



## TRANSITIONS PATHWAYS AND RISK ANALYSIS FOR CLIMATE CHANGE MITIGATION AND ADAPTATION STRATEGIES

### D3.2 Context of 15 case studies:

#### India: Solar & Wind Energy

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# TRANSrisk

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# 1 COUNTRY CASE STUDIES OF THE HUMAN INNOVATION SYSTEM (HIS): THE ENABLING ENVIRONMENT FOR SUSTAINABILITY

India is one of the largest global emitters of greenhouse gasses (GHG) and is also vulnerable to climate impacts. However, the country is committed to contributing to building an effective, cooperative and equitable global architecture based on climate justice and the principles of equity, common but differentiated responsibilities and respective capabilities. In its Intended Nationally Determined Contributions (INDC), the country intends to decrease its emission intensity of Gross Domestic Product (GDP) by 33-35% below 2005 level by 2030.

In Asia, China and India are the largest emitters of GHG. With both of these countries adopting ambitious mitigation plans, Asia has the potential to contribute actively to overall GHG abatement in the region.

In its INDC, India accords tremendous importance to the provision of non-fossil fuel based energy. India looks at electricity generation as a driver of both growth and development. At present, about 38% of the GHG emissions in the country are attributed to electricity generation - with 70% of electricity generated from fossil fuel based sources. The country's plan is to achieve a transformation of its electricity generation regime by increasing the share of the renewables to 40% by 2030. The predominant sources of the planned renewable energy capacity addition are solar and wind power.

## 1.1 Research questions for the Indian case study

1. What are the different priorities (e.g. economic, social and environmental) of India for planning a transition for electricity generation in India?
  - a. What are the impacts on GHG emissions under BAU situation?
  - b. Which are the dominant technological pathways that India may follow for reducing GHG emission from electricity generation?
  - c. What impact will the intended transition have on the global climate?
2. What changes are required in India for achieving the intended transformation in the way electricity is produced in India?
  - a. What challenges to the planned pathways for low carbon transition of electricity generation does India face?
  - b. Who are the major actors for realising these low carbon trajectories?
  - c. What are the interests and capabilities of actors? How are the networks of actors expected to respond and perform?

- d. What are the contextual factors that might affect the performance of the transition pathways?
  - e. How can these transition pathways be governed? What support do the different technological pathways for transition need?
  - f. What are the costs, benefits, risks and opportunities of different transition pathways arising out of these challenges?
3. What are the policy options for realising pathway(s) for achieving the intended transition?
- a. What factors do the policy options depend on?
  - b. Can policy conflicts be resolved?
  - c. What are the risks, uncertainties and opportunities in implementing policy options?
  - d. What are the effects of different policies on the performance of pathways - scenario analysis (modelling?)
4. How can India prepare to deal with these risks and options, what policy tools and actions could we take within and across transition pathways?
- a. How can the risks and uncertainties in implementing the policy options be reduced/mitigated?
  - b. What strategies should the actors follow considering the respective (national) proprieties?

## 1.2 Introduction to the general context

### 1.2.1 Policy overview

Since independence in 1947, and until the 1990s, India treaded a planned path of growth and development. Socialist philosophy influenced the plans that the country followed (Jalan, 1991). The state exercised full control over important sectors of the economy and electricity, being an important sector, witnessed full ownership and control of the state.

As per the constitution of India, the electricity sector - often called power sector - belongs to the 'concurrent list'<sup>1</sup>, whereby both the central (national) and the state (sub-national) governments have major stakes in the functioning of the power system in the country. Besides the national level entities<sup>2</sup>, State Electricity Boards (SEBs) were created as sub-national entities for provisioning electricity to the country's increasing population. The national entities and the SEBs assumed full responsibility for generation, transmission and distribution of power in the country (Singh, Jamasb, Nepal, & Toman, 2015), (Tongia, 2003). However, the status of the power sector in the 1990s was dismal (Gol, 2001). The situation of the power sector in 1989-90 has been presented in Table 1. More than 70% of power was generated from thermal sources. Water (hydel) sources accounted for the balance of power generated in the country. About 51% of the population was without access to electricity. Per capita electricity consumption was lower than that of Pakistan. The state owned utilities suffered from financial losses and had to be heavily subsidised through national and sub-national plans (Gol, 2001).

**Table 1 Status of Indian power sector in 1989-90**

<b>Total installed capacity for power generation</b>	<b>66100 MW</b>
<b>Total installed capacity for thermal power generation</b>	47300 MW
<b>Total installed capacity for hydro power generation</b>	18800 MW
<b>Extent of T&amp;D Losses</b>	23% of the total generation
<b>Per capita generation</b>	~ 300 KWh/capita

*Source: (Gol, 2001), (ADB, 2009)*

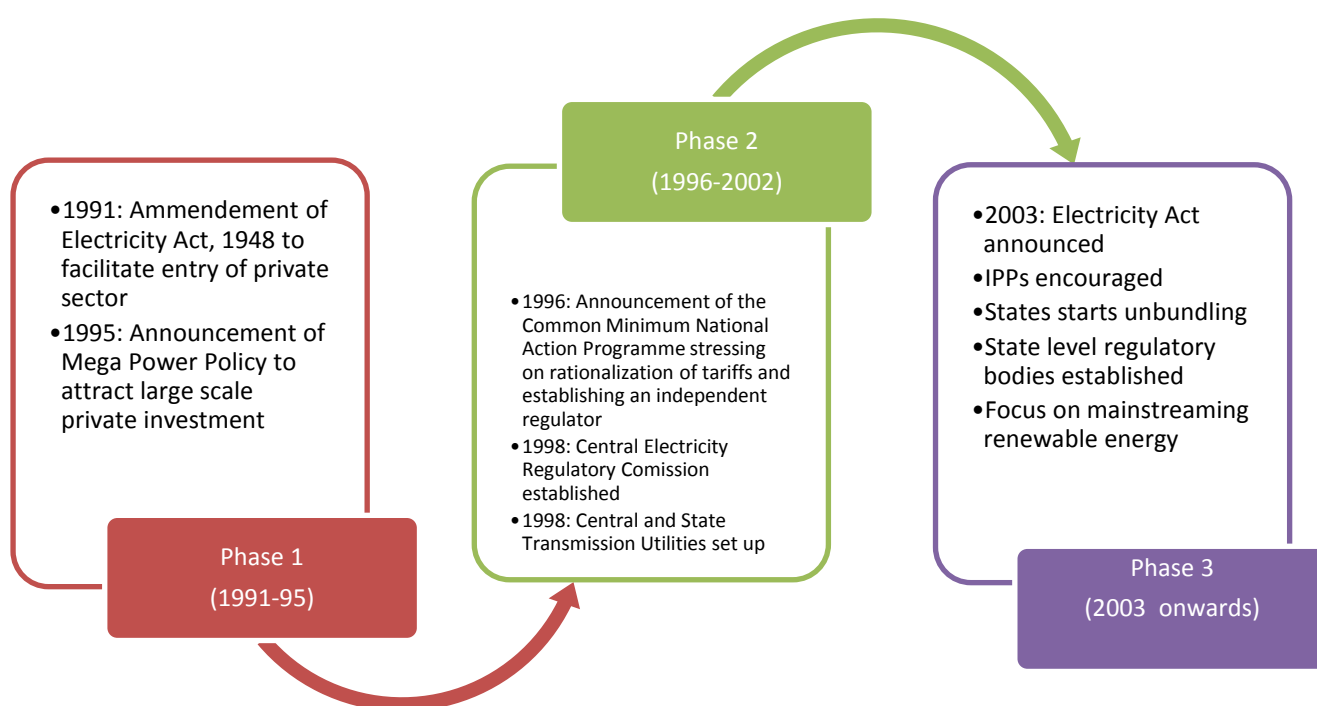
During the 1990s, the electricity sector went through a set of reforms. Prior to the initiation of reforms, the sector was underperforming in many aspects. The average plant load factor was only 54%.<sup>3</sup> Reliability of power supply was dismal, mostly on account of inefficient operation of the power plants and high transmission and distribution (T&D) losses. The sector suffered from

<sup>1</sup> As per the seventh schedule of the constitution of India, in the federal governance structure, some items (including electricity) are the joint responsibility of the union government and the state governments.

<sup>2</sup> The national entities were created for generation and transmission of electricity.

<sup>3</sup> During these years, the industry average was 65% - 75% (Gol, 2001).

commercial losses and an increasing burden of subsidies (Singh, Power sector reform in India: current issues and prospects, 2006). With this backdrop, and at the insistence of the World Bank and IMF<sup>4</sup>, as a fallout of the ‘Washington consensus’, reforms in power sector of India were started in the 1990s. The reforms were aimed at unbundling the sector, enabling and encouraging private sector participation and forming independent regulators both at the national and sub-national levels. Regulators would supervise the overall performance of the sector, create conditions for fostering competition within the sector, set tariffs which are economically meaningful for the viability of the sector and other such measures. The power sector reforms in India can be divided into three distinct phases (Dun & Bradstreet, 2016). A brief overview of the phases is provided in the figure below.



**Figure 1 Phases of Reforms in Power Sector in India**

During the first phase the government eased barriers to entry for the private sector in the then state-controlled electricity sector. The second phase stressed the need for the functional unbundling of the sector. It was also during the second phase that the independent regulatory authority was established. The authority was mandated to decide on principles of tariff setting with a view to increase the financial viability of the sector. The third phase encouraged the independent power producers in the country and also focused on introducing and mainstreaming electricity from renewable sources in the Indian electricity landscape. Thus, in hindsight, the reforms in the electricity sector in India had prepared the country to achieve a set of changes in

<sup>4</sup> During 1990-91 India had faced a financial crisis. To overcome the crisis, the country had sought financial assistance from the World Bank and International Monetary Fund (IMF). The interested readers may refer to (Jalan, 1991)



the sector. The effects of the reforms would be evident in the years to come. Some of the changes achieved:

- Developing an efficient and competitive power market with adequate incentives for improving generation, transmission and distribution.
- Creating an enabling environment for attracting private and foreign investment in the electricity sector, both in the conventional, hydro-carbon dependent technologies and also in the new and emerging technologies for power generation.
- Setting the stage for launching ambitious universal electrification programmes. In 2005, India launched its nation-wide rural electrification programme<sup>5</sup> for providing electricity to all villages and all rural households in the country (Gol, 2014).
- Initiating the process of introducing and mainstreaming renewable energy in the Indian electricity sector (Besant-Jones, 2006), (Bhattacharya, 2006). As the private sector participated in power generation they introduced emerging RE technologies. These technologies developed in response to factors like: the global climate mitigation agenda, and the need for distributed generation to increase access to electricity and rural electrification.

