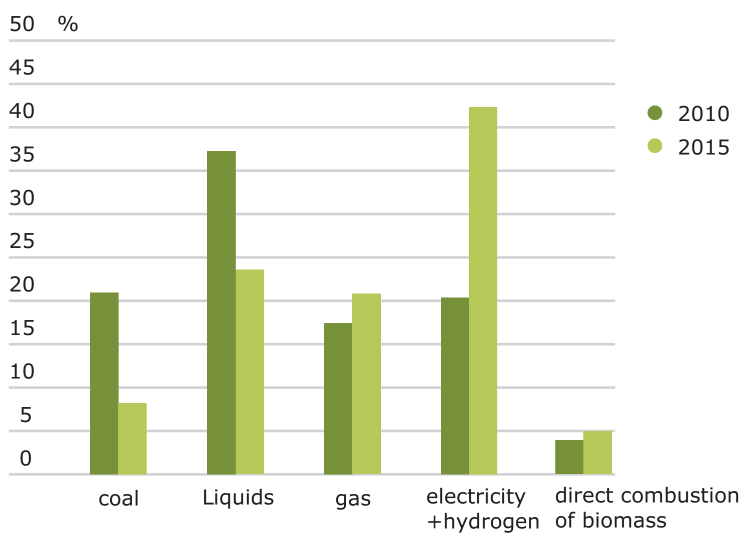
Source: TERI, based on data from (Enerdata, 2017)

2.2 Role of the Electricity Sector in the De-carbonization of Energy Systems

The electricity sector has a crucial role in the de-carbonization of energy systems. On the one hand, the substitution with low emitting technologies is easier and more cost-effective in the electricity sector than in other sectors, such as industry. On the other hand, electrification is a crucial de-carbonization strategy in end-use sectors, particularly in the passenger transport and residential and commercial sectors. Thus, the electricity sector must decarbonize at a faster rate than other sectors, and electricity should become the dominant low carbon energy carrier.

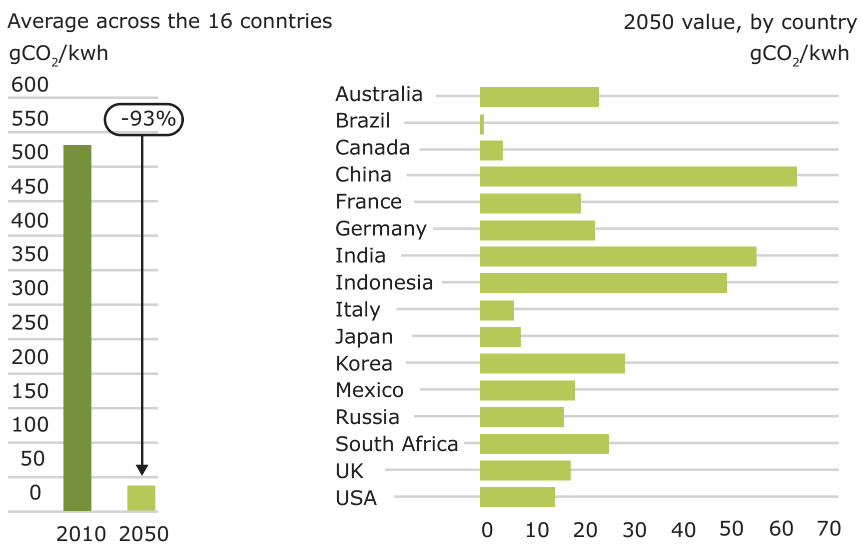
Figure 2 shows the share of different energy carriers in final energy in 2010 and 2050 in a stringent mitigation scenario consistent with limiting warming to below 2°C. In such scenarios, the share of electricity in final energy must at least double from about 18% in 2010 to~ 40% in 2050. Figure 3 shows the carbon intensity of electricity production in 2010 and 2050, under a scenario limiting warming to below 2°C. In stringent mitigation scenarios, electricity production must be essentially decarbonized by 2050, with an emissions factor in the order of >50 gCO_2/kWh by 2050.

Figure 3: Share of different energy carriers in final energy consumption in a scenario to limit warming to below 2°C, 2010 and 2050[2]



Source: Deep Decarbonization Pathways Project (DDPP) (IDDRI & SDSN, 2015)

Figure 3:Carbon intensity of electricity production in a scenario limiting warming to below 2°C, 2010 and 2050



Source: Deep Decarbonization Pathways Project (IDDRI & SDSN, 2015)

Such an ambitious contribution is required from the electricity sector in order to leave room in the "emissions budget" for harder to abate sectors, such as heavy industry, freight transport, and aviation.

2.3 The Paris Agreement on Climate Change and Nationally Determined Contributions

2.3.1 Overview of the Paris Agreement

In 2015, the world agreed to a ground-breaking new treaty on climate change, the so-called Paris Agreement. Compared to previous efforts to forge global cooperation on climate change, such as the Kyoto Protocol (1997) and the Copenhagen

[2] N.B. the geographical coverage of this scenario is Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, UK, and USA, covering about 74% of current global CO2 emissions from energy.

Accord (2009), the Paris Agreement represents several important innovations, which are likely to make it more robust and effective:

- Strong legal foundation as a ratifiable treaty under international law.
- A clear identification of the long-term global goal of limiting warming to well below 2°C and the global emissions pathway consistent with this goal (Articles 2.1(a) and 4.1).
- Universal participation and contribution from all countries, based on a flexible and dynamic architecture of differentiation between developed and developing countries.
- A dynamic and flexible architecture of national undertakings, based on: i) 'nationally determined contributions' (NDCs) aligned with domestic development priorities in the context of the global effort to combat climate change (Article 4); ii) periodic review of global progress and 'ratcheting up' of NDCs on a regular cycle every 5 years (Articles 4.9 and 14).

The Paris Agreement has been signed by all countries of the world and ratified by 170 out of the 197 Parties to the United Nations Framework Convention on Climate Change (UNFCCC). The threshold for entry into force was set at 55 Parties representing 55% of global GHG emissions, and hence it entered into force on 4 November 2016. This gap of less than a year between the adoption of the Paris Agreement (12 December 2015) and its ratification and entry into force is remarkable in the context of the history of international law. It should be compared with other treaties, such as the Kyoto Protocol (8 years) or the UN Convention on the Law of the Sea (12 years). Such a speedy entry into force is a sign of the high legitimacy and buy-in behind the Paris Agreement.

The US Administration under President Trump has announced its intention to withdraw from the Paris Agreement, a decision which can only take effect four years after notification thereof, namely by 2020 in this case. Nonetheless, no country has followed the US out, and all major economies have explicitly reaffirmed their commitment to the Paris Agreement, for example in the 2017 G20 Communiqué: "The Leaders of the other G20 members [except the US] state that the Paris Agreement is irreversible … We reaffirm our strong commitment to the Paris Agreement" (G20 Germany, 2017).

Thus, it can be expected that the Paris Agreement will retain its legitimacy and buy-in, even in the face of the announced withdrawal of the US.

According to the Paris Agreement, a global stocktake of progress towards the achievement of the overarching objective of limiting warming to less than 2°C should be conducted in 2018, in order to inform the upward revision of NDCs in 2020 (Decision 1.CP/21, paras 23, 24 & 115). While this particular cycle of stocktaking and NDC strengthening is voluntary, subsequent cycles beginning in 2023 are mandatory. In any case, consistent with previous assessments (UNFCCC, 2016), the stocktaking effort in 2018 will certainly find that the current level of ambition in NDCs is insufficient to meet the stated 2°C objective. The pressure will be on, in one way or another, to reflect increased ambition in climate mitigation already by 2020.

Certainly, the geopolitical climate at present is somewhat less favourable than at the time of the adoption of the Paris Agreement. Nevertheless, one can expect that the combination of scientific assessment about the insufficiency of current trajectories to meet the stated objective, and the Agreement's system of regular review and ratcheting up of contributions, will keep climate change high on the global political agenda in years to come.

2.3.2 The Electricity Sector in National Determined Contributions

As a bottom-up treaty based on NDCs, the Paris Agreement does not in any way directly regulate the electricity sector (or any other sector for that matter). However, given the importance of the electricity sector to de-carbonization strategies and the increasing competitiveness of low carbon substitutes in the sector, it is not at all surprising that electricity is at the heart of NDCs. Generally speaking, NDCs come in three forms:

- Absolute economy-wide emissions reduction targets.
- Economy-wide relative emissions reduction targets, for example based on indicators such as GHG or CO_2 emission per unit GDP or a reduction relative to a counter-factual baseline.
- Quantified sectoral targets, for example in the land-use or energy sector.

Many countries have mixed and matched among these different types according to their policy preferences and national circumstances, selecting several targets across these types. For example, China has pledged to peak emissions before 2030, reduce the CO_2 intensity of GDP by 60%–65% by 2030 relative to 2005, and increase the share of non-fossil fuel energy in primary energy to 20%. Among such sectoral targets, the energy sector and the electricity sector in particular predominate. Altogether, 109 Parties included some form of quantified target for renewable capacity addition in their NDCs, which amount to a capacity deployment of some 1.3 Terawatt (TW) of renewable power capacity by 2030 (IRENA, 2017). Some 22 NDCs mention natural gas, some 7 mention clean coal, and 9 mention nuclear power as part of the envisaged mitigation strategies (WFC, 2016).

Several assessments have been made of the effect of NDCs not just on aggregate emissions pathways, but also on the underlying energy and electricity sector transition (Spencer T. e., 2015). These studies used a combination of country and region-specific energy system models, calibrated to the NDC targets for the energy sector. The results show that the targets in the NDCs "…accelerate and consolidate a significant transition in the electricity sector and in energy efficiency in the next 15 years, driving innovation and reduced costs". For six of the world's largest economies, the NDCs are estimated to reduce the carbon intensity of electricity by 40% by 2030 relative to today's level, while the low emissions share of electricity generation would increase by more than 10 percentage points from 30% to 41% (Spencer et al., 2015).[3] Under the NDC scenario, the penetration of low carbon electricity and variable renewables in particular, would need to reach a high share in major economies by 2030 (Figures4 and Figure 5).