However, given the administrative and governance mechanism of the Indian electricity sector, the full array of benefits from national-level reforms could not be achieved unless the sub-national governments also introduced such reform measures in the sector. This process started in the middle of 1990s. In 1996, at the insistence of the World Bank, Orissa became the first Indian state to initiate reforms through the adoption of the Orissa Electricity Reform Act, 1995. While introducing the reforms, the government of Orissa also stressed the need to create an enabling environment to tap the abundant RE sources - particularly, solar, biomass, wind and geothermal - to realise twin objectives: (a) protecting environment while producing power, and, (b) generating employment. This was spelt out in the *Policy Guidelines on Power Generation from Non-Conventional Energy Sources* published by the Department of Science and Technology, Government of Odisha in 2005. Additionally, during this period, the state also created the State Electricity Regulatory Commission (Pal, 2013).<sup>6</sup> Many other states<sup>7</sup> started following the Orissa model thereafter.

In 2003, the Government of India enacted the Electricity Act that advocated: (a) constitution of a Central Electric Regulatory Commission (CERC); (b) mandating all states to set up State Electricity Regulatory Commissions; (c) promoting new and non-conventional sources of power, along with the conventional ones; (d) emphasising on rural electrification and universal access to electricity. The Act, often considered to be the most comprehensive policy for power sector reforms in South

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<sup>5</sup> The programme was named as Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)

<sup>6</sup> In the literature, the reform introduced by Orissa is popularly termed as “the Orissa model”.

<sup>7</sup> During 1996-2000, apart from Orissa, the following states had set up independent regulator - Haryana (1998), Andhra Pradesh (1998), Uttar Pradesh (2000), Rajasthan (2000), Karnataka (2000).

Asia (Singh, Jamasb, Nepal, & Toman, 2015), contributed to: formulating measures to promote competition; safeguarding consumer interest; rationalising tariffs and subsidies; promoting environment sustainability; as well as introducing renewable energy through promulgating laws relating to generation, transmission, distribution and trading (MLJ, GOI, 2003). In 2007, the Act was further amended to promote captive power generation<sup>8</sup> and ease power availability to industrial consumers. It also permitted the captive power generators to supply power to the grid by institutionalizing open access (Singh, Jamasb, Nepal, & Toman, 2015). Through this act, the stage was prepared for mainstreaming renewable energy in India.

## 1.2.2 Natural resources and environmental priorities

Until the 1990s, India depended on thermal and hydro sources for electricity generation. Changes in the structure of power generation started after the reforms were introduced in the 1990s. India ranks third among the highest coal producing countries in the world<sup>9</sup>. Because of abundance of coal in the country, historically, the energy system has been designed in favour of coal based power generation. The country also uses natural gas to produce power. It is only during the last decade that India has started exploring and tapping its vast renewable potential for generating power. Nuclear power is still at the nascent stage in the country. The share of different sources of electricity generation is presented in Figure 2. It can be seen that coal has consistently remained the dominant source of electricity generation - contributing close to 70% of the total electricity generation in the country between 2003-2013. The share of natural gas has decreased over the years. However, coal, natural gas and diesel oil (referred to thermal sources) are the dominant sources of electricity generation in India - accounting for more than 80% of electricity generation. Nuclear power, shrouded with debate, contributes approximately 2-3% of the electricity generation. The share of this source has remained constant over the years.

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<sup>8</sup> Captive power plants generate power close to the local source of use (i.e. the end-user).

<sup>9</sup> Because of high demand of coal in the country, it also imports coal from China and Australia.

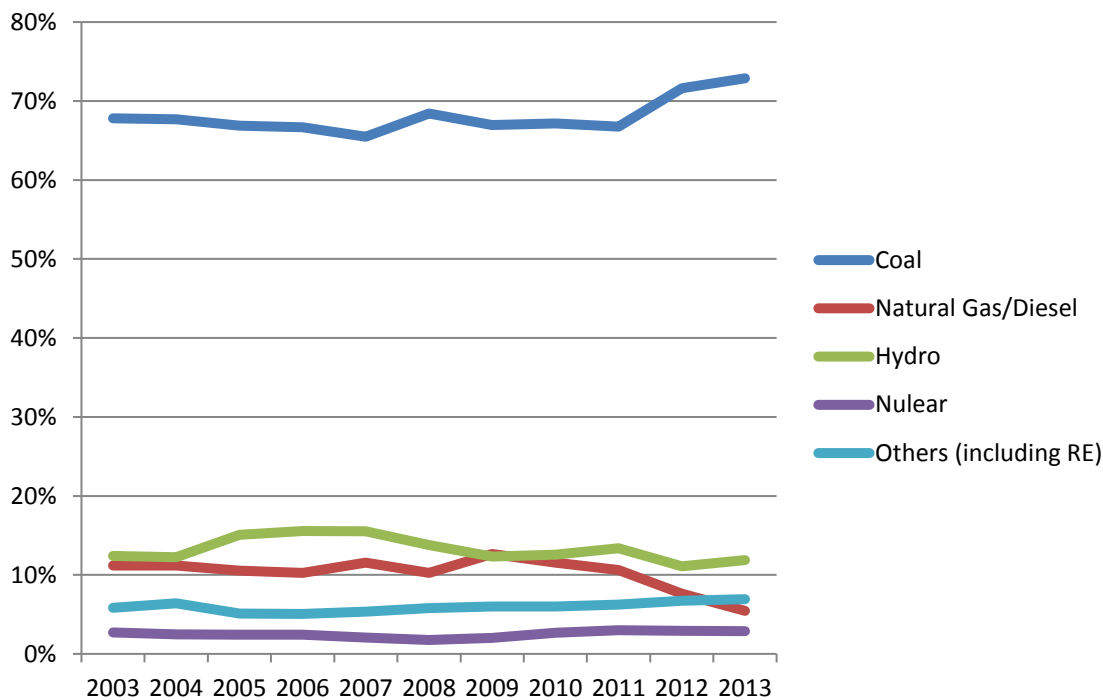


Figure 2 Share of different sources in electricity generation in India<sup>10</sup>

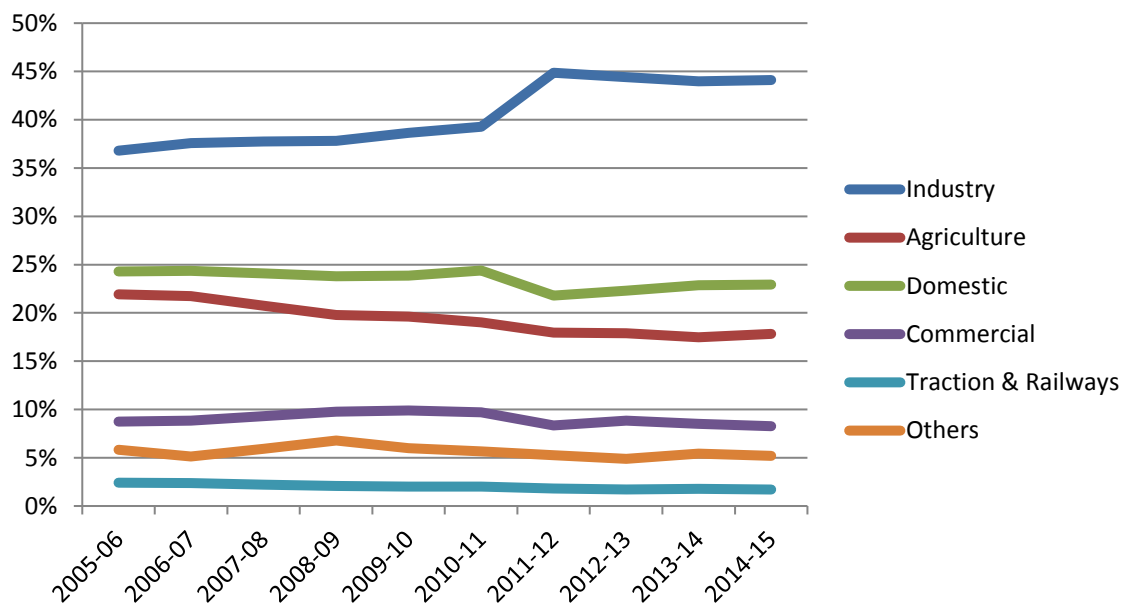
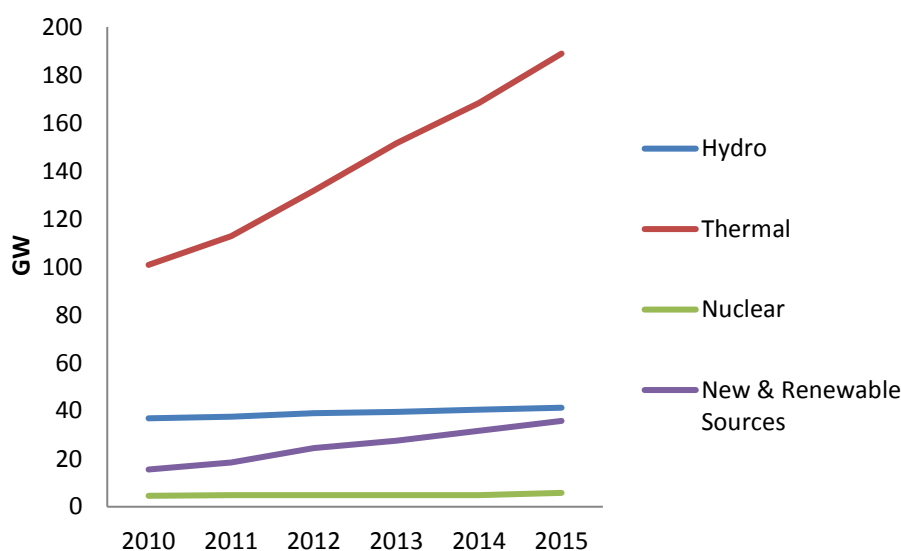


Figure 3 Share of different end-user groups in consumption of electricity in India<sup>11</sup>

<sup>10</sup> Source: (The World Bank, 2016) [Accessed on 11th November, 2016].

<sup>11</sup> Source: (Gol, 2016)

The pattern of consumption of electricity by different end-user groups is presented in figure 3. With regard to consumption of electricity, industry has remained the largest consumer with this trend rising over the years. The increasing trend can be explained by the rapid growth of the Indian economy since 2000. The decreasing trend in the share of domestic sector in electricity consumption may be partially attributed to the large-scale penetration of energy-efficient appliances and an increase in the general awareness among households pertaining to conservation of electricity. With this, increases in the domestic tariff across the country has encouraged households to regulate electricity usage (Buckley, 2014). The falling share of the agriculture sector in electricity consumption stem from measures to encourage farmers to shift from flooded type of irrigation to other forms of irrigation that are less energy intensive, and conserve water (Gol, 2014).



**Figure 4 Installed capacity of power generation (utilities) in India<sup>12</sup>**

Figure 4 depicts the trend in utility-scale capacity for power generation in India during recent years. During 2010-15, the compounded annual growth rate (CAGR) of installed capacity for power generation from thermal sources was 13.4% p.a., implying that there is still considerable reliance on the thermal power generation. Although, historically India had leveraged its hydro power potential, in recent times there has not been any appreciable increase in the addition of hydro capacities (2003-2013) and is now only slightly increasing its share in power generation. Seasonality of water availability, disputes over sharing of water resources, problems with regard to evacuation of power from the hilly terrains and concerns over loss of bio-diversity are some of

<sup>12</sup> Source: Gol (Energy Statistics, various issues). While calculating the figures, non-utilities and captive power generation facilities have been excluded.

the major reasons for stagnancy in capacity addition for hydro power. The new and renewable sources<sup>13</sup> of energy have a share of 13% in the Indian electricity sector, with the share is increasing over the years. The capacity for generating electricity from the non-conventional sources and renewable sources shows an appreciable increase in the recent years. During 2010-15 the highest compound annual growth rate (CAGR) for installed capacity has been observed in the case of new and renewable sources. In India, nuclear power has a marginal share (approximately 2%) in the electricity sector. This form of power has attracted several criticisms in terms of technology, waste disposal and raw materials. The issue has been highly debated, particularly, in the aftermath of the Fukushima crisis. There is also intense political opposition that has resulted in the relative stagnancy of capacity addition for nuclear power generation during the recent years.

GHG emission from different sectors of the economy have been presented in Table 2. Given the structure of the electricity generation in India, the electricity sector is one of the highest GHG emitters in the country. In 2007, electricity generation accounted for about 37.8% of gross emission in India. In absolute terms, emissions from this sector was about 719.31 million tonnes of CO<sub>2</sub> equivalent (mTCO<sub>2</sub>e) - the highest among all sectors (Gol, 2010). The electricity sector has remained the largest emitter of GHG since 1994.<sup>14</sup>

Various factors contribute to the emission from electricity sector in the country. Activity, structure and efficiency of the sector play a significant role in determining the quantity of the emissions from the sector (Ghosh, Dasgupta, Ghosh, & Ghosh, 2014). Electricity generation in India is increasing rapidly. During 1980-2013, the electricity generation in the country has grown at a rate of about 10% p.a. Given the structure of the electricity generation in the country - which is heavily skewed in favour of thermal power, the increase in generation has resulted in increased emissions. With the anticipated change in the structure of the electricity generation (as evident from the increasing capacity addition in RE), it is expected that the rate of increase in emissions will decrease even if the amount of electricity generated increases. Another important factor that contributes to emissions from the electricity sector is the impaired efficiency of the generation facilities. Many state-owned facilities are old and hence inefficient (sub-critical). Although the new facilities added for thermal power generation are mostly super-critical in nature closing down old plants is not a feasible policy option, particularly in the face of the existing power deficit in the country. Further, due to geo-physical reasons, the coal produced in India is high in ash-content hence, increased consumption of coal leads to increase in emissions. Although there is an option for using imported coal from Australia, this is a costly and economically risky option, since the sector will face high cost of electricity generation and will be vulnerable to price and currency risk.

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<sup>13</sup> New and renewable sources include small hydro projects, wind power, biomass power, biomass gasifier, power from urban and industrial waste and solar (Gol, 2016a).

<sup>14</sup> Gol had presented the emission profile of 1994 in Initial National Communication to the UNFCCC.

Table 2 Emission from Different Sources in India (1994-2007)

Sector	1994 (Emission in mTCO <sub>2</sub> e)	2007 (Emission in mTCO <sub>2</sub> e)	CAGR (% p.a.)
Electricity	355.03 (28.4%)	719.30 (37.8%)	5.6
Transport	80.28 (6.4%)	142.04 (7.5%)	4.5
Residential	78.89 (6.3%)	137.84 (7.2%)	4.4
Other Energy	78.93 (6.3%)	100.87 (5.3%)	1.9
Cement	60.87 (4.9%)	129.92 (6.8%)	6.0
Iron & Steel	90.53 (7.2%)	117.32 (6.2%)	2.0
Other Industry	125.41 (10.0%)	165.31 (8.7%)	2.2
Agriculture	344.48 (27.6%)	334.41 (17.6%)	-0.2
Waste	23.23 (1.9%)	57.73 (3.0%)	7.3
Gross Emission (without LULUCF)	1251.95	1904.73	3.3
LULUCF	-14.29	-177.03	
Net Emission (with LULUCF)	1228.54	1727.71	2.9

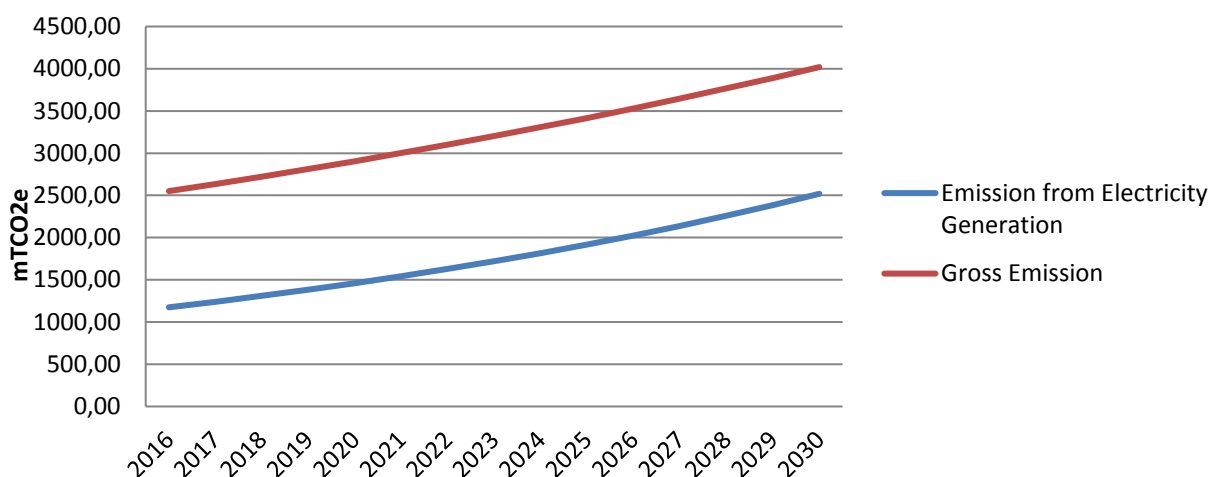
Note: (a) Figures in parenthesis denotes share in gross emissions; (b) Other Energy: includes GHG emissions from petroleum refining, manufacturing of solid fuel, commercial & institutional sector, agriculture & fisheries and fugitive emissions from mining, transport and storage of coal, oil and natural gas; (c) Other Industry: includes GHG emissions from production of glass and ceramics, soda ash, ammonia, nitric acid, carbides, titanium dioxide, methanol, ethylene oxide, acrylonitrile, carbon black, caprolactam<sup>15</sup>, ferro alloys, aluminium, lead, zinc, copper, pulp and paper, food processing, textile, leather, mining and quarrying, Non-specific industries and use of lubricants and paraffin wax; (d) Agriculture: includes GHG emissions from livestock, rice cultivation, agricultural soils and burning of crop residue; (e) Waste: includes GHG emissions from municipal solid waste (MSW), industrial and domestic waste water; (f) LULUCF: includes GHG emissions and removals from changes in forest land, crop land, grass land, wet land, settlements and combustion of fuel wood in forests.

Source: (Gol, 2010)

From the above table it is evident that the electricity sector has, historically, remained the largest emitter of GHG in the Indian economy. The share of emission from this sectors in overall gross emission is increasing over the years. Together the emissions from the sector is growing at a high rate. Therefore, if India has to control its GHG emissions, attention towards electricity sector is an imperative. While, given the anticipated economic growth of the country, activity in the electricity sector cannot be reduced, the country must pay attention to changing the structure and efficiency of the sector so that the reductions achieved through these improvements can partially offset the increase in emission due to increase in increase in activity level.

<sup>15</sup> This is a variant of nylon - a product of petrochemicals processing.

Given the above findings, assuming 2007 as base year and the historical growth rate, under the business as usual (BAU) scenario it is estimated that, by 2030, emissions from electricity generation in India are expected to be more than 2500 mTCO<sub>2e</sub>, contributing to about 63% of total emissions.<sup>16</sup> Therefore, from the emission perspective, the electricity sector will continue to play a very significant role in the Indian economy.



**Figure 5 Emission from Electricity Generation in India (2016-2030)**

India has a huge untapped RE potential. Potential and capacity utilisation has been presented in Table 3. It is seen that less than 1% of the solar power potential has been utilised to date. Only about 25% of the wind and biomass power potential has been tapped and translated into generation. Small hydro-power projects have realised only 2% of the potential. Translating the large potential into actual use is not without its share of roadblocks. Hydro power generation capacity is seasonal in characteristic and depends on the politics of trans-boundary, interstate and intrastate water sharing treaties. Again, biomass power generation depends on livestock availability and infrastructure to collect and process livestock waste. On the contrary, generation of solar and wind power do not suffer from such complex issues. Therefore, the Government of India (GoI) has focused on developing the solar and wind power (GoI, 2015) in addressing the concerns associated with energy access, universal electrification and achieving the SDGs.

<sup>16</sup> This is a very simplistic result. Detailed modelling involving activity, structure and intensity effects of the electricity generation in the country is required to arrive at a more realistic estimate. In the literature, there exists a variety of estimates for emission pathways for India (GoI, 2009). However, the estimates vary widely across models deployed for predicting emission trajectory. The total emission in 2031 is estimated to vary in the range of 4.00 - 7.30 billion tons of CO<sub>2e</sub>.

**Table 3 RE Potential and Installed Capacity as on 31.3.2015**

Source	Potential for generation (GW)	Installed capacity (GW)*	Capacity Utilisation (%)
Solar power	748.99	4.88	0.65
Wind power	102.77	25.09	24.41
Small hydro power	197.49	4.18	2.12
Biomass	17.54	4.45	25.37
Bagasse based Cogeneration	5.00	N.A.	

\* Installed capacity for off grid power

N.A. - Not available

Source: (Gol, 2016a)

Solar power can be both grid integrated and stand-alone systems. There is limitation with respect to data on stand-alone systems. Therefore, for the purpose of this case study, the trends of grid-integrated solar and wind power in India has been compared. The trends have been presented in figures 5 and 6. Evidence shows that the solar power has started picking up after the announcement of the Jawaharlal Nehru National Solar Mission (JNNSM) in 2010. Although, during the period 2008-15, both grid-integrated solar and wind power installations reveal an increasing trend, solar power shows an exponential trend. The CAGR of solar power during this period is almost 202% p.a. On the other hand, wind power shows a CAGR of about 16.22% p.a. Overall, grid-integrated renewable energy in India is growing at a rate of about 17.70% p.a. Prior to 2010, wind power facilities determined the majority of grid integrated RE generated in India. However, in the recent years, the share of solar in the total grid-integrated RE in India is increasing appreciably. As a consequence, the share of wind power in the grid-integrated RE is decreasing<sup>17</sup>.

<sup>17</sup> Please see section 2.3.2 TIS life cycle value chain for a discussion on how the solar and wind power value chain has further impacts on the environment and society.