Figure 4: Electricity mix in the European Union, NDC Scenario (EJ)

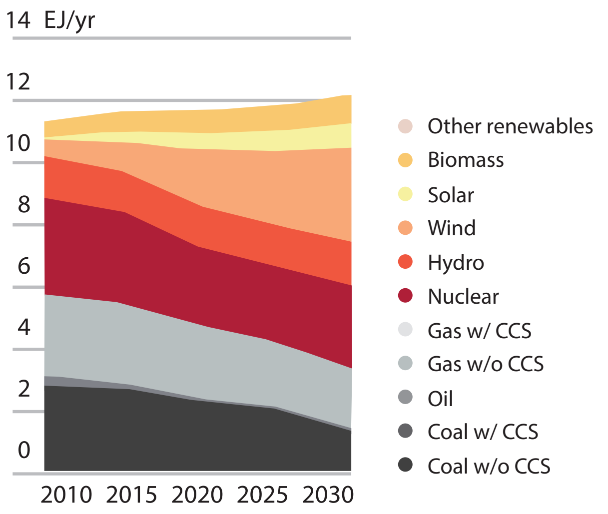
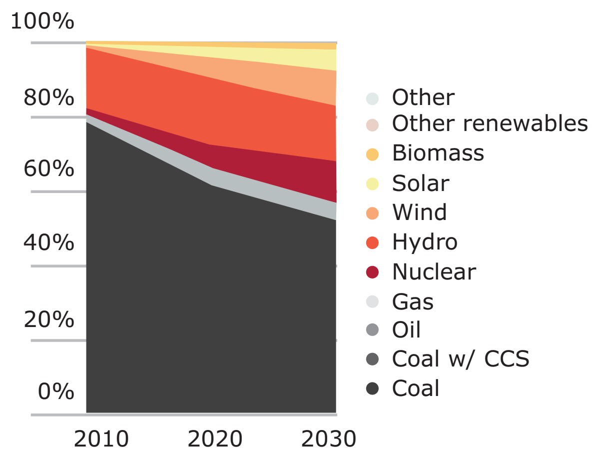


Figure 5: Electricity mix in China, NDC Scenario (% share)



Source: Deep Decarbonization Pathways Project (IDDRI & SDSN, 2015)

The NDCs are, however, insufficient to transform the energy sector in line with limiting warming to less than 2°C, and further policy action would be required to meet this objective.

2.4 Energy Transition Policy in Major Economies

As of 2015, the NDCs are only the international reflection of a dynamically evolving domestic policy context at the national level. This section aims to briefly set out some central trends of these domestic policies.

2.4.1 China

China's NDCs envisage a peaking of emissions by 2030, reduction in carbon intensity by 60%–65% by 2030 on 2005 levels, and a 20% non-fossil fuel share in primary energy. The 13thFive Year Plan sets out numerous energy sector targets to 2020 in line with these longer-term objectives and includes an absolute cap on coal use in primary energy (Spencer et al. 2016). Current policies focus on the introduction of a national carbon market, electricity market reform, and the improvement of the transmission infrastructure to integrate a large share of renewables far from load centres, among numerous other issues. Analysts have expressed the view that China is likely to overachieve its energy sector and climate targets by 2030, as the macro-economic transition characterized as the 'New Normal' leads to a sustained slowing of energy and electricity demand growth (Grubb, et al., 2015; Qi, Stern, Wu, Lu, & Green, 2016). This, coupled with continued strong build-out of coal, has raised concerns about the risk of 'stranded assets' in the coal-fired power sector (Spencer, Berghmans, & Sartor, 2017). Figure 5presents the projected electricity mix to 2030 under a current policies scenario; Table 1 shows a number of key electricity sector indicators for recent years.

Table 1: Key electricity sector indicators for China, 2010–2016

	Unit	2010	2016	CAGR
Hydro	TWh	722.2	1193.6	8.7%
Nuclear	TWh	73.9	212.7	19.3%
Wind	TWh	44.6	241.6	32.5%
Solar	TWh	0.7	77.8	119.2%
Coal	TWh	3239.7	4201.9	4.4%
CO_2 intensity of electricity production	gCO2/kWh	741.86	621.99	-2.9%
Share of renewables, including hydro	%	18.8%	25.4%	5.1%
Share of coal	%	77%	68%	-2.0%

Source: TERI based on data from (Enerdata, 2017)

[3] These economies were India, China, Brazil, Japan, US, and the European Union.

2.4.2 European Union

The European Union's (EU) NDCs entail an absolute reduction in emissions by 40% by 2030 compared to 1990 levels. At the EU level, this emissions target is part of a broader policy package that also includes targets for energy efficiency and renewables, namely an absolute reduction in final energy consumption of 27% by 2030 against a counterfactual baseline and a share of renewables in final energy of 27%. The EU is currently in the last stretches of a substantial policy process, involving the adoption of legislation on reforming wholesale and retail electricity markets, strengthening regulatory coordination at transmission system operator (TSO) and distribution system operator (DSO) level, boosting energy efficiency, strengthening the EU Emissions Trading Scheme (EU ETS), and facilitating interconnections and market integration across European Member States (European Commission, 2016 a).All these measures are intended to facilitate the energy and climate goals for 2030 by adapting markets and regulation to the new challenge of integrating variable renewables. Under current policy settings, before the additional impetus of these new policy frameworks, variable renewables are already expected to reach some 24% of gross electricity generation by 2030, a doubling from the 2015 level (European Commission, 2016b). Figure 4 depicts the expected electricity mix by 2030 under the NDC scenario; Table 2 shows some key electricity sector indicators for recent years.

Table 2: Key electricity sector indicators for the EU, 2010–2016

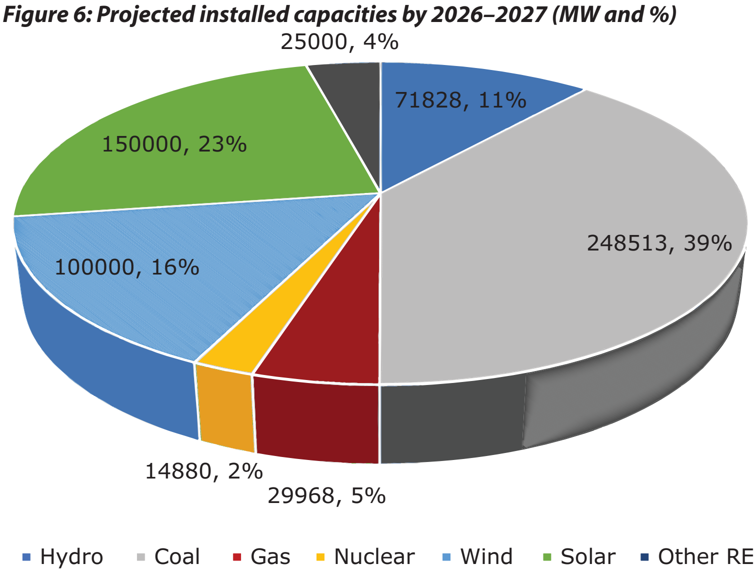
	Unit	2010	2016	CAGR
Hydro	TWh	408.0	381.8	-1%
Nuclear	TWh	916.6	839.6	-1%
Wind	TWh	149.4	299.9	12%
Solar	TWh	23.3	111.0	30%
Coal	TWh	861.4	736.7	-3%
CO_2 intensity of electricity production	gCO_2/kWh	332.3	286.6	-2%
Share of renewables including hydro	%	21%	30%	6%
Share of coal	%	26%	23%	-2%

Source: TERI based on data from (Enerdata, 2017)

2.4.3 India

India is still a lower middle-income country, with a GDP per capita just 40% of the global average and energy consumption just 35% of the global average. As such, the provision of energy access and affordability are key policy priorities. Nonetheless, the Government of India has embarked on an ambitious policy project. Non-hydro renewables should reach 175 GW by 2021–22, which would take the share of non-hydro renewables in electricity production from about 6% today to about 22% by 2021–22. This would be an unprecedented rate of expansion for a country of India's size and relatively lower economic development (for comparison, only the United Kingdom has experienced something close to this rate of expansion, with non-hydro renewables growing from 5.82% in 2010 to 22.86% in 2016). Other policy priorities include the provision of universal energy access (SAUBHAGYA Scheme), improving the financial position of DISCOMS (UDAY scheme), and building out the transmission infrastructure and regulatory institutions to support renewables integration (e.g. green energy corridors and regional renewable energy management centres). India is also developing an off-shore wind policy, and has in place a renewable energy certificate (REC) scheme which is intended to aid states in achieving their targets under the 175 GW national renewable target. This ambitious policy of renewables expansion is facilitated in part by falling costs: auction tariffs for solar PV have fallen from about 9 R/kWh to 2.5–3 R/kWh over the last five years, for example; while recent auctions have delivered onshore wind power at 2.62 R/kWh compared to the previous CERC regulated tariff

Figure 6: Projected installed capacities by 2026–2027 (MW and %)



Source: (CEA, 2016)

of 5 R/kWh. Integrating a large share of renewables can be expected to be a significant challenge, perhaps more so than aggregate costs in the medium term, given current cost trends. Figure 6 shows the projected installed capacity by FY2026–2027 across different technologies; Table 3 shows key electricity sector indicators for India in recent years.

Table 3: Key electricity sector indicators for India, 2010–2016

	Unit	2010	2016	CAGR
Hydro	TWh	123.1	139.1	2%
Nuclear	TWh	26.3	37.7	6%
Wind	TWh	19.7	50.1	17%
Solar	TWh	0.1	10.2	112%
Coal	TWh	658.0	1093.0	9%
CO_2 intensity of electricity production	gCO2/kWh	795.4	761.3	-1%
Share of renewables including hydro	%	16%	15%	-1%
Share of coal	%	67%	75%	2%

Source: TERI based on data from (Enerdata, 2017). N.B. while the share of all renewables has fallen somewhat from 2010–2016 (see chart) due to seasonal variability in hydro production, there share of non-hydro renewables has increased from 3.48% in 2010 to 5.98% in 2016.