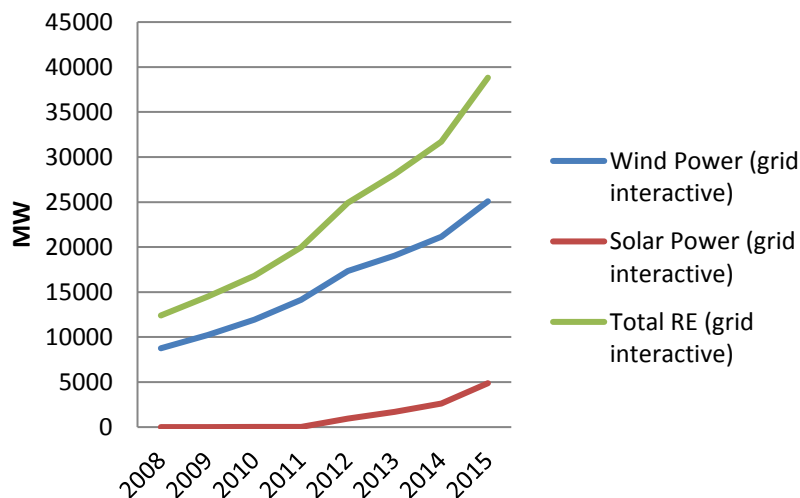


Figure 6 Trends in grid-integrated RE installations<sup>18</sup>

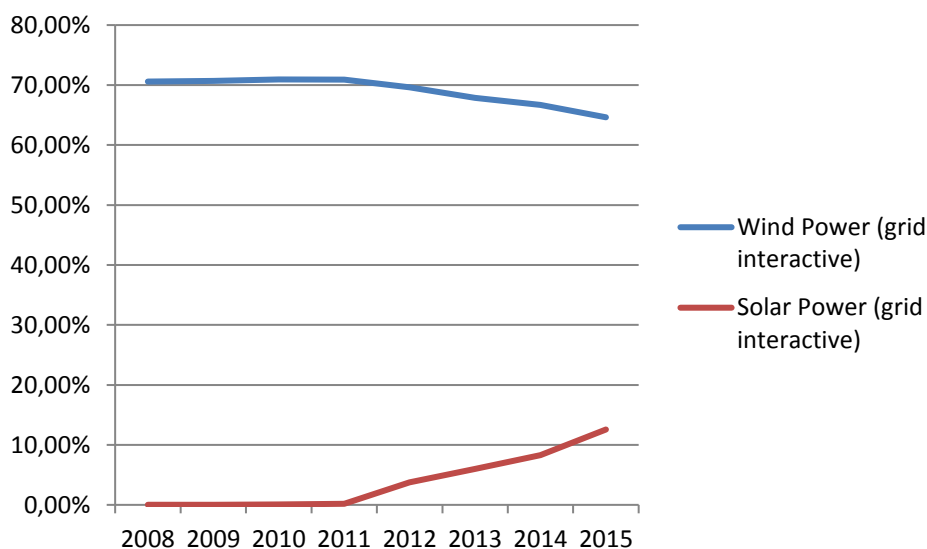


Figure 7 Share of grid integrated solar and wind power in total grid integrated RE in India

### 1.2.3 Economic priorities

There is a strong correlation between electricity use and, wealth creation, economic growth and social development (Apergis & Payne, 2011), (Wolde-Rufael, 2006), (Besant-Jones, 2006), (Ferguson, Wilkinson, & Hill, 2000). Improving provision of electricity positively impacts poverty eradication and income generation, and facilitates development of social capital through improvements in health and education (Shiu & Lam, 2004). Consequently, researchers often

<sup>18</sup> Source: Compiled from GoI, Energy Statistics (various issues)

advocate that the share of electricity in the overall energy use in a country should be used as an indicator for development (Ferguson, Wilkinson, & Hill, 2000).

The electricity sector in India is one of the largest<sup>19</sup> and most complex power systems in the world (PwC & CII, 2015). The system is required to serve approximately 1.2 billion people<sup>20</sup> within a geographical span of 3.28 million sq. km. India also has the largest rural population in the world and the rate of rural-urban migration is lower than many other transition economies (IEA, 2011). Provisioning reliable electricity to this large population - both rural and urban - is one of the stated priorities of the Government of India (GoI). The country is also engaged in cross-border trade in electricity with its neighbours - it exports power to Nepal and Bangladesh and imports electricity from Bhutan. As of 31<sup>st</sup> March, 2015, the recorded an installed capacity for power generation in India was 316379 MW. Between 2006 and 2015, the compounded annual growth rate (CAGR) of installed capacity for power generation was over 8% p.a. (GoI, 2016a).

Table 4 presents a comparative analysis of trends of electricity consumption in countries of South Asia. Compared to many other countries in South Asia, over the last three decades, India's performance with regard to electricity access and consumption has been impressive.

The attractiveness of the Indian power sector as a lucrative destination for investment has also risen since the 1990s (Table 7) when the country opened its economy to global private enterprises. As a result electricity generation in the country has increased significantly registering a CAGR of 10% p.a. during the period 1980-2013 (Table 6). However, transmission and distribution losses (as presented in Table 5) are a problem because of power theft, infrastructure, and other such factors. Given the anticipated economic growth of India, the rising population and its geographical vastness, there exists enormous scope for the Indian electricity sector to help the country achieve its intended development goals.

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<sup>19</sup> In 2014, it was the 4<sup>th</sup> largest country in terms of installed capacity for electricity generation. The first three countries are China, United States of America and Japan, respectively (IEA, 2015).

<sup>20</sup> The figure is as per (GoI, 2011)

**Table 4 Electricity Consumption in selected countries of South Asia**

Country	Electricity Consumption (kWh/Capita)			
	1980	1990	2000	2013
Bangladesh	19	48	102	293
India	142	273	395	765
Nepal	12	35	59	128
Pakistan	136	278	373	450
Sri Lanka	97	154	297	526
South Asia	127	246	357	673
World	1587	2120	2378	3104

Source: <http://data.worldbank.org/> [accessed on 25<sup>th</sup> August, 2016]

**Table 5 Transmission & Distribution Losses in selected countries of South Asia**

Country	T&D Losses (% of electricity generated)			
	1980	1990	2000	2013
Bangladesh	35%	34%	15%	13%
India	18%	19%	27%	18%
Nepal	21%	19%	21%	31%
Pakistan	29%	21%	24%	17%
Sri Lanka	15%	17%	21%	10%
South Asia	19%	20%	27%	18%
World	8%	9%	9%	8%

Source: <http://data.worldbank.org/> [accessed on 25<sup>th</sup> August, 2016]

**Table 6 Electricity generation in selected countries of South Asia**

Country	Electricity Generation (TWh)					CAGR (% p.a.)
	1980	1990	2000	2010	2013	
Bangladesh	2.35	7.73	15.77	40.79	53.04	15%
India	120.41	292.73	569.69	979.42	1190.00	10%
Nepal	0.22	0.88	1.66	3.21	3.65	13%
Pakistan	14.97	38	68.12	94.38	97.80	9%
Sri Lanka	1.67	3	7	10.80	12.02	9%

Note: CAGR = Compounded Annual Growth Rate

Source: <http://energyatlas.iea.org/> [Accessed on 25 August, 2016]

**Table 7 Trends of Investments in Electricity Sector in selected countries of South Asia**

Country	Investment in Electricity Sector (Million USD)*				
	1995	2000	2005	2010	2012
Bangladesh		18.50		137.13	1527.80
India	1008.30	1953.78	943.13	37837.51	9081.50
Nepal		15.10	17.50	39.10	267.40
Pakistan	1778.60		904.60	166.00	1210.90
Sri Lanka	21.70		64.10	681.60	64.00

Note: This is total investment and includes both public and private investments.

Source: <http://data.worldbank.org/> [accessed on 25<sup>th</sup> August, 2016]

Besides the issues concerning electricity access and reliability of supply, there are a range of economic challenges that India faces while planning for safe, reliable and affordable energy for all in response to the SDGs. Some of these concerns are:

- India is a net coal and oil importer. As the population of India increases it is expected that, in the long run, as domestic fossil fuel resources deplete the import bill would increase. Thus, remaining locked-in the present structure of electricity generation will increase the country's import bill and impair the balance of payment situation (MNRE, 2015).
- A fossil fuel based electricity generation system in India faces numerous risks - energy security, price volatility of fossil fuels, depleting water availability for cooling in thermal power plants, (IEA, 2012).
- Technologies for generation of electricity from thermal sources are centralized in nature and economy of scale is extremely important for financial viability of such systems. Given the scale of the thermal power plants, grid connectivity is an important critical success factor for such plants. Many Indian villages are situated in remote and difficult terrains, where grid connectivity is a difficult (and costly) technological proposition. Therefore, India needs to explore options for generating electricity through off-grid technologies as an alternative source for ensuring energy security (MNRE, 2015), (Niti Aayog, GOI, 2015).
- The environmental cost of a fossil fuel regime is high. As long as India remains locked in into its current electricity generation structure, it will continue to incur the environmental costs that negate the economic viability of the sector (ADB, 2012). Together, India will continue to play a negative role in the global actions against climate change. The country will also defeat the goals of mitigation that it has set for itself in the National Action Plan for Climate Change in 2008.

Enabling universal electricity accessibility is therefore just one part of the challenge facing India, while the other part is to address a range various socio-economic and political concerns. While ensuring last mile delivery of energy - across India, government energy policies have stressed the need to identify ways and means for improving energy access in such a way that not only lessens the burden on the exchequer but also guarantees environmental sustainability. Consequently, the

government of India in its INDC has proclaimed that “promoting greater use of renewables in the energy mix” is a strategy for ensuring universal energy access with “minimum growth in carbon emissions” (Gol, 2015).

Governments’ keenness and initiatives to mainstream RE in India, there are challenges. RE solutions can be costlier than traditional energy sources, and hence a transition to RE as a substantial component can be economically challenging (Caperton, 2010), (Ward, 2010). In India, a dominant narrative is that the power generation from renewables is more capital intensive than conventional fossil fuel based power plants, thereby making it an expensive investment option (Niti Aayog, GOI, 2015). Also there are technological challenges like requirement of grid-parity for efficient transmission of power from renewable sources along with the power generated from conventional sources. Furthermore, as described in later sections<sup>21</sup> challenges can stem from coherence of budgetary allocations and economic incentives for renewable power formulated by the national and sub-national governments. The issue of policy alignment is very important in a multi-level governance set-up like India, characterised by fiscal federalism.

## 1.2.4 Societal priorities perspective on climate change

In 2015, the United Nations declared “ensuring access to affordable, reliable, sustainable and modern energy for all” as one of the seventeen Sustainable Development Goals (SDGs)<sup>22</sup> that will guide the course of human development during 2015-2030. Removing energy poverty<sup>23</sup> through mainstreaming of clean energy sources is a priority for most nations. Table 8 presents the status of electricity access in India and selected countries (regions) in 2013. It is seen that approximately 20% of people without access to electricity in the world reside in India. In Asia, although China has more population, in terms of providing access to electricity to the population it shows a much better performance than India. While India shows a significantly good performance with regard to electrification in urban areas, the situation in the rural areas is dismal, with rural electrification rate being lower than that of developing Asia.

The seventh SDG aims at fostering a transformative change in the energy system (i.e. the way energy is produced, accessed and consumed). Given this goal of transition, countries like India - characterised by inequalities in energy access and pronounced dependence on fossil fuel - needs to put in place policies, programmes and actions to bring about a systemic change in their electricity generation trajectory. The task, though not impossible, is challenging. The Indian energy policies and programmes need to simultaneously focus on two major priority areas: a)

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<sup>21</sup> For a more detailed discussion on policies and politics of RE, please refer to section 2.2.5.

<sup>22</sup> This is the seventh goal in the list of the 17 sustainable development goals.

<sup>23</sup> Energy poverty is the lack of access to modern energy services like electricity and clean cooking fuel (IEA, 2012). Energy is seen as a critical component for a nation’s growth and development. Yet, across the world, 1.2 billion people have no access to electricity and 2.7 billion people are without access to clean energy for cooking (IEA, NEA, 2015)

meeting the energy demand of a rising population; and b) mainstreaming clean energy in the overall portfolio.

**Table 8 Status of electricity access in India**

Region	Electricity Access in 2013			
	Population without electricity access (in Millions)	Electrification Rate (%)	Rural Electrification Rate (%)	Urban Electrification Rate (%)
India	237	81	74	96
China	1	100	100	100
Developing Asia (including India and China)	526	86	78	96
Africa	635	43	26	68
Latin America	22	95	85	98
Middle East	17	92	79	98
Transition Economies & OECD	1	100	100	100
World	1201	83	70	95

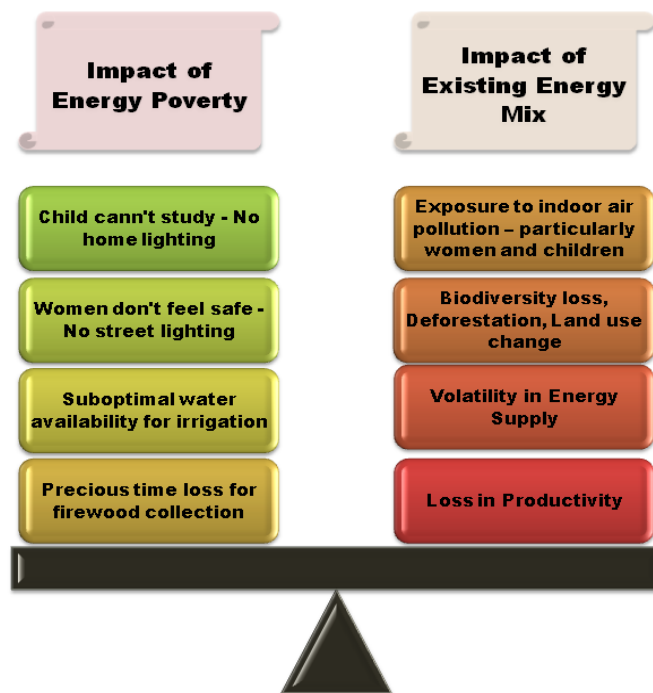
Source: World Energy Outlook/ IEA 2015

<http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/>

[Accessed on 14.4.2016]

Eradicating energy poverty is an important development challenge for India. In comparison to the world average, India exhibits a significantly high dependence on fossil fuel and biomass for cooking and lighting. The electrification rate in India is below average as compared to the rest of the world in general and Asia in particular. In the absence of electricity, a substantial proportion of the population resort to use of biomass for lighting and cooking, which precipitate serious health risks because of indoor air pollution (Smith & Mehta, 2003), (WHO, 2016). Significant dependence on fossil fuel for generation of electricity is adding to the country's import bill while simultaneously putting a strain on its environment and social health.

The impacts of energy poverty and impacts from the use of biomass as principal source of energy is significantly negative (Kumar, 2013). Particularly, such negative impacts are more pronounced for the lower income groups. This has been depicted in Figure 8.



**Figure 8: Impaired energy access: What it means for the poor?**

The necessity to prioritise energy accessibility stems from the fact that it has significant impacts on human health, education and productivity (GEA, 2012). Hence, eradicating energy poverty and ensuring last mile delivery of energy is an important driver for socio-economic development (Davis, 1998), (Bhattacharya, 2006), (Roy, Ghosh, Ghosh, & Dasgupta, 2013), (Pachauri, Mueller, Kemmler, & Spreng, 2004). Realising the significance of energy access in improving the quality of life, promoting human capital and generating economic development (MoSPI, 2014), the central objective of India's energy policy<sup>24</sup> has been to assure reasonable access to safe, clean, convenient and affordable energy for all, including the poor and marginalised sections of the population. The Government of India (GoI), in the country's Intended Nationally Determined Contribution (INDC) has stressed that "universal energy access and energy security is one of the fundamental development goals of the country" and the GoI is committed to meet the demand for energy of all citizens of India (GoI, 2015).

The challenge for providing electricity to all is particularly tough in rural India where almost 69% of the population reside<sup>25</sup>. Electricity delivery in rural areas is plagued by deficiencies in infrastructure, together with abject poverty leading to the inability of consumers to pay for the

<sup>24</sup> This is proclaimed as a national priority. The entire document is available in the website of Planning Commission, Government of India (<http://planningcommission.nic.in/sectors/index.php?sectors=energy>)

<sup>25</sup> 2011 Census statistics released by the Ministry of Home Affairs, GoI ([http://censusindia.gov.in/2011-prov-results/paper2/data\\_files/india/Rural\\_Urban\\_2011.pdf](http://censusindia.gov.in/2011-prov-results/paper2/data_files/india/Rural_Urban_2011.pdf))

electricity (Bhattacharya, 2006). Therefore, although the Rural Electrification Corporation Limited was set up in 1969 with a goal for enhancing electricity access in villages, many rural households in India still have constrained access to electricity. Furthermore, as per the definition of village electrification<sup>26</sup>, the electrification of a village in India does not necessarily entail providing electricity connection to all the households in a village. Again, in many instances, it is observed that the installation of infrastructure for electrification in villages has not necessarily translated into power availability in the area, as transmission of electricity to the village is delayed and/or kept at abeyance. Even where power connection is available, supply is not reliable - the system is plagued by frequent power cuts, low voltage, etc. Additionally, administrative issues like long and tedious procedures for getting connected, hassles in paying bills, absence of regular maintenance and repair of the infrastructure, etc. have impeded the success of the rural electrification programme. High transmission costs (particularly in remote areas) and, transmission and distribution losses have also added to the problems (Kumar, 2013).

### 1.2.5 Politics of energy development priorities

In India, policies and institutions governing the future direction of energy systems are often guided more by the political mandate than by a systems approach. Short-term gains for the political class scores over long-term impacts and consequences in the decision making process. Therefore, motivating the political class in policy-framing and decision making processes assume importance (Krishna, Sagar, & Spratt, 2015). Policies supporting renewable energy are often about lobbying over policy goals and design of a favourable institutional structure (Jacobsson & Bergek, 2004). If the renewable energy lobby of a country is weak, then investor interest in RE in the region wanes.

In view of the above, in India, policies and politics concerning new technologies for energy generation are often perceived as sources of risks and uncertainty by investors (Ghosh & Ghosh, 2016). This erodes the attractiveness of projects and deters investors from entering unchartered markets like solar, wind and other forms of RE (The World Bank, 2011). Some of the risks, as perceived by the investors, in RE projects, arising out of politics and policy defects are summarized in Table 9.

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<sup>26</sup> Officially, a village in India is electrified when: (a) Basic infrastructure like distribution lines and distribution transformers are installed in the inhabited locality within the revenue boundary of the village including at least one hamlet/Dalit Basti as applicable; (b) Any of the public places like Schools, Panchayat Office, Health Centres, Dispensaries, Community centres etc. avail power supply on demand; (c) The ratings of distribution transformer and LT lines to be provided in the village would be finalized as per the anticipated number of connections decided in consultation with the Panchayat/Zila Parishad/District Administration who will also issue the necessary certificate of village electrification on completion of the works; (d) The number of household electrified should be minimum 10% for villages which are not electrified (Gol, 2016b) [Accessed on 21.11.2016].



**Table 9 Impacts of policies and politics on solar, wind and other RE projects**

<b>Nature of policy / politics</b>	<b>Impacts on solar, wind and other RE projects</b>	<b>Risks in investment in solar, wind and other RE projects</b>	<b>Source</b>
<b>Skewed policies favouring conventional energy</b>	Market distortions; doubtful cost competitiveness of projects	Uncertainty over the demand for energy generated from RE projects; increase in the probability of suboptimal returns from RE projects	(The World Bank, 2011), (IRENA, 2012)
<b>Disregarding positive externalities for tariff setting and allied policies for RE</b>	Uncertain cost competitiveness of projects	Uncertainty over the demand for RE; increase in the probability of suboptimal ROI from RE projects	(The World Bank, 2011)
<b>Non-alignment of policies concerning RE</b>	Competing and conflicting policies create a space where investors and other stakeholders are unclear about the policy direction	Fear about feasibility of RE project; delay in execution; uncertainty over returns from the project; overall scepticism about RE at the grassroots	(IRENA, 2012), (UNDP, 2013b)
<b>Grand goals but incomplete policies</b>	Execution of RE projects is extremely difficult	Risks concerning timely completion of projects; suboptimal ROI	(Krishna, Sagar, & Spratt, 2015), (The World Bank, 2011)
<b>Ambiguous long-term commitments</b>	Uncertainty over cash flows associated with RE projects	Suboptimal ROI; investors are discouraged	(Hamilton, 2009), (IRENA, 2012)
<b>Uncertain duration of commitments and agreements</b>	Uncertainty over cash flows associated with RE projects	Suboptimal ROI; investors are discouraged	(Hamilton, 2009), (Nakhooda, 2011), (IRENA, 2012)
<b>Frequent changes in policies</b>	Uncertainty over execution and operation of RE projects	Loss of motivation for project developers; projects not bankable	(IRENA, 2012)
<b>Unfavourable credit policies</b>	More reliance on equity and international financing	Decrease in the size of projects; sub-optimal ROI; fear of bankruptcy	(The World Bank, 2011)
<b>Too much importance of the political mandate in policy framing</b>	Uncertainty over stability of policies	Loss of motivation for implementers; high probability of suboptimal ROI	(Hamilton, 2009)

*Adapted from (Ghosh & Ghosh, 2016)*

As has been discussed, the policy space for RE in India is indeed complex, as both national and sub-national governments are responsible for framing and adopting policies for RE. Furthermore, India follows a multi-party democratic system of governance. Therefore, very often the political

ideology of the national government is at variance with that of the sub-national governments.<sup>27</sup> Hence there is a high probability of policy variance across different layers of the multi-level governance structure that Indian democracy follows. Even if the variance between RE policies at various levels of governments have minimal differences, there are other policies which have direct bearing on the future of the solar and wind power in India, for example, policies concerning land allocation, agriculture, industries, structure of the power system, etc. There may be large degree of variances with regard to such policies. Policy conflicts and non-alignment of policies may affect the future of solar and wind power projects in the country (Hamilton, 2009).