2.4.4 United States

Federal policy on the energy transition has been rolled back under the Trump administration, including the flagship 'Clean Power Plan' (CPP). This was intended to support notably the retirement of older coal plants, the deployment of renewables, and energy efficiency. In the absence of federal level policy, the transition in the US electricity sector will depend on the economic competitiveness of different technologies (notably coal versus gas) and state policy. The economics of renewables are already highly favourable in the US, with unsubsidized levelized costs of electricity (LCOE) for utility-scale solar estimated at USD 46–53 and USD 30–60/MWh for wind, compared to USD 35–85/MWh for natural gas combined cycle, and USD 57–148/MWh for coal (Lazard, 2017).[4] In some cases for the US, the cost of new wind or solar is estimated to be lower than the generation costs of existing coal or gas (Lazard, 2017). Thus, market-driven deployment of renewables is expected to continue at a significant rate. Table 5 shows that the removal of the CPP is not likely to have a significant impact on the deployment of renewables by 2030. Renewables generation is expected to roughly double by 2030, reaching about 22% of total generation. On the other hand, the scrapping of the CPP is expected to slow the rate of retirement of old coal capacity, and its substitution with natural gas (Table 5). **Thus, a market-driven transformation of the US electricity market can be expected to continue, despite the recent federal policy decisions.** Table 4 displays key electricity sector statistics for the US in recent years.

Table 4: Key electricity sector statistics for the United States, 2010–2016

	Unit	2010	2016	CAGR
Hydro	TWh	286.3	290.2	0.2%
Nuclear	TWh	838.9	839.5	0.0%
Wind	TWh	95.1	229.3	15.8%
Solar	TWh	3.9	55.6	55.5%
Coal	TWh	1994.2	1350.0	-6.3%
CO_2 intensity of electricity production	gCO_2/kWh	516.74	422.37	-3.3%
Share of renewables including hydro	%	10.6%	15.3%	6.3%
Share of coal	%	46%	31%	-6.1%

Source: TERI based on data from (Enerdata, 2017)

[4] Upper end of the range for coal includes CCS.

Table 5: Impact of the CPP on the electricity generation mix in the United States (TWh)

	2015	2030	
		Reference scenario	Reference scenario without CPP
Coal	1354.5	1023.9	1421.8
Petroleum	27.9	10.3	12.0
Natural Gas	1340.6	1498.5	1344.1
Nuclear Power	797.2	768.0	768.0
Renewable Sources	559.8	1114.4	1030.9
Other	19.9	26.5	26.4
Total Net Electricity Generation	4099.8	4441.6	4603.2

Source: TERI based on data from (EIA, 2017)

2.5 Conclusions

The electricity sector is crucial to addressing climate change, both due to its role as a source of emissions and its potential for de-carbonization on the supply side and demand side (electrification). The Paris Agreement represents a significant step forward on climate change: its universal,[5] flexible, and dynamic architecture is well suited to addressing a complex, evolving problem like climate change. It is likely that the dynamism built into the Paris Agreement will lead to progressive strengthening of global efforts on climate change in the coming years. However, a brief look at the energy transition policy in major economies reveals that the global framework on climate change and NDCs are only the tip of the iceberg. At the national level, development imperatives, declining costs, as well as the global objective of mitigation of climate change are driving a rapid and deep transition in the electricity sector. While NDCs provide a useful indicator of policy ambition as of 2015, they are more static than technology, markets, and policies at the national level.

[5] At least until the announced withdrawal of the US effective in 2020, the Paris Agreement has universal participation.

3. OTHER ENVIRONMENTAL IMPACTS OF THE ELECTRIC UTILITY SECTOR

3.1 Introduction to Environmzental Externalities of the Electric Utility Sector

The electric utility sector is responsible for a number of environmental impacts other than climate change, which are discussed in this section. Table 6 provides an overview of these impacts.

Table 6: Environmental externalities of the electric power utilities sector

Pollutant or externality	Source	Impacts	Mitigation and management	Impact on utility business
Air pollution				
NOx, SO2, Particulate Matter (PM), O3, Hg.	Fossil fuel combustion in power plants, particularly coal	Ecosystem damage, smog and acid rain, Decrease in crop productivity, increased human morbidity and mortality	National regulatory regime and laws, Regional air pollution control treaties, Global treaties, such as Minimata Convention on Mercury	Costs of implementing technology solutions, environmental management costs in siting of power plants.
Solid waste				
Waste sludge	Coal mining	Pollution of rivers and water bodies, Leaching into land	National regulation and laws, implementation of safe mining guidelines	Cost of disposal and management
Fly ash	End of operations	Pollution of land and water and air	Waste utilization, disposal, management, and reduction	Cost of disposal and management, potential economic benefits from reuse
Disposal and recycling of materials, e.g. PV panels	End of operations	Pollution of land and water	Waste disposal, management, and reduction.	Cost of management
Water use and pollution				
Water withdrawals for cooling (thermal power), cleaning (PV), etc.	Operations	Depletion of scarce resources	Dry cooling technologies	Cost of management and resource management
Water pollution, including thermal pollution	Operations	Heating of local water bodies, change in flora and fauna	Technology to recover heat	Cost to operations, and Lower residual heat leading to poor recovery
Land-use				
Land-footprint of infrastructure and allied activities like mining	Operations	Change in land-use, loss of forest land, land degradation, change in land ecology	Avoidance of eco-sensitive and forest land. Avoidance of common property and agricultural land. Land restoration after mining	Cost of land restoration, compensation for land acquisition and conversion
Impact on community	Operations, siting and construction	Health impacts, impact on access to land and forest resources, livelihoods and displacement of communities.	Avoidance of eco-sensitive areas, adequate compensation and rehabilitation and restoration	Cost of land, compensation and time delays in land acquisition

Source: TERI Analysis

A detailed treatment of local air pollution, water, and land related impacts from electricity generation are presented hereinafter.

3.2 Local Air Pollution

The power sector makes a significant contribution to air pollution levels worldwide. It is one of the major sources of generation of SO_2 emissions (one-third of the global total), 14% of nitrogen oxides and 5% of total particulate matter 2.5 (PM 2.5) (IEA, 2016). Over the years of 2005–15, a decoupling between growth of coal-powered plants and emissions of SOx, NOx, and PM levels has been observed, primarily due to stringent emission norms introduced in many countries. Table 7 provides a collation of policy and emission standards for new and existing plants for various countries and regions including India, China, the EU, and the US (IEA, 2016a).

Table 7: Air Quality Standards for thermal power plants in different countries

Region	Policy	SO2		NOx		PM	
		Existing	New	Existing	New	Existing	New
China	Emission standard of air pollutants for thermal power plants	200-400	100	200	100	30	30
European Union	Industrial emissions directive	200-400	150-400	200-450	150-400	20-30	10-20
United States*	New source performance standards	160-640	160	117-640	117	23	23
India	Environmental (Protection) Amendment Rules 2015	200-600	100	300-600	100	50-100	30
Indonesia	MoE decree no 212008	750	750	850	750	150	100
Japan**	Air Pollution Control Law	-	-	123-513	123-513	30-100	30-100
Mexico***	Mexican Official Standard NOM-085-ECOL-1994 (in PPMV for SO2 and NOx)	550-2200	30-2200	110- 375	25- 375	60- 450	60- 450
Philippines	National Emission Standards for Particulate Matter for Stationary Sources	1000 -1500	200- 700	1000-1500	500-1000	150- 200	150-200
South Africa	The Minimum Emission Standards are published	3500	500	1100	750	100	50
Korea	Special measures for metropolitan air quality improvement	286	229	308	164	40	20-30
Thailand	Royal Thai Government Gazette	700-1300	180-360	400	200	80-320	80
Vietnam	Industrial emission standards for dust and inorganic substances	1500	500	1000	650-1000	400	200

Notes: 'Existing refers to the emission limit for currently operating power plants. 'New' refers to the limit for planned or proposed plants. * US emission limits were converted from lb/MBtu to mg/cum assuming an F-factor of 1800 standard cubic feet of CO2 and a CO2 content of 12% in the flue gas. ** Japan's Air Pollution Control Law (APCL) specifies emission limits for SOx, NOx and PM that differ depending on the scale.

Source: (IEA, 2016a). It should be noted that in the case of India, even existing plants have to conform to the new norms.

Technology plays an important role in mitigating environmental impacts from thermal power plants. Various technologies that can be employed in power plants for mitigating air pollution are enumerated in Table 8. The use of clean coal (e.g. coal beneficiation or low-ash coal) and substituting gas for coal in thermal power plants are other measures for mitigating adverse environmental impacts. However, this is significantly dependent upon, as evident from the case in China and India, the availability of natural gas and low-ash coal in the country.

Table 8: Mitigation technologies

Pollutant	Mitigation Technology	Type of technology	Abatement efficiency
SO_2	Wet flue-gas desulfurization spay drier absorption	End-of-pipe End-of-pipe	70%–98% 50%–70%
NOx	Low and ultra-low- NOx burners Selective catalytic reduction Selective non-catalytic reduction	Integral to the combustion process End-of-pipe End-of-pipe	20%–30% 90% <50%
PM2.5	Fabric filtration Electrostatic precipitators	End of pipe End of pipe	>99% >99%

Source: (IEA, 2016a)

Box 1: Air pollution control in China and India

China and India are recognized to have the largest disease and economic burden from air pollution in the world. It should be noted that the electricity sector is only one source of local air pollution, with the industry sector and land-use sectors being prominent sources in China and India, respectively.

In China, during the 11th Five Year Plan (2006–2012) new instruments were introduced and the national goal of reducing total sulphur-dioxide (SO2) emissions by 10% was achieved. However, regional compound air pollution problems, dominated by fine particulate matter (PM2.5) and ground level ozone (O3), emerged and worsened. After the winter-long PM2.5 episode in eastern China in 2013, air pollution control policies have been experiencing significant changes on multiple fronts. Strategies, such as shifting districting heating and some power stations within cities to gas; implementing end of pipe abatement technologies; and increasing power import from remote generating stations in the Western region of the country, have been employed. However, as Tsinghua University notes, "Simply relying on end-of-pipe regulation will not be sufficient to tackle the air pollution problem in China. Even with the strictest end-of-pipe treatment measures, almost half of Chinese cities risk failing to meet air quality standards in 2030" (Tsinghua University, 2014). Thus, the major arm of the strategy to address local pollution consists in a broad-based energy transition to energy efficiency, electrified end-uses and low-carbon generation technologies. Numerous studies show that there are significant co-benefits from such an energy transition strategy for China (Spencer T. e., 2015).