Policy volatility is also a serious issue (Bhattacharya, 2006). In the case a single party does not come to power, the political parties resort to forming alliances to come to power. In such cases, the continuity of the government is uncertain, as some constituents of the alliance can withdraw support midway in the tenor of the government. This vitiates the continuity of policies. Also, in the presence of alliances, the dominant partner in the alliance is forced to frame policies which are accepted by all the constituents of the alliance. Therefore, the role of policies as drivers and (barriers) for scaling up and mainstreaming solar and wind energy in India merits careful attention.

The RE space in India is diversified. There are both grid-connected as well as decentralised RE systems in the country. Among the decentralised systems there are RE solutions that are earmarked for urban industrial spaces while others are used in rural areas. Consequently, a single one-size-fits-all policy, institutional framework, operational system, etc. for promoting RE is not conducive for the Indian RE landscape. Therefore, there needs to be multiple policies at various levels and different technologies without losing alignment between policies. Together, given the structure of governance in India, policies concerning RE influence various other sectors. Simultaneously, the policies in other sectors also have a bearing on the scaling-up of RE in India.<sup>28</sup> Often there are conflicts between policies and priorities of many other sectors which negatively influences policies for scaling-up of RE in India. Such conflicts between policies can become a serious barrier for scaling-up RE. In India, this has been seen in many cases, particularly where national and sub-national policies are not aligned.

On the other hand, drivers to developing RE include zero fuel cost, it is environment friendly, prices free from volatility and external influence, and low dependence on import. These benefits have been highlighted by many political parties and governments in India to gain popular support for RE. The benefits of RE have also prompted the Indian government to introduce RE as a solution for achieving social, economic and environmental gains, together with addressing the need and aspiration of the poor and rural population. The GoI has also published an RE Roadmap that endeavours to bring down the switching cost of migrating from a fossil fuel dependent electricity

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<sup>27</sup> In the recent past a distinct trend in the Indian democracy is a rapid rise of regional political parties as dominant political forces in forming the sub-national governments. This further complicates the situation as policies at sub-national levels are often motivated by a wide array of political philosophies.

<sup>28</sup> For more detailed description of the interrelations between policies concerning RE and those of other sectors, please refer to section 2.3.2.

space to an RE-intensive electricity landscape. The GoI expects that this will promote a wider acceptance of RE among the people of India (Niti Aayog, GOI, 2015). However, despite these advantages, to date the country is yet to fully tap its huge solar potential even though it is one of the largest generators of solar power in the world. Furthermore, though the capacity utilisation of wind power is high as compared to solar, much still needs to be done to fully tap this source.

### 1.2.6 Conflicts and synergies of priorities

Although there is a policy focus on mainstreaming RE in the energy landscape in India, there are barriers in the form of doubts and questions over the technical feasibility and economic viability of RE projects. It is seen that both the national and sub-national governments have tried to evolve policies that would facilitate the up-scaling of RE. The policy space is laden with synergies. RE has been positioned as one of the solutions to the numerous problems, economic, social and environmental, that face India. However, the success of RE depends on how well the actors behave in leveraging synergies and weeding out barriers. Since, various actors may have contradictory views and expectations concerning RE, conflicts in mainstreaming RE are inevitable. The challenge lies in resolving such conflicts in India.

## 1.3 The Human Innovation System Narrative

### 1.3.1 Overview of the development of the case study focus

A focus on mainstreaming RE - particularly, solar and wind power - in the electricity landscape has started only about a decade ago. After independence in 1947 the Indian economy accepted hydro power as an important component of the energy system, however in the recent years this source of energy has lost its momentum in the country. The reasons are numerous and have been discussed earlier in section 2.2. On the other hand, although India has had a vast potential for generating electricity from solar and wind sources, the potential was not explored prior to the 1990s. The solar and wind potential of the country was only developed after the electricity sector opened up for private participation and the Electricity Act of 2003 was implemented to transform the energy system. However, the pace and progress of wind and solar power generation in India during the last decade has been healthy, as seen in the previous sections concerning trends of grid-integrated solar and wind installations. However, India is far from utilising the full potential of the solar and wind power resources available in the country.

Scaling up solar and/or wind power and, as such, all forms of renewable energy is not merely a technology related issue (Rehman, et al., 2010). Social and economic factors play a significant role in the process. Some very important factors are the beliefs and behaviour of the users (and actors) which guides acceptance and large-scale use of RE. Scaling up RE is also guided by factors like: (a) availability of appropriate technology solutions; (b) social and cultural norms of users; (c) economic ability and education of users; (d) peer pressures existing within user communities and;

(e) perception about RE among users, etc. Overlooking these critical issues may hinder the pace and potential of scaling up RE. Additionally, scaling up RE requires addressing the important issue of grid parity. So far, the design and operation of the Indian national grid has been mostly guided by the prospects of generating thermal power. Hence, for a large scale shift to a new regime - an electricity sector with RE as a major component - the grid may need to be reengineered. Thus, there is need to develop new and different skill sets and institutional capacities at all levels of operation and governance of the present energy system. This would help ensure that mainstreaming RE, and not mere experimentation with RE, becomes the focal point of policies and programmes. Therefore, as India strives to mainstream RE and address the issue of inequity in energy access, it is important to understand the challenges of embedding RE in the energy portfolio.

Studies explaining the dynamics of transition suggest that the network of actors play an important role in maturing new innovations and deploying new technologies (Geels, *Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-level Analysis and A Case Study*, 2002) (Geels & Schot, *Typology of sociotechnical transition pathways*, 2007). The networks direct the process of socio-technical transitions and navigate the challenges. They also act as vehicles of expectations and promise, articulators of renewed requirements and demand, sources of resources and enablers of learning and dissemination of learning across (and between) actors and locations (Raven, 2012). Networks need to be 'inclusive' so that a seamless delivery of all desired functions in the value chain can be performed (Rehman, et al., 2010). A deficient network can hamper the process. Articulation of promises of benefits by actors and networks of actors motivates a country to adopt measures for de-carbonizing the economy. The interests and priorities are not always at congruence. This gives rise to conflicts within the network.

The nature, scale and complexity of the network of actors for deployment of renewable energy technologies vary with the type and scale of RE projects (Ghosh & Ghosh, *Rapid Desk-based Study: Evidence and Gaps in Evidence on the Principle Political Economy Constraints and Opportunities to Successful Investment in Clean Energy in Asia*, 2016). Large scale grid connected projects (e.g., utility-scale solar and wind power projects) have a network of actors which, in composition and nature, is very different from that of the smaller standalone programmes targeting households and/or communities (e.g. small scale solar PV projects, solar home systems, etc.). This case study intends to focus on the understanding of networks of actors and the dynamics within and between networks as sources of uncertainty in scaling up solar and wind power projects in India. Furthermore, it intends to investigate the competing priorities, aspirations and interests between actors and networks that may pose threat to the solar and wind power trajectories in the country. The case study also intends to delve into the policy conflicts and politics surrounding the solar and wind power in India. These are extremely important elements as they will either facilitate enforcing or weakening the two trajectories.

### 1.3.2 TIS life cycle value chain: a cradle to grave analysis

Figure 9 illustrates a schematic representation of the value chain of the solar and wind power in India. The blue boxes represent the components of the value chain. Transportation has been shown separately as this affects many of the components of the value chain. The white boxes represent the institutions and actors who facilitate the process of generation, transmission and distribution of the solar and wind power. The solid and dotted lines have been used to represent relationships between components of the value chain and actors governing the same. Solid lines represent the interrelations between different activities. The dotted lines represent relationships between actors and components.

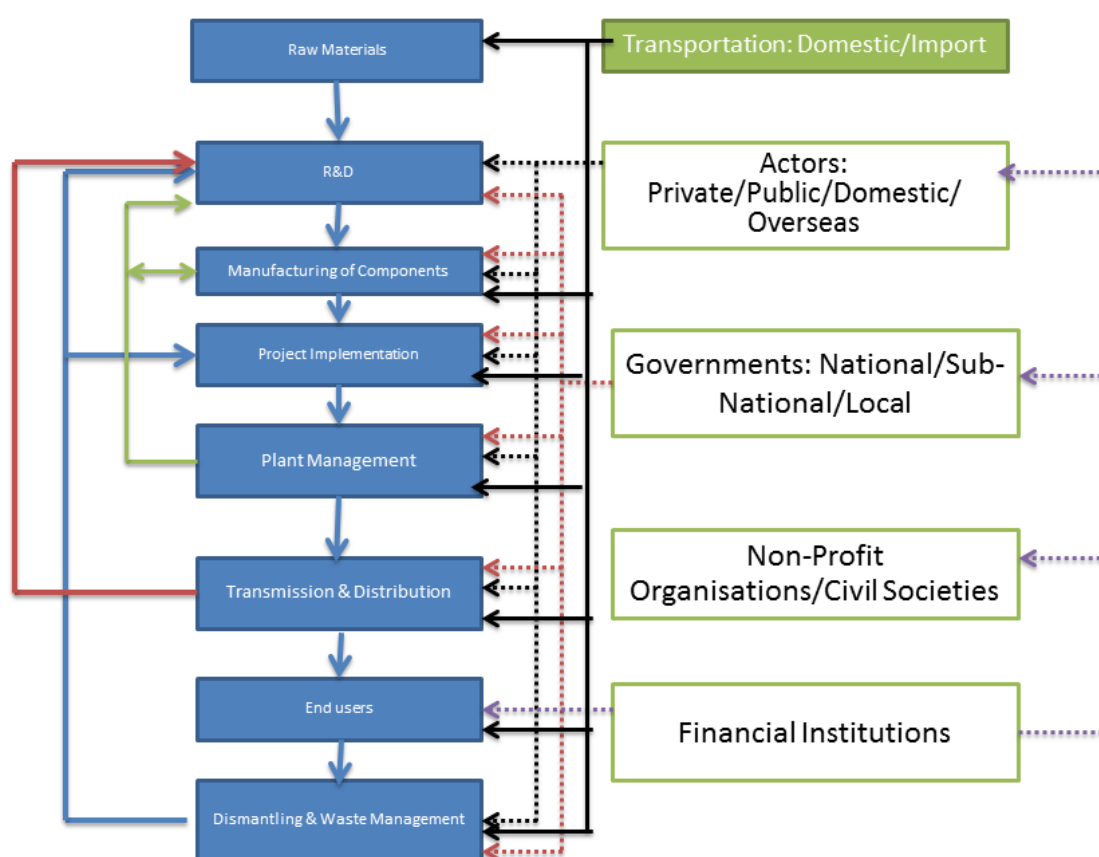


Figure 9 Value chain of solar and wind power in India

Source: Author's own conceptualization

It is important to note that the value chain and associated complexities depend on the type and scale of the solar and wind power projects. For example, the value chain for stand-alone solar power projects (e.g. roof-top solar home systems, solar water heaters, etc.) is relatively simpler in nature than the more complex value chain for the utility-scale solar projects (e.g. solar thermal

plants). Considering these differences, the schematic representation of the value chain is ‘general’ in nature. Some important points regarding the value chain in India are listed below.

- **Impacts on resources:** Although the ‘fuel’ for both solar and wind power is naturally available, the installations for generation, storage and evacuation of power needs various resources - steel, fibreglass, thin film, etc. For storage, batteries are an integral component. All such requirements for solar and wind power projects have an adverse impact on the natural capital within the country or outside. However, the requirement for such components has a positive impact on the economy as it helps the country diversify economic activities, generate employment and grow (Besant-Jones, 2006).
- **Impacts on agriculture and food system:** Large scale solar projects and wind power projects require large amounts of land. In a country like India, where a large proportion of population depends on agriculture, such projects have been criticised for taking away land from agriculture and horticulture. In some states like Gujrat, water bodies are being used for installation of solar panels. Doubts have been raised in such cases over the issue of damage to eco-system and adverse impacts on activities like pisciculture<sup>29</sup> (Ghosh & Ghosh, Rapid Desk-based Study: Evidence and Gaps in Evidence on the Principle Political Economy Constraints and Opportunities to Successful Investment in Clean Energy in Asia, 2016). Also, land being a sensitive issue, proper policies need to be in place for allocating land to such projects.
- **Impacts on building systems:** Mainstreaming roof-top solar installations require change in building norms, building plans, etc. Some of the municipal authorities in India have institutionalized such changes, together with declaring incentives for construction companies and home-owners for facilitating such installations. Also, in the case of decentralised generation and distribution systems using solar resources, buildings are required to have access to smart-grids and mini-grids. Mainstreaming alternative forms of energy in urban areas therefore require changes in building design, building codes and building norms.
- **Impacts on international trade:** India depends on imports from the rest of the world for generating solar and wind power at low cost. Countries like China, Germany, Spain and Japan have made remarkable progress in developing technologies for generating solar power at low cost. Similarly, in the case of wind power, many countries in the EU have showed remarkable progress in developing low-cost but efficient technologies. These countries export technology, skills and components to India. Hence, large-scale development of solar and wind power has significant impacts on issues like bilateral relations, geo-political conditions and international trade (and, hence, balance of payments).

The schematic value chain also highlights the role of actors in facilitating the scaling up of solar and wind energy projects in India. The network of actors for both solar and wind energy, as evident

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<sup>29</sup> Pisciculture refers to the farming of fish.

from the schematic value chain, is highly fragmented and involves actors from both formal (and organised) and informal (and unorganised) sectors<sup>30</sup>, for example local solution providers, small local sellers<sup>31</sup> of RE products and maintenance workers, etc. Individually and collectively, these actors perform various important functions that shape the complete value chain for RE in urban and rural areas. However, the existence of a diverse range of actors in the network makes the network vulnerable to conflicts due to diverging goals and behavioural characteristics (REN21, 2015). As an example, this vulnerability is much in evidence in those cases where the unorganised sector has flooded local market with cheap but inferior quality components for RE solutions. This happens particularly in rural areas, and in the case of stand-alone RE solutions. While such network dynamics help the actors in the unorganised sector gain economic opportunities, it simultaneously generated doubts among users regarding the reliability and sustainability of RE solutions. This negative perception acts as a barrier for the penetration of RE by the actors belonging to the more formal and organized sector. Therefore, careful attention need to be accorded to resolving conflicts that impede the performance of the network of actors in scaling up RE, particularly in the case of stand-alone RE solutions.

A brief overview of actors along with their functions, roles and responsibilities in the value chain of the solar and wind energy in India is presented below:

- **Global Climate Forums:** Such forums/groups steer the climate agenda throughout the world. They set global climate goals and influence climate related development policies, targets and actions of countries. Some examples of such groups/forums are UNFCCC, IPCC, COP, etc. In the recent past India has witnessed a rapid growth of its GDP accompanied by a high level of emissions. However, India has also been slow in achieving universal electrification, provisioning of clean fuel among the poor and other such development goals. There is enough evidence in the literature that such forums have had active negotiation with India to ensure that the Gol pursues a policy for mainstreaming clean energy for achieving development goals and reducing GHG emission.
- **National Government:** The national government sets national level goals and frames policies and regulations concerning developing and deploying RE in the country. Various line ministries operate as crucial actors since RE has linkages with, and consequence upon, various other sectors: conventional power generation, grid management, transport, industry, rural development, trade and commerce, agriculture, finance, geo-political considerations, etc. The line ministries of the national government are responsible for framing national level policies and programmes concerning solar and wind power (and their applications) in India.

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<sup>30</sup> The informal sector consists of economic units where the employment relationship is not subject to national labour legislation, income taxation, social protection or entitlement to certain employment benefits like advance dismissal notice, paid annual or sick leave, etc. On the contrary, those economic units which are subject to labour laws, social protection, employment benefits, tax, etc. constitute the formal sector.

<sup>31</sup> Very often these small sellers are not authorised channel partners of original equipment manufacturers.

The Ministry of New and Renewable Energy is the nodal<sup>32</sup> ministry, however this Ministry depends on the policies and actions of other ministries.

- **Sub-national Governments:** Given the federal structure of governance in India, and given that electricity is the joint responsibility of both the national and sub-national governments, the planning, implementation and continuation of the solar and wind power projects and programmes also depend on the strategies and policies of the sub-national government. Based on the principle of fiscal federalism, a major source of funds for the sub-national governments is the budget allocation by the Central Government in the form of states' share of central taxes. This means budgets for many centrally sponsored RE programmes are routed through the departments of the sub-national governments. To this extent, it is extremely difficult to separate the roles of the national and sub-national governments in the case of RE programmes and projects. In some cases, the sub-national governments participate in RE projects directly: financing projects (through debt and/or equity), implementing projects, ensuring availability of land for private players, declaring incentives, designing policies for setting tariffs, etc. Like the national government, various departments of the state governments are also involved in this process. A very important function of the sub-national governments is setting of tariffs in power purchase agreements, which, determines the financial viability of utility-scale solar and wind projects.
- **Local Governments:** The 74th Constitutional Amendment of 1992 vests a high degree of autonomy (administrative and financial) to the city corporations, municipalities and village level administrations.<sup>33</sup> These administrative entities have the autonomy to decide specific service deliveries<sup>34</sup> in cities and villages. Such authorities not only plan and identify potential end users who could derive maximum benefit from RE programmes, particularly stand-alone programmes, but also plan for mainstreaming RE in urban and village development plans, respectively. For certain RE related programmes, local governments are also mandated with the distribution of funds among beneficiaries of RE programmes, particularly stand-alone programmes.
- **Technology Developers:** The technology developers are an integral part of solar and wind power projects in India as they focus on research and development for offering customised solutions considering various parameters - geographical terrain, grid interaction, financial constraints, etc. (IEA, 2011). These developers can be public or private and domestic or foreign entities. Sometimes, research institutions and universities play a crucial role in developing suitable technologies. Thus, this actor group represents a constellation of participants from academia and industry, both from within the country and outside it. In some

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<sup>32</sup> In the context of India, line ministry that is principally responsible for formulating policies for a particular sector and/or coordinating with other ministries for development of a particular sector is called the nodal ministry for that sector.

<sup>33</sup> Village level administration is referred to as Panchayats.

<sup>34</sup> The list is provided in the 12<sup>th</sup> Schedule of the 74th Constitutional Amendment Act, 1992.



cases, there are joint ventures and consortia where a group of technology developers work together to develop feasible technologies for solar and wind applications.

- **Technology Implementers/Project Developers:** Like technology developers, this group of actors could be private or public entities (by constitution) and domestic or foreign (by location of origin). The actors may operate individually or in groups (consortia, joint ventures, PPP, etc.). Their responsibilities generally include manufacturing and/or supply, installation, testing, commissioning and comprehensive maintenance work during the maintenance period as specified in the contract (JREDA, 2011). Another integral part of this group of actors is the ‘channel partners’ of the original equipment manufacturers (OEMs). These channel partners ensure the last mile delivery of various components required for operation and maintenance both for the project and by the consumers. These channel partners may either belong to the formal or informal sector<sup>35</sup>. However, the linkage between the domestic and foreign actors is highly dependent on the international trade policies pursued by India, the complexities of geo-politics and international relations between India and other countries.<sup>36</sup>
- **Financing Partners:** The financing of solar, wind and other RE projects is done through a range of instruments: grants, equity, debt. The degree of blending of different sources of finance varies with the scale, cost and risk associated with the project. The financing partners include corporate and retail investors (domestic and foreign), venture capitalists (domestic and foreign), financial intermediaries, financial regulators (in both debt and equity markets), governments (national and sub-national) and, multilateral and bilateral financing institutions. Microfinance institutions also play a very important role, particularly for stand-alone RE projects targeted at rural areas. In a typical rural set-up private money lenders also assume an important role in financing stand-alone solar solutions. Since the consumers are not creditworthy, the formal sector (e.g. banks, other lending agencies, microfinance institutions, etc.) refrains from providing financial assistance to these consumers. It is here that private money lenders fill the gap by providing debt at a higher-than-market interest rate. The debt is used for purchasing solar solutions - solar home system, solar photovoltaic system, etc.<sup>37</sup>
- **Civil Society:** Non-Government Organizations (NGO) and activists (individually and/or in groups) constitute this group of actors. These actors play a crucial role in: generating awareness about need for RE in the society, project implementation (in certain cases), ensuring the last mile delivery of RE solutions, and supporting consumers, etc. However, in certain cases civil society also play a negative role in planning and execution of RE projects by resisting land-acquisition endeavours during large scale solar and wind projects. A recent case in point is Maharashtra, where, a total of 125 MW solar projects in the districts of

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<sup>35</sup> This issue has been touched upon previously.

<sup>36</sup> For example, many solar projects use solar panels that are manufactured in China. Active research and development among the Chinese manufacturers has reduced costs of the solar panels and, hence, have also reduced the generation cost of solar power. However, the imports from China are heavily dependent upon the bilateral relation between India and China.

<sup>37</sup> This phenomenon has been observed in many poor villages of Odisha and Jharkhand, where the author (along with a team of researchers) had conducted a survey for identifying opportunities and barriers for up-scaling RE solutions for rural applications.

Osmanabad and Parwani were stalled in 2014 due to intense resistance offered by various activist groups against acquiring agricultural land. (The Times of India, 2014)

- **Users:** This group of actors consists of households and businesses. They either accept or oppose solar, wind and other RE technologies as a solution. This group of actors also provide feedback on RE projects which are used to design the future trajectory of low-carbon solutions for electricity provisioning.