In India, in the first half of 2015, the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, issued drafts of stricter norms for emissions and water consumption for coal-based thermal power sector. According to the new norms, thermal power plants are expected to cut emissions and usage of water significantly. The table below outlines the emissions norms set out.

1.1.1.1 Mg/Nm3	Unit size	Installed before end 2003	Installed 2004-2016	Installed from 2017
PM	All	100	50	30
SO2	<500 MW	600	--	--
	>=500 MW	200	100	100
NOX	All	600	300	100
Hg	All	0.03 (>500 MW)	0.03	0.03

However practical difficulties have been reported in compliance of these norms. The practical difficulties include lack of space for retrofitting new equipment, lead time for procurement, phased installation and implementation that is needed to maintain supply of electricity, and the challenge of finance in competitively bid projects (Bhati, 2017). In meeting these norms, it is envisaged that upwards of 34 GW of coal capacity may need to close, where retrofit is not feasible or economic (Bhati, 2017). CPCBs and SPCBs in India, responsible for enforcement of these norms, may find the need for further institutional and resource capacity enhancement for strict enforcement of these norms. In view of the practical difficulties MOEFCC has extended the timeline for compliance of emission standards for thermal power plants ranging upto 2022. Other initiatives taken in India to improve efficiency of coal power plants and reduce their environmental impacts include mandatory requirement of all new ultra mega power projects plants to be based on super critical technology from 1st April 2017 (MoP, 2015).

Source: TERI

3.3 Land-Use and Water Impact of the Electric Utility Sector

A huge environmental impact of coal power is the fact that extensive coal mining causes environmental pollution. Some of the serious environmental problems caused by coal mining include diversion of farmland and local ecosystems and damage to land resources. Coal-fired power generation requires a large amount of water and generates significant waste water. Water has been identified as a risk in both mining and running of coal-fired utilities. The water-energy nexus is well known. Apart from challenges of water pollution and discharge, scarcity and competition with local communities in water use and abstraction is another aspect that requires attention. Table 9 provides an overview of the amount of water required for conventional coal power plants with different types of cooling systems.

Table 9: Water requirement in coal power plants for cooling

	Once-through		Recirculating		Dry-cooling	
	Withdrawal	Consumption	Withdrawal	Consumption	Withdrawal	Consumption
Coal (conventional)	20,000–50,000	100–317	500–1,200	480–1,100	N/A	N/A
Water withdrawn and consumed for cooling, in gallons of water required per megawatt-hour of electricity produced.						

Source: (J. Macknick, 2012)

In the case of power from hydroelectric sources, flooding land for a hydroelectric reservoir has extreme and permanent environmental impacts insofar as it may destroy forest, wildlife habitat, agricultural land, and scenic lands. The regulatory environment for land and water and its impacts on utilities is presented hereinafter for China and India.

3.3.1 China

In 2012, mining areas covered around 2 million ha in China, an area expanding by 33,000 to 47,000 ha every year. However, only 15% of land is being reclaimed and restored after the completion of mining activities (Hub, 2014) , thus, leading to eventual loss of livelihood and relocation of local population. China passed the Land Restoration Regulation in 2011 aiming to increase the rate of land reclamation for coal mines. Apart from use of land, coal mining leads to ecological damage, leaching of chemicals into the soil, and transfer of sludge and chemicals to water bodies. The 2011 regulation therefore now includes plans to rehabilitate, restore, and redesign the degraded mined land as part of the mining plan. Funds need to be secured for rehabilitating the land. The financial and planning impact lies with the mining companies, and is eventually transferred to the cost of coal. An example is Hulunbeier located in north-eastern Inner Mongolia in China, which produces 30 million tonne coal per year, where from 2006 to 2012, the Shenhua Group invested more than 112 million RMB (~US$18.7 million) to reclaim mining sites throughout the Baorixile coal mine area. The reclaimed land has a huge positive impact on local communities and the environment.

Land, community, and ecology can be impacted by construction of large dams. China has its share of dams and hydropower generation and by 2020, China plans to nearly triple its hydropower capacity to 300 Giga Watt (GW). The impacts have been more on the community, surrounding land, geology, ecology, and waterways rather than on the utility businesses in China. In many instances, such as the Three Gorges Dam in China, entire communities have also had to be relocated to make way for reservoirs. Nearly 1.2 million people in two cities and 116 towns clustered on the banks of the Yangtze have been moved with very little compensation (Hvistendahl, 2008).

Regulations and licensing for abstraction of water is evolving in China and the risk to utility businesses is that the framework for regulation is not well coordinated and implemented. In China, the Ministry of Environment Protection (MEP) is responsible for protection of water resources. According to IRENA & China and Water Risk, 2016, coal and water resources are unevenly distributed across China's landscape. Northern provinces, for instance, hold only 25% of renewable water resources but account for 51% of thermal power generation, 82% of coal production, and 86% of coal reserves. This increases risks to water supply and intensifies competition for limited water resources with sectors, such as agriculture. China has incorporated two plans, the 'three red lines' plan for 2030 and the 'water for coal' plan. The 'three red lines' plan considers water use, efficiency, and ambient air quality. The water for coal plan provides that future coal plants be developed in consultation with water utilities implying the use of closed and dry cooling methods.

3.3.2 India

Land acquisition, from a utility perspective, poses an increasingly significant challenge in the Indian power sector, particularly for hydropower. Power plants and utilities have been facing delays in acquiring possession of land and obtaining the requisite environmental and other clearances for projects. In addition, it has been reported that in some cases, even after land owners were asked to sell and handover their land in 'public interest', the project could not be completed for several years due to other delays. Consequently, there is a significant mismatch of expectations from the Project Affected Persons (KPMG, 2010). Areas that are abundant in coal are often inhabited by tribal communities in India. The acquisition of land for coal is governed by the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013; Coal Bearing Areas Act, 1957; the Environment Protection Act, 1986; and the Forest Rights Act, 2006. From the perspective of the land owners or inhabitants, many times acquisition can cause serious disruption and unfair compensation. This mismatch in expectation of the local residents, government compensation packages, and project developers over rights and livelihoods can cause agitations and time delays leading to financial losses.

Currently in India, renewable energy power plants are exempt from environment clearance. Wind farms in coastal areas are subject to Coastal Regulation Zone (CRZ) rules. Wind farms in forest land are subject to clearance from the Forest Departments. Land acquisition for renewable energy, including solar power plants, is subject to the above acts including Forest Acts.

All thermal plants with once through cooling are subjected to new norms specified in 2015 to achieve specific water consumption of 3.5 m^3/MWh within a period of 2 years from December 2015. The Environment (Protection) Amendment Rules, 2017, states that the specific water consumption shall not exceed maximum of 3.0 m^3/MWh for new plants installed after the 1 January, 2017, and these plants shall also achieve zero waste water discharge. These new norms have a cost implication due to the required change in technology for reuse of water, including construction of pipes, pumps, and water recovery, which will be added to the power generation cost for each power plant.

3.4 Conclusions

The above discussion highlights the multiple environmental impacts of the electric utility sector, from climate change, local air pollution, water consumption, and land use. These impacts in turn are being addressed by the social and environmental regulatory measures of each country in ways that have and will increasingly exercise a material impact on the electric utility sector. Of course, these drivers will occur in conjunction with other drivers, such as technology change. We have identified a number of these impacts in Table 9.

Table 9: Categorization of impacts on the electric utility business model

First order impacts	Second order impacts on the utility sector
A shift in the generation mix to increasing shares of renewables	▪ Increased competition from new entrants, e.g. distributed energy resources ▪ Decline in wholesale market prices in liberalized markets ▪ Increasing importance and market value for flexible operation of conventional power plants ▪ More complex grid management between the transmission and distribution segments with the emergence of distributed energy resources and the importance of demand-side management ▪ Potential risks of impaired or stranded assets ▪ Social impacts like change in jobs to RE sector and perceived job losses in the coal industry ▪ Impacts on land use and land use change due to land acquisition for RE projects ▪ Positive impacts on health due to decreased pollution, reduced health costs, increased longevity, and life expectancy.
Implementation of best available technology and end of pipe abatement technologies to address local air pollutants, and eventually CO_2 (e.g. CCS)	▪ Investment cost and operational impacts; risk perceptions and socio-economic feasibility (e.g. around CO_2 leakage)
Increasing implementation of energy efficiency regulations and accelerated technology learning on energy efficiency	▪ Lower than expected demand growth, declining wholesale prices ▪ New business opportunities in energy management
Implementation of policies to promote electrification of end-uses (e.g. electric vehicles)	▪ New sources of demand growth ▪ New business segments in the provision of energy services in new end-use sectors
Fiscal policies such as taxes or carbon trading schemes	▪ Net incremental cost if costs cannot be passed onto consumers ▪ Change in the relative competitiveness of technologies, e.g. coal versus gas.

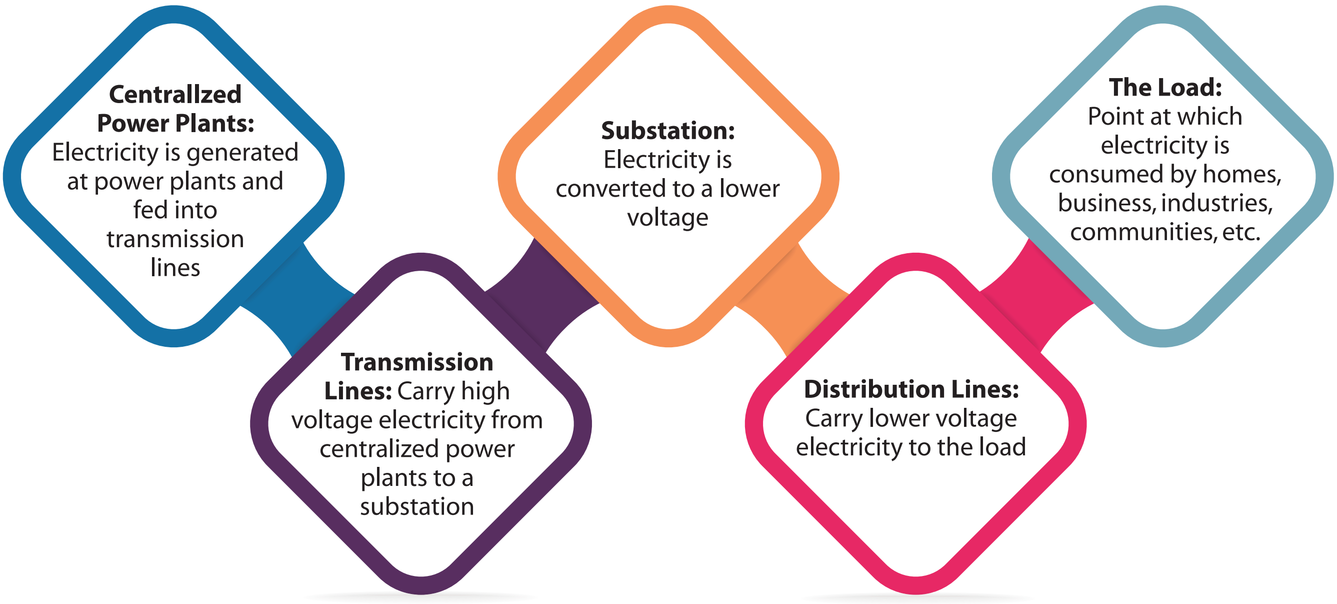
Source: TERI Analysis

The trends and impacts described in Table 9 are not solely to be ascribed to environmental regulation, nor are impacts solely on the fossil fuel side of electricity generation. More importantly, policymakers and corporate strategists should be mindful of the links between environmental regulations and more endogenous change within the sector, driven, for example, by technology change. The following section seeks to elucidate some of the impacts of the primary and secondary impacts on the electric utilities sector.

4. IMPLICATIONS FOR FUTURE BUSINESS MODELS FOR THE ELECTRIC UTILITY SECTOR

The global electric utility industry is poised to experience significant change, in view of stricter air quality requirements, climate change and energy transition strategies, and technology innovation. The consequence of these drivers will be a shift away from the traditional model of the electricity sector. This model is characterized with bulk production in large-scale power plants fuelled by fossil fuels, nuclear, or hydro, and nearly one-way flows from production, to transmission, to distribution, to passive consumption. A schematic representation of this traditional model is presented in Figure 7. A number of changes in the electricity sector will bring disruption to this model: i) emergence of decentralized generation resources, implying greater two-way coupling between the transmission and distribution sectors and diversity and complexity of production mixes; ii) introduction of zero-marginal cost, variable renewables and their influence on scheduling and dispatch of power from conventional power stations; iii) transformation of the demand-side in view of potential for demand-side management and the electrification of new end-use sectors.

Figure 7: The traditional electricity model



Source: (WRI, 2016)

Though external factors, such as rapid cost reduction in renewable energy technology and climate policy, will influence this transition at the global level, country-specific political, social, economic, technical, and financial characteristics will determine the path this transition could follow. Demand growth scenarios will be very different in developed and developing countries. The potential of integration of renewable technologies also differs widely across the countries. Some countries have abundant solar and wind resources located close to load (e.g. India and Mexico) while others have abundant wind and solar far from load (e.g. the US and China). Different countries have followed different models in the design of their electricity markets, notably with respect to deregulation and liberalization.

Zinaman *et al.* (2015) presented a typology of five potential archetypes of electricity transition in the face of increased cost-competitiveness of RE and regulatory interventions to deliver environmental and other socio-economic goals. The key determinant of the archetype is the current starting point of the sector in terms of its regulatory structure and market design, in particular regarding the degree of deregulation and liberalization. A brief description of the different pathways is provided in Table 10. **While an in-depth discussion of the proposed pathways is not a point for deliberation here, the table serves to illustrate the point that environmental-policy impacts on utility business models will differ**

depending on the existing power market design and the regulatory strategy undertaken to facilitate environmental objectives and the integration of new technologies such as RE, storage or Demand Side Management (DSM).

Table 10: Archetypes of electricity sector transition pathways

Current market design	Transition pathway	Characteristics of the pathway
Vertical integration - little or no power market restructuring (liberalization and deregulation) - utility as single buyer	"Next generation performance based regulation"	Regulatory framework shifts towards encouraging performance against multiple socio-economic goals, including energy saving and emissions abatement Adaptive shift, rooted in cautious incrementalism
	"Clean restructuring"	Power market liberalization and deregulation, incorporating new elements to promote achievement of environmental goals, such as forecasting and dispatch optimized for clean energy integration This pathway represents a reconstructive shift from the regulated centralized utility paradigm to decentralized & distributed generation resources with potential for significantly different power flows in terms of quantum and direction
Restructured market - intermediate/high levels of power market restructuring - independent system operator	"Unleashing the Distribution System Operator (DSO)"	DSOs are transformed into distribution-level retail market operators who use dynamic price signals to invite consumers, marketers, and other service providers to participate. These low-voltage markets coordinate with bulk power markets on both a technical and financial basis This pathway represents an evolutionary shift—a gradual yet fundamental change—from a narrow set of utilities, system operators, and IPPs to a thriving ecosystem of diverse market actors.
Low energy access - unreliable, limited or no access to electricity - Can occur in either vertical integration or restructured market settings	"Bottom up coordinated grid expansion"	The design of this pathway couples the incremental pace of central grid expansion with comparatively fast, affordable, and innovative expansion of community-scale mini-grid systems. The key design innovation in this pathway is technical and regulatory backwards compatibility of mini-grids to the central grid. Ideally, mini-grid systems are planned, regulated and financed in a coordinated manner with central grid systems.
	"Bundled community energy planning"	While community-scale energy services are typically organized in one of four commercial models (community, utility, private, and hybrid), fragmented energy services operate in product-based markets

Source: adapted from (Zinaman, et al., 2015)

With the above analytical framework in the backdrop, the following sections detail some of the potential impacts of environmental regulation on the utilities sector, starting with the upstream generation sector and moving onto the downstream distribution.

5. UPSTREAM: GENERATION, POWER MIXES, AND WHOLESALE MARKETS

5.1 Change in Generation Mix

Historically, the fuel mix of global electricity generation has been dominated by the use of fossil fuels. More than half of the world's electricity demand is met with generation from thermal power plants. However, there is inevitable rise of concerns around climate risk while considering the future electricity supply mix in the power sector. The future electricity supply mix will change significantly and renewable technologies will dominate not only investments but also generation in the power sector.

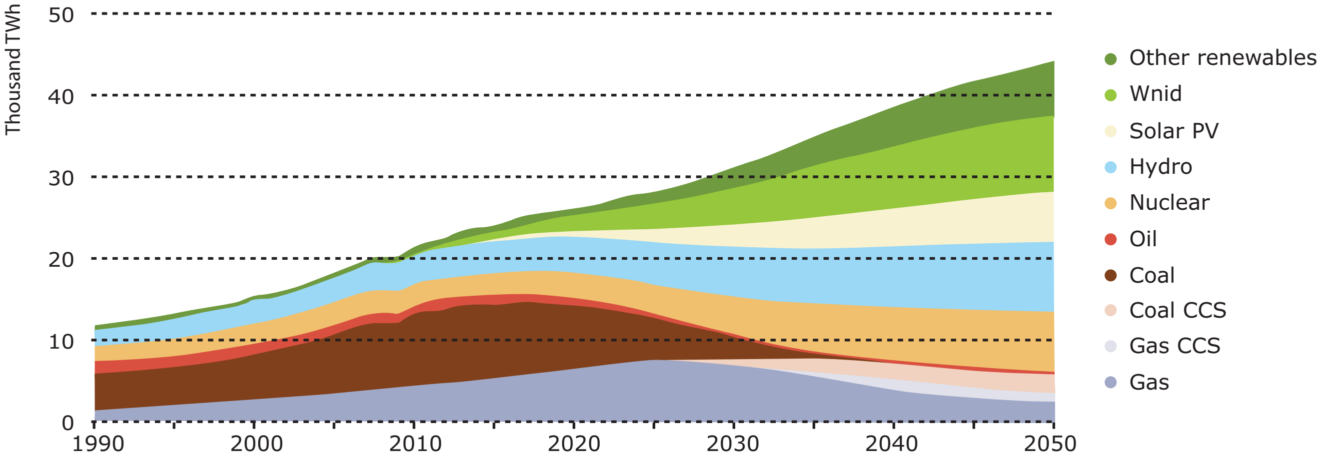
In the last two years, renewable capacity addition accounted for 63% of the net total capacity addition globally, which is greater than any other source in the power sector (IEA, 2017b). Renewable technologies contributed almost 40% of the growth in power generation in 2016. At the global level, over the last 10 years, solar PV capacity has increased from 6GW (2006) to 303 GW (2016), while during the same period wind capacity s also increased from 74 GW to 487 GW (IEA, 2017b). Along with this significant increase in the capacity of renewable technologies, this period is also characterized by increased competitiveness of renewable energy technologies driven by sharp declines in the cost of technology, supportive policy regime, and sustained global efforts towards cleaner technologies. According to REN 21 global trend analysis, installation costs of utility-scale solar PV projects fell by 65% and those of wind projects by 18% in the last ten years. The global report predicts average growth of 2.5% to 3% per annum till 2040 for renewable technologies which eventually will substitute the fossil fuel generation in long run (IRENA O. a., 2017).

The IEA scenario predicts that RE will capture two-third of future investments in the electricity sector in future. All future global energy scenarios predict multi-fold increase in renewable capacity substituting fossil fuel-based capacity addition. Further, a number of countries have started pricing environmental externalities caused by fossil fuel projects, which will make these projects less competitive, as compared to renewable projects.

IEA and IRENA in their report titled *Perspective for the Energy Transition* published in 2017 (fig.8), under scenario of restricting global temperature below 2°C with 66% probability predict a significant decline in the demand for all types of fossil fuels. According to the report, in order to keep pace with the overall emissions targets of the 66% 2°C Scenario, unabated coal-fired power plants, i.e. those without CCS, would need to be phased out as soon as possible.

Under the low carbon development path, many countries would have to phase out the least-efficient coal-fired power plants soon. In many cases, these plants may result in stranded capacity by retiring prior to reaching the end of their technical lifetime, while existing highly efficient coal-fired plants will continue to generate electricity for a longer period of time.

Figure 8: Global Electricity Generation by Source in the 66% and 2°Cscenario



Notr: TWh - terawatt-hours; CCS - carbon capture and storge

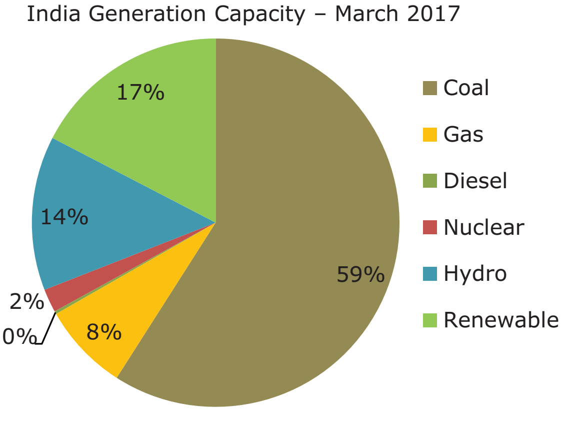
Source: (IRENA O. a., 2017)

5.1.1 Differences between Developed and Developing Countries

While the above picture of the progressively increasing role of cleaner sources of generation holds, generally speaking across countries, the precise pathway taken by capacity mixes will depend on country-specific policy preferences, resource endowments, and load growth scenarios. Several fundamental differences between developed and developing countries stand out. Firstly, while load-growth has been stagnant or falling for developed countries, it is expected to grow strongly for developing countries, given their lower current levels of consumption. This means that while clean sources of generation are expected to play an increasing role, a number of developing countries are considering additional investments in fossil capacity. Secondly, generally speaking, the production mixes of developed countries tends to be more diversified and, on average, cleaner than that of developing or emerging countries. For example, the carbon intensity of electricity production of OECD countries is some 31% lower than that of non-OECD countries (Enerdata, 2017). Thus, the penetration of cleaner electricity sources will go further and faster in developed than developing countries. Two case studies, one from a developed and one from a developing country, are presented hereinafter to briefly elaborate the impact of environmental regulations along with the push for more renewables in energy mix on the business plan of the generation utilities.

Case Study of NTPC, India

India, like many other developing countries, has been dependent on fossil fuel generation for some 82% of its electricity production (Enerdata, 2017). State-owned electricity utilities have played a critical role in India's rapid economic development. India's electric utility, NTPC Ltd. provides around 25% of India's electricity supply and is amongst the top 10 coal-fired power generators in the world. The company owns around 50GW of the generation capacity in the country. With its strong balance sheet, the utility is now looking to lead the transformation of the future energy mix by diversifying its generation portfolio from conventional to non-conventional sources of energy generation.



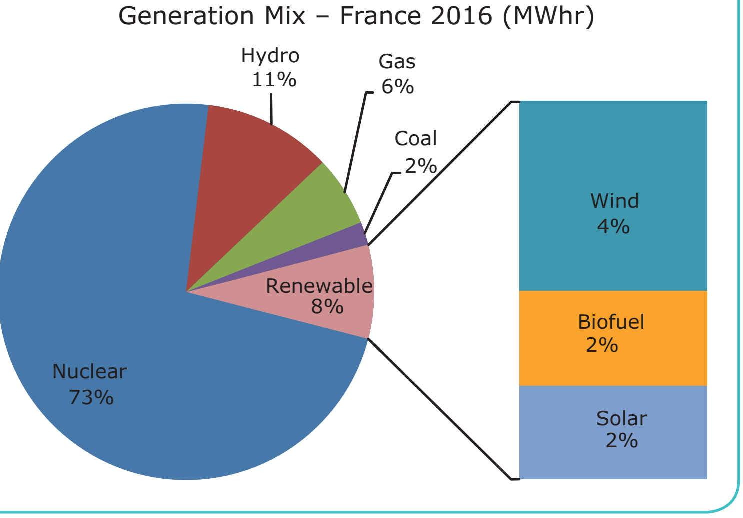
In addition, in order to comply with the new environmental norms forthermal power plant specified by Ministry of Environment, Forest and Climate Change, Government of India, in 2015, NTPC is planning to close down 11GW of its old and less efficient thermal capacity.[6] On the other hand, with less increase in demand than expected, plant load factors of many thermal power plants of NTPC are declining, although they are significantly higher than the all-India average. NTPC, anticipating future investment in renewables instead of conventional technologies, has started diversifying its generation mix to include renewable technologies.

Accordingly, NTPC has set an ambitious goal of contributing 10 GW of solar capacity to the overall 100 GW target of the Government of India along with an initial wind power target of 1 GW by 2022. NTPC is changing as it rapidly rolls out in-house, utility-scale solar projects and signs power purchase agreements for off-take of solar power from private solar operators. The organization has also begun entering the vehicle-mobility sector by setting up charging stations for electric vehicles.

Case Study of Électricité de France (EDF), France

France has a low carbon electricity mix, with more than 70% of electricity generation from its nuclear fleet. The share of renewable energy has increased from 3% to 8% in total electricity mix in the last decade.

France has put in place an energy policy framework for the energy transition to green economic growth towards 2030. The new framework reflects France's international climate change ambitions and leadership at COP21. The Energy Transition for Green Growth Act 2015 represents the legal framework of energy transition in France, and establishes diversification of the energy mix as one of the main five principles. The electricity industry in France is facing financial uncertainly and securing the future investment for the transition is a significant challenge facing French



[6] http://pib.nic.in/newsite/PrintRelease.aspx?relid=155395

utilities. The Act envisages a reduction of greenhouse gas emissions by 40% by 2030, a renewables share of 32% in gross final energy consumption and 40% of total electricity generation by 2030, a reduction of the nuclear share in the electricity mix down to 50% by 2025 and capping the installed capacity of nuclear power at the current level of 63.2 GW. However, recently, based on the Generation Adequacy Report of RTE,[7] the transmission system operator, the French Government has extended the commitment of reducing the nuclear share citing risks of supply shortages after 2020.

Électricité de France (EDF) is the biggest utility in France wherein the majority is owned by the Government of France, involved in generation, distribution, and construction of power plants. Its electricity generation consists of 64.3% nuclear, 12.4% renewable energy (including hydro), 8.3% gas, and 14.5% coal. Under the Energy Transition Law enacted by the French Government, 17 nuclear power reactors operated by EDF would be decommissioned to achieve the target of reducing dependency on nuclear generation.

Against the backdrop of the energy transition, EDF has defined a strategy known as CAP 2030[8] which aims at being an efficient, responsible electricity company that champions low-carbon growth. Under this strategy, EDF plans to double the Group's net installed power in the field of renewable energies, thus increasing from 28 GW today to over 50 GW in less than 15 years. The utility is also investing in the modernization and performance optimization of this hydroelectric fleet to minimizing the environmental impact of development.

5.2 Impact on the Power Market and its Operation

In countries with well-established liberalized wholesale electricity markets, an increase in renewable generation would play a significant role in determination of the wholesale price of electricity. With increase in the share of renewables, the number of decision-making units would increase significantly, with investment and production decisions made at much smaller scale than in the past. Earlier markets characterized by oligopoly would be changed to more distributed, competitive, and complex markets.

The negligible marginal cost of generation from renewable technologies would have impact on the merit order dispatch, if dispatch takes place according to marginal prices in a wholesale market. Renewable generation would get preference over generators from conventional technologies (Mulder, 2017). This means that generation from conventional sources may have to be backed down significantly due to higher marginal costs, which may not only affect their revenue but also financial viability in long run. Further, as the generation from renewable sources depends on weather conditions, this may create a situation where electricity will be offered when prices are low which may result in profile shift with significant variation in electricity price from day to day and week to week market. (Rintamäki*et al.*, 2017)

Thus, the impact of increase of renewable energy sources may cause a reduction in profit margins due to increased competition and high price volatility in liberalized wholesale electricity markets. This may create uncertainty in the market where some utilities may be threatened to recover their cost of generation.

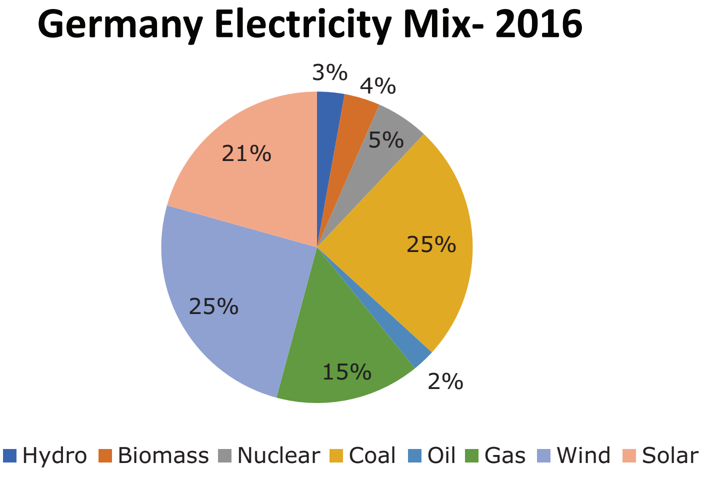
5.2.1 Differences between Developed and Developing Countries

However, it is worth noting that this effect depends on the characteristics of the power market, its competitiveness, and composition of overall energy mix along with respective government's policies towards renewable technologies. In developed countries where the power market is well developed, this will lead to greater incentive among generation sector to reduce cost of generation and eventually reduction in the electricity wholesale price. In Germany and Netherlands, for example, the electricity market has become more competitive with increase in renewable share (Hirth, 2015). According to media reports, wholesale electricity prices in Europe have slumped from around €80 a megawatt-hour in 2008 to €30–€50 in 2016.[9]According to the assessment of EY, utilities across Europe wrote off €120bn of assets because of low power prices between 2010 and 2015. An example of this kind of challenge is provided with the case study of Germany, as enumerated in the box below.

Germany is one of the most ambitious EU countries in integrating the high renewables in the systems. It has already reached a 30% share and targets 35% by 2020. It has already formulated its objectives for 2050 in which 60% of its total energy consumption and 80% of its total electricity consumption should come from renewable sources. Germany has modified its balancing and intra-day electricity markets to provide greater flexibility for renewables. Both of these markets provide additional power on short time framesto handle the imbalances between supply and demand that might occur as renewable output varies. The market rules and designs have improved flexibility, opened the markets to more participants, allowed for faster balancing and ramping responses, and made it easier for demand response.

7 http://www.rte-france.com/sites/default/files/bp2016_complet_va.pdf
8 https://www.edf.fr/sites/default/files/contrib/groupe-edf/espaces-dedies/espace-medias/dp/dp_201603_cap2030_va.pdf
9 https://www.economist.com/news/briefing/21717365-wind-and-solar-energy-are-disrupting-century-old-model-providing-electricity-what-will

However, incidents are observed where high renewable generations have caused electricity market prices to decline in Germany even go to zero or negative. The profitability of Germany's coal-fired power stations declined rapidly as they were pushed down in dispatch merit order by the renewable energy capacity with zero fuel costs. Wholesale power prices declined 55%from 2011 to 2016 in Germany. The result has been havoc for the old-style utilities. Germany's biggest electricity companies, RWE and Eon, have taken massive write-downs on their coal and gas-fired power stations, which barely break even at such prices. RWE has shut down 12 GW of its capacity and has reported declining revenues over the past five years. E.ON is also facing costs related to the shutdown of its nuclear capacity. In addition to this, both utilities are also facing additional pressure of complying with the new EU regulations on power plant emission which includes new limits on nitrogen oxide and mercury (Tim Buckley, 2017).



E.ON and RWE, both split into two entties last year, separating their renewables and grid businesses from indebted and loss-making conventional generation. E.ON spun off its assets into new company, Uniper, in 2016 after stock market reaching record low price for its share, while RWE spun off its renewable assets in new company, Innogy, while holding its thermal capacity in distress. Even after this spinoff, both utilities suffered significant impairments as their Coal and Nuclear Capacities struggled in a low wholesale price markets. Both RWE and E.ON have significantly underperformed on the German stock market ever since the decline in the wholesale electricity price. (Tim Buckley, 2017)

RWE and EON have reported combined losses of €28 billion ($30 billion) in over just last two years. These utilities are facing the threats of never returning to business as usual which have once built their fortunes on coal, gas, and nuclear energy.

On the other hand, developing countries, such as India and China, tend to have a different structure of their electricity markets, implying that the impact of renewables penetration will be mediated differently than in developed countries with liberalized wholesale markets. China's bulk electricity market traditionally operated on the principle of cost-plus regulated tariff setting, with dispatch according to a principle of equal load hours. A combination of slower than expected demand growth, overbuild, and the introduction of renewables, has pushed coal power load factors to below 50% in 2016. This, in turn, is leading to the risk of financial distress and significant stranded assets for Chinese utilities (Spencer, Berghmans, & Sartor, 2017), although this is not mediated by the wholesale market as such but rather regulated dispatch for a declining share of residual demand after must-run generators are dispatched. However, the Chinese government is progressively introducing more economic competition into bulk power pricing and dispatch, a development which could place significant pressure on power prices and hence, the financial health of utilities.

In India, on the other hand, wholesale power pricing is based on a combination of cost-plus regulated tariffs and competitive bidding. In both cases, tariffs are divided into two parts, namely an energy charge and a capacity charge intended to cover fixed costs. However, in recent years, a share of generation capacity has been built without tie-up in long-term power purchase agreements (PPAs), which means that such generators are vulnerable to lower load factors and prices in the small wholesale market. As in China, in India lower than expected demand growth and to a less extent overbuild and the introduction of renewables has pushed coal power load factors to about 57% in 2016. In turn, there has been a challenge to the financials of some coal power plants stuck without PPAs, inadequate PPA coverage, or unviable PPA terms.

The preceding discussion has shown that the introduction of renewables has a significant impact on wholesale markets, be those liberalized and deregulated wholesale markets as in developed countries or 'markets' for regulated dispatch (China) or long-term PPAs (India). Managing this and ensuring that unduly disruptive impacts do not occur on electric utilities will be a major challenge for the energy transition. The box below discusses the risk of stranded assets in the electricity sector.

Box: Risk of Stranded Assets in the Power Sector

IRENA in its report (OECD/IEA and IRENA 2017) concludes that phasing out of unabated coal-fired power plants, i.e. those without CCS, would be required in order to keep pace with the overall emissions targets under the 66% 2°C scenario. The report expects that the least-efficient coal-fired power plants would be phased out by 2030 in most regions and by 2035 in all regions. In many cases, these plants would be retired prior to reaching the end of their technical lifetime and, hence could result in stranding a portion of the original capital investment. Further, according to the assessment of IRENA, the delay in shifting to cleaner technologies would result in a significant increase in stranded assets based on fossil fuels in the system with financial loss. Many segments of the investment chain in mature and developing capital markets could be affected in various ways by stranded assets.

Addressing this challenge requires finding ways to effectively address unemployment, lost profits and reduced tax income that are associated with stranded assets for a holistic approach to the energy transition. The path for transmission needs to address concerns about systematic planning of such assets in generation, cost-benefit analysis, and required institutional and regulatory framework to reduce the risk from stranded assets. As per the IEA study, the stranded assets would cost around USD 320 billion worldwide over the period to 2050 in terms of fossil fuel power plants which become stranded assets prior its recovery of capital investments (IEA 2015).The degree of capital recovery when an asset is retired requires a detailed understanding of investment and operating costs, utilization and production rates, commodity prices, and other potential revenue streams that it generates over its lifetime, all of which would be country-specific.

5.3 Additional investment in flexible system operation

The electricity supply system needs to cater to variation in demand as well as on the supply side. However, the need for flexibility in generation resources increases significantly due to inherent variability and intermittency of variable renewable energy (VRE) sources, such as solar and wind, which are dependent on weather conditions. Thus, flexibility requirements for balancing demand and generation would increase as penetration of VRE increases. The requirements of any particular electricity utility would, however, depend on system characteristics (generation and load), inherent flexibility in the existing system, market structure and regulatory framework. A critical assessment of these is needed in identifying the quantum and optimal location of the flexible resources. Commonly employed flexibility-providing resources include pumped storage and reservoir plants, gas turbines, energy storage (e.g. batteries), etc. Added focus on forecasting (both demand and generation) and scheduling, demand-side interventions, such as DSM and Demand Response (DR), cross border power trading, and deployment of smart grid technologies also become important in the context.

For countries such as China and India, investment in the flexibilization of the existing coal power fleet is seen as a crucial intervention, although it comes with potentially high costs and the need to consider changes in the operational model and financial remuneration of the sector, for example to cover retrofit for flexibility (GIZ, 2016). Studies indicate that expanding the balancing area is one of the most effective tools to bring down the cost of renewables integration. For example, it is estimated in India that optimizing scheduling and dispatch of renewables at a regional rather than state level would result in annual operating cost savings of 2.8% (NREL, LBNL, and POSOCO, 2017). In this regard, India is making important progress having achieved a country-wide synchronous grid, and undertaking significant investments in expanding transmission infrastructure.

This additional flexibility in the system may, depending on the generation mix, requires additional investment to balance the grid. In regulated power systems, the central planning may have to address the concerns with regard to sufficient planning or investment clarity on flexibility, while in a system with competitive market, sufficient investment signals are required take care of potential needs for flexibility in the system. In the absence of sufficient planning or investment clarity, the resulting power system may not have sufficient flexibility to operate efficiently.

According to OECD report 2017, under the future energy scenario of 66% 2 °C, demand-side technologies and energy storage would become increasingly crucial for ensuring the security and reliability of the electricity supply. With high share of renewable scenarios by 2050, it has been intimated in this report that more than 990 GW capacity would be required to provide flexibility in the system (OECD 2017). Mobilizing the capital for flexible assets would be challenging for the utility with traditional business model. Many market rules and regulations do not capture the need of such operational flexibility which will make reaching higher level of variable generation economically and technically challenging.

6. DISTRIBUTION & CUSTOMER INTERFACE

6.1 The Rise of Distributed Energy Resources (DERs)

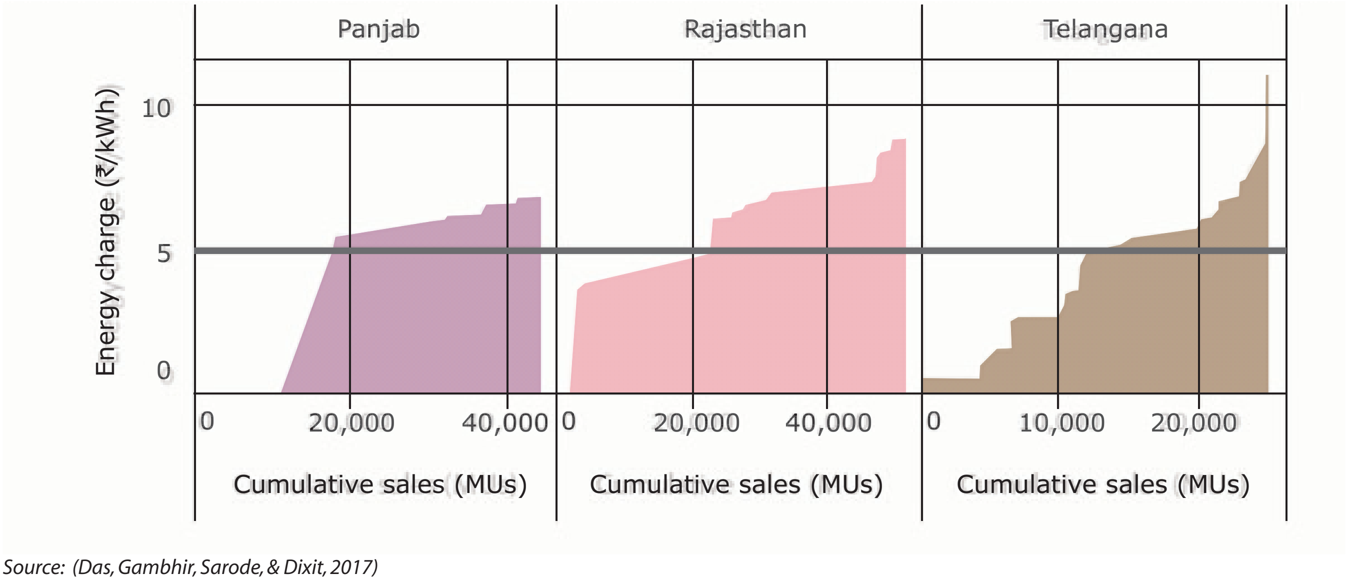
One of the major consequences of the transition to power systems with higher shares of renewables is the rise of distributed energy resources (DER). According to Perez-Arriaga & Knittel (2016):

"…DER is defined as any resource capable of providing electricity services that is located in the distribution system. DERs include demand response, generation, energy storage, and energy control devices, if they are located and function at the distribution level".

Technological innovation, regulation, environmental pressures, and, to a certain degree, customer preferences are driving the increasing competitiveness of DER, relative to the traditional centralized model of electricity generation, transmission, distribution, and marketing. The gamut of DER includes, in particular decentralized solar PV, energy storage, and demand-side response. For example, while there has been a trend towards the growth of utility-scale PV, distributed PV still represented some 26% of global capacity additions of 75 GW of PV in 2016 (REN21, 2017). The value of DER is highly context-dependent, because it is often derived from overcoming location-specific network constraints (such as network congestion). Typically, the systemic value proposition of DERs may be different from the private monetized benefits, if the DER provides system services, such as deferral of network upgrades, reduction in losses, or balancing and ancillary services (Perez-Arriaga & Knittel, 2016). Thus, providing an overarching view of the value of DERs is not possible. However, we can get a sense of the scale of the potential shift to DERs by looking at the case of India.

Figure 9 shows the cumulative electricity sales in three Indian states at the given regulated tariff of sale (essentially the demand curve). It compares this with a benchmark solar tariff for rooftop solar, as revealed in recent auctions, namely 5Rs./kWh. It can be seen that a significant share of state electricity sales is currently priced above the level of the benchmark rooftop solar tariff. This suggests that a significant cost-effective potential exists for DER in the form of rooftop solar, although other barriers, such as lack of awareness, expertise, capital, and transaction costs may hold back its development.

Figure 9: Electricity sales and tariffs compared to the cost of rooftop solar



Source: (Das, Gambhir, Sarode, & Dixit, 2017)

6.2 The Emergence and Diversification of Energy Services

Rather than being seen as a commodity, electricity and other forms of energy are increasingly being seen in terms of the services provided through the consumption of energy: mobility, heating, lighting, and so on. A combination of competition for market share, regulation, and new opportunities opened up through technological innovation are increasing the importance of business models centred across the provision of energy services as opposed to bulk commodities. In particular, deregulation of the distribution segment and the separation of carriage and content have been intended to increase the competitive pressures on the distribution segment. In addition, regulatory pressures on energy savings has forced distribution utilities to diversify into the provision of integrated energy services, including energy efficiency and management. In developed countries, the stagnation of electricity demand growth has also forced utilities to look for other sources of revenue.

In future, it can be expected that this trend will intensify. New ICT technologies will increase the scope for the 'smart' management of end-use demands, which, in turn, will require the active involvement of market players to install, monitor, and market the services rendered by smart and connected end-use equipment. Potential economic value here is significant, with the IEA estimating that ICT-enabled demand response could avoid roughly USD 270 billion in upstream investments by 2040 (IEA, Digitalization & Energy, 2017c). The role of aggregators of demand response will be particularly important, with the market for aggregator expected to grow five-fold between now and 2022 globally (IEA, Digitalization & Energy, 2017c).

Thus, with regulation and technology change increasing the importance of a smart, efficient demand-side, the scope for utility business models to shift into becoming service providers in this segment is significant, provided they have the requisite agility.

6.3 Changing Complexion of Interaction between the Transmission and Distribution Segments

As the deployment of DERs increases, the one-way model of grid management between centralized generators, transmission, and passive consumers will change. System balancing traditionally took place at the transmission level, with centralized generators providing reserves, load following and ramping services in response to natural demand variability and supply-side outages. In future, there is a possibility of increasing shares of system variability and flexibility being located at the distribution. This will come alongside the increased penetration of variable renewables at the transmission level, increasing the variability on the supply side. As a consequence, there will be a need for much greater coordination between transmission system operators (TSOs) and distribution system operators (DSOs), in order to ensure the effect and secure operation of the grid (Perez-Arriaga & Knittel, 2016). Consideration will need to be given to the restructuring and allocation of responsibilities within the distribution segment. Multiple business models including different kinds of aggregators are emerging for the provision of system services at distribution levels in different markets, and these models appear to be significantly driven by policy and regulation.

6.4 Reforming Rates and Regulation

For a number of reasons, the emergence of DER will lead to a need to reconsider the setting of distribution level tariffs and regulation. Several factors are driving this:

- The possibility of significant grid defection (see section 6.1).
- The need for significant new investments in distribution, e.g. for the deployment of smart infrastructure
- The increasing need for distribution utilities to play a role in delivering system services, such as flexibility (see section 6.3).
- The desire of policy makers for utilities to help in the delivery of other aims, such as energy efficiency.
- Stagnant demand growth (in developing countries).

All of these factors are driving significant reflection on how the reform of rates and regulation can assist with the achievement of these policy objectives (Satchwell, Cappers, Schwartz, & Fadrhonc, 2015; Perez-Arriaga & Knittel, 2016). Accordingly, changes will have to be made in terms of pricing structures to recover different kinds of services provided - temporally or locationally differentiated prices for energy or distribution services, price structures that reflect how costs are incurred (fixed, demand-based or energy based); and incentive payments for dspatchable demand response or ancillary services to the grid (reference). In USA, for instance, there is considerable discussion on the need for restructuring fixed and energy charges, as currently fixed charges recover very little of the utilities costs. Since actual energy supply may become lesser and unpredictable, it would make more sense for utilities to recover fixed costs through the fixed or demand charges. This however raises equity concerns as higher fixed charges may discourage smaller (and poorer) customers from connecting to the grid.

6.5 Conclusion

Environmental regulation on de-carbonization and technology change are leading to significant changes at the distribution level, not just at the bulk generation and transmission level. The emergence of DER as significant market players will lead to considerable structural changes in the organisation, regulation, and rate-setting in the distribution sector. Given the complexities involved, a challenge for environmental policymakers will be to ensure the existence of sufficient understanding of the environmental stakes of distribution segment reform among policymakers (e.g. ensuring a level playing field for DERs). By the same token, the growing commercial competitiveness of DERs will have to be combined with regulatory preparedness, and environmental policymakers should be aware of the need to align the regulatory infrastructure around DER in order to avoid backlashes related to its rapid deployment. All of this suggests the high importance of increased dialogue and cross-sectoral policy competence between environmental and climate change policymakers, electricity sector regulators and policy-makers, and the private sector.

7. CONCLUSION AND DISCUSSIONS QUESTIONS

This paper has examined the impact of the electric utilities sector on the environment, including global climate change and more local or regional environmental issues such as air pollution. The electric utilities sector is responsible for some 40% of global emissions of energy-related carbon dioxide (CO_2) in 2015, and some 25% of global greenhouse gas emissions (GHGs). Generally speaking, emissions reductions are relatively easier and cheaper to achieve in the electricity sector, than in other sectors such as heavy industry or freight transportation. In addition, electricity is emerging as probably the preferred energy carrier for decarbonizing end-use sectors such as buildings, passenger transport, and light industry. The electrification of such end-uses is thus a crucial mitigation strategy. For this reason, the electric utilities sector is at the heart of policy efforts to address climate change.

At the same time, the electric utilities sector is subject to a number of other forces that are shaping the sector in significant and fast-moving ways. Most prominent among these is technology innovation. The cost declines in RE have been impressive, with levelized costs of wind and solar declining 67% and 86%, respectively, over the last 8 years, while battery costs have declined at a compound annual rate of 20% per year since 2010. Moreover, technological innovation is also occurring outside of the energy sector as such, in particular with the digitization of all segments of the energy value chain. This will open up new challenges and opportunities for policy-makers and utilities.

The exact form of this transition pathway will depend on context-specific factors, including the existing electricity mix, the rate of demand growth, the current regulatory and market structure, as well as diverse social and policy imperatives. The structural trend in supply mixes and wholesale markets appears to be the increasing importance of variable renewable energy. This will have a significant impact on wholesale markets, both in terms of incentives for flexible operation and dispatch but also on incentives for new generation. The structural trend in the demand side is the emergence of distributed energy resources, including distributed generation, in particular renewables; batteries' and demand-side response and management. It is here, as well, that the exogenous trend of technology innovation in digitalization will likely have the biggest impact. As a consequence, there will be a need for much greater coordination between transmission system operators (TSOs) and distribution system operators (DSOs), in order to ensure the safe and secure operation of the grid.

The preceding discussion leads to a number of questions that need to be debated between policy-makers and the private sector:

1. How can the transition in the electricity sector be accelerated such that climate change goals can be achieved?
2. What key policies are required in order to drive the transition to a more environmentally friendly electric utilities sector?
3. What policies could foster a transition in utility business models in line with the changes emerging in the sector?
4. How to ensure that this transition is made with a minimum of disruption to the key players in the sector?
5. How should wholesale markets be reshaped in view of the increasing penetration of zero-marginal cost renewables?
6. What are possible pathways for electricity market reform in view of a high share of renewables in developing countries which have not yet undergone a high degree of liberalization?
7. From an economic and institutional perspective, how to ensure the coordination between the transmission and distribution levels in view of the emergence of distributed energy resources?

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Citation

TERI.2018

Knowledge Paper: Impact of Environmental Regulation in Utility Business

Authors: Thomas Spencer, Mrinal Mathur, Ravindra Kadam, Mr. A.K. Saxena, Mr. K Ramanathan

New Delhi: The Energy and Resources Institute, 40 pp.

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ACKNOWLEDGEMENT

The **World Utility Summit™** committee members are indebted to our knowledge partner for their significant contribution in helping produce this body of knowledge around the summit theme.

The committee members are also thankful to the reviewers, speakers and moderators who have contributed to make this paper available to the larger ecosystem.

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World Utility Summit

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