The network of actors for RE development and deployment in India is a fairly complex and fragmented web (ADB, 2015). Within each class of group of actors there are sub-groups of actors with competing priorities and constraints (UNDP, 2013a). Investors and implementers in RE, including solar and wind power, therefore, have to co-ordinate with multiple stakeholders each having their own goals, priorities and targets. This co-ordination escalates the transaction cost of doing business (Ghosh & Ghosh, Rapid Desk-based Study: Evidence and Gaps in Evidence on the Principle Political Economy Constraints and Opportunities to Successful Investment in Clean Energy in Asia, 2016). Furthermore, it may also hinder project implementation (Ölz & Beerepoot, 2010). The multi-layered network of actors may also be plagued by capacity deficiency in terms of knowledge and training on RE, RE potential and solutions (IRENA, 2012). Communicating the opportunities and benefits of RE to all actors, and aligning these with the goals and aspirations of the actors, is a time consuming process. All these factors have negative impacts on the returns on investments in RE projects.

### 1.3.3 Enabling environment: policy mixes in the socio-economic system

This case study to investigate the role of a variety of policies, both at the national and sub-national levels as enablers or barriers to mainstreaming solar, wind and other forms of RE in India. It is proposed that the stakeholders will be engaged in a detailed discussion concerning the efficacy of policies and also about the defining characteristics of the policy space in India. This is extremely important, given the discussions earlier in the section. The following policies, identified through literature review, are shortlisted in the table below.<sup>38</sup> It may be noted that the list is not indicative, though not exhaustive.

**Table 10 Policies and Programmes of National and Sub-National Governments**

Policies/Programmes at the National Level	Policies at the Sub-national Level
Electricity Act, 2003 (and its amendments)	Relevant Sub-national policies and programmes
National Action Plan on Climate Change, 2008	

<sup>38</sup> These policies have also been mentioned in the TIS matrix.

Jawaharlal Nehru National Solar Mission, 2010	Allocation in various sub-national budgets for development of clean energy
Deen Dayal Upadhyay Gram Jyoti Yojana, 2015	
National Renewable Energy Act, 2015	Allocation in National Budget for development of clean energy
India's INDC, 2015	
Policy for Repowering Wind Power Project, 2016	Other relevant policies/programmes
National Off-shore Wind Energy Policy, 2015	
Lending Policy of the Reserve Bank of India, 2015	

Given the multiple development challenges facing India there is a dominant view among experts that India needs to leverage its vast renewable energy (RE) sources to tackle the dual challenges of (a) addressing energy poverty particularly in its myriads of villages (often remote and situated in difficult terrains), and (b) providing clean energy to its population (Hiremath, Kumar, Balachandra, Ravindranath, & Raghunandan, 2009), (Rehman, et al., 2010). Although a large-scale focus on RE started with the adoption of the Electricity Act, 2003, there are a number of policy initiatives undertaken during the last decade which have established India among one of the most proactive countries in adopting and mainstreaming RE in its energy portfolio.

The Gol, during the past decade, has gradually fostered a distinct paradigm shift in the electricity sector. The new paradigm favours RE in different energy related strategies. Some of the major policies adopted during this period have created an enabling environment for scaling-up penetration of RE in the energy landscape of India. A brief overview of some such policies is presented here.

- (i) The National Action Plan on Climate Change (NAPCC) in 2008 sought to promote solar and other forms of renewable energy including wind, through a National Mission on Solar Power (MoEF, 2008).
- (ii) In line with the NAPCC, the Jawaharlal Nehru National Solar Mission was launched in 2010. The objective was to create an enabling environment for (a) deploying 20000 MW of grid connected solar power by 2015; (b) promote R&D in solar power technologies; and (c) increase domestic production of important raw materials, components and products to achieve grid tariff parity by 2022 (MNRE, 2012).
- (iii) In 2011, the Gol announced the Strategic Plan for New and Renewable Energy Sector for the period 2011-2017. The objective stated in this plan is to gradually replace conventional energy sources by RE, particularly solar, wind, biomass/ bagasse cogeneration and small hydro power, through both grid integrated and standalone generation systems. (MNRE, 2011)

- (iv) As per India's Intended Nationally Determined Contribution (INDC), announced in 2015, the GoI targets achieving a 40% non-fossil fuel based power capacity by 2030 with the help of technology transfers and low cost international finance (GoI, 2015).
- (v) Acknowledging the role of RE in addressing critical energy related issues, the Indian Government drafted the National Renewable Energy Act in 2015 (MNRE, 2015), (Niti Aayog, GOI, 2015). The objective of the Act is to explore, develop and mainstream RE as a possible alternative solution to energy related problems in rural India.
- (vi) In 2015, the Reserve Bank of India declared that lending by commercial banks to RE projects will be accorded the status of 'priority sector lending'.<sup>39</sup> This would ease the flow of credit to the RE sector and also reduce cost of funds to the implementers of RE projects. The policy is also seen as an instrument to encourage banks to lend to RE projects in a target-driven approach.
- (vii) Pursuant to the national strategy on RE, various sub-national governments in India have undertaken policies promoting clean energy sources particularly solar, wind and hydro, in their respective administrative jurisdictions. These have been documented and adopted in the State Action Plan for Climate Change (SAPCC)<sup>40</sup>. A few of the policies that have been adopted so far includes the Andhra Pradesh New Wind Power policy 2008, Andhra Pradesh Solar Power Policy 2012, Bihar Renewable Energy Development Agency Policy for Promotion of New and Renewable Energy Sources 2011, Chhattisgarh Wind Energy Policy 2006, Chhattisgarh Solar Policy 2012, Gujarat Solar Power Policy 2009, Gujarat Wind Power Policy 2013, Orissa Solar Power Policy 2013, etc. (IREDA, 2016)

The seventh SDG proclaims “increasing substantially the share of renewable energy” (RE) in the energy mix (United Nations, 2015). For a long time now, RE has been regarded as a solution for removing inequity in energy access and electrification of remote areas (Martinot, Chaurey, Lew, Moreira, & Wamukonya, 2002), (Unruh, 2002). The focus on RE implies a complete paradigm shift for South Asian countries, including India, that are traditionally locked in fossil fuel based energy regimes. In India, a shift to RE may not only address the nation's energy deficit issues, but can also improve the nations budgetary and other economic imbalances (Sovacool, 2012), (Bhide & Monroy, 2011), (Bhattacharya, 2006). Given this perspective, over the last two and half decades, the policy landscape in the country has favoured mainstreaming of RE in the country's energy strategies.

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<sup>39</sup> There are some sectors of the Indian economy which are considered extremely important for the achieving development goals. The Reserve Bank of India - the Central Bank of the country, recognizing the importance of these sectors in the national development calls these sectors as “priority sectors”. It mandates all banks in the country to provide at least 40% of the total credit to these sectors. The rates of interest are also concessional. Some examples of priority sectors are: loans to farmers, home loans made to middle and lower income groups, loans for education, etc.

<sup>40</sup> For a detailed study of SAPCCs of various states in India, the reader may refer to: <http://envfor.nic.in/ccd-sapcc>

### 1.3.4 Enabling environment: government institutions

Literature asserts that it is the government, through its various arms (ministries, agencies and various institutions) that creates an enabling environment in which the RE receives required momentum for being scaled-up and mainstreamed in the incumbent energy landscape (Amin, 2015), (ADB, 2015), (Roy, Ghosh, Ghosh, & Dasgupta, 2013), (Besant-Jones, 2006). The government institutions create an investment-grade regime (Bruckner, et al., 2014), (Hamilton, 2009), in which the investors, particularly from the private sector, are encouraged to invest in different components of the RE value chain (Ghosh & Ghosh, Rapid Desk-based Study: Evidence and Gaps in Evidence on the Principle Political Economy Constraints and Opportunities to Successful Investment in Clean Energy in Asia, 2016), (Caperton, 2010).

In India, with regard to solar and wind energy, there are numerous government institutions who are playing a direct and/or indirect role in providing the stimulus for scaling-up solar and wind energy in the country. An indicative list has been provided in section 1.3. However, it is often argued that the actions and policies by different ministries and institutions of government are conflicting and can shroud the future trajectory of RE in India with uncertainty and risk (Bhattacharya, 2006). Therefore, the exact interaction between various institutions of the government needs to be analysed to understand the nature of risk they pose to the solar and wind energy trajectories in India. This case study intends to investigate the nature of interaction, nature of interdependencies and relations. Stakeholders, during the consultation process, will be asked about these issues. The TIS matrix identifies a set of government ministries. These are detailed below in Table 11 along with their roles in scaling-up solar and wind power projects in India.

**Table 11 Government institutions: roles and issues**

Government Institution	Role	Issues
<b>Ministry of New and Renewable Energy (MNRE)</b>	Nodal ministry at the national level for development of clean energy	To what extent the policies and programmes of MNRE are aligned with those of the other Ministries - e.g. Ministry of Power, Ministry of Rural Development, etc.? To what extent is MNRE able to 'push' the solar and wind projects in the overall plans of the national government? To what extent are sub-national policies influenced by the policies of MNRE?
<b>Ministry of Power (MOP)</b>	Responsible for overall power situation in the country	How aligned are the policies of MOP with the national goal of mainstreaming clean energy?
<b>Ministry of Environment Forests and Climate Change (MOEF&amp;CC)</b>	Nodal ministry responsible for planning for mitigation and adaptation in the country	How well is this Ministry able to influence the actions of MNRE, MOP, MOF and sub-national governments?

<b>Ministry of Finance</b>	Responsible for framing overall financial plan for the country	How much financial provision is made for solar and wind projects? To what extent it is motivated by the need to address climate change and clean energy?
<b>Various line departments of sub-national governments</b>	Responsible for making plans and programmes at the sub-national level	To what extent are the sub-national actions/policies are influenced by the need to address climate change and environment?

## 1.4 The Innovation System map

Based on the discussions above, an innovation system map for the solar and wind power trajectories in India has been constructed, depicted in Figure 10. The context comprises of the economic, social and environmental priorities of the country. However, an important component of the context is the international relations, since India imports skill, technology and components from many countries like China, Germany, Spain, etc. This highlights the need for a stable international relationship with such countries, conducive international trade rules and a regime of affordable tariffs so that the cost of generating solar and wind power do not exceed the expectations.

Financing also plays an important role. Following the past trend, it is expected that solar and wind power projects (at least the large scale projects) will be financed through a blending of budgetary allocations, finance from bilateral and multilateral financial institutions and a mix of debt and equity. This calls for measures for strengthening the debt and equity market for financing solar and wind power projects. Although in 2015 the national government, through the Reserve Bank of India, has accorded renewable energy the status of priority sector for lending to the banking system of the country, it is a relatively new area and therefore there may be initial hesitation to direct credit to this sector. Thus policies and strategies need to be in place for addressing barriers to financing solar and wind power projects.

Since the structure of the Indian electricity sector is highly skewed towards thermal power, the national grid has been designed in favour of transmitting thermal power. With the anticipated share of renewable energy in the energy portfolio, the existing grid infrastructure may not be sufficient. The grid needs to be redesigned and reengineered for mainstreaming solar and wind energy in the energy landscape of India. This not only calls for high investment, but also is contingent upon research, development and adoption of grid related technologies. Strategies are required for channelling resources into this area.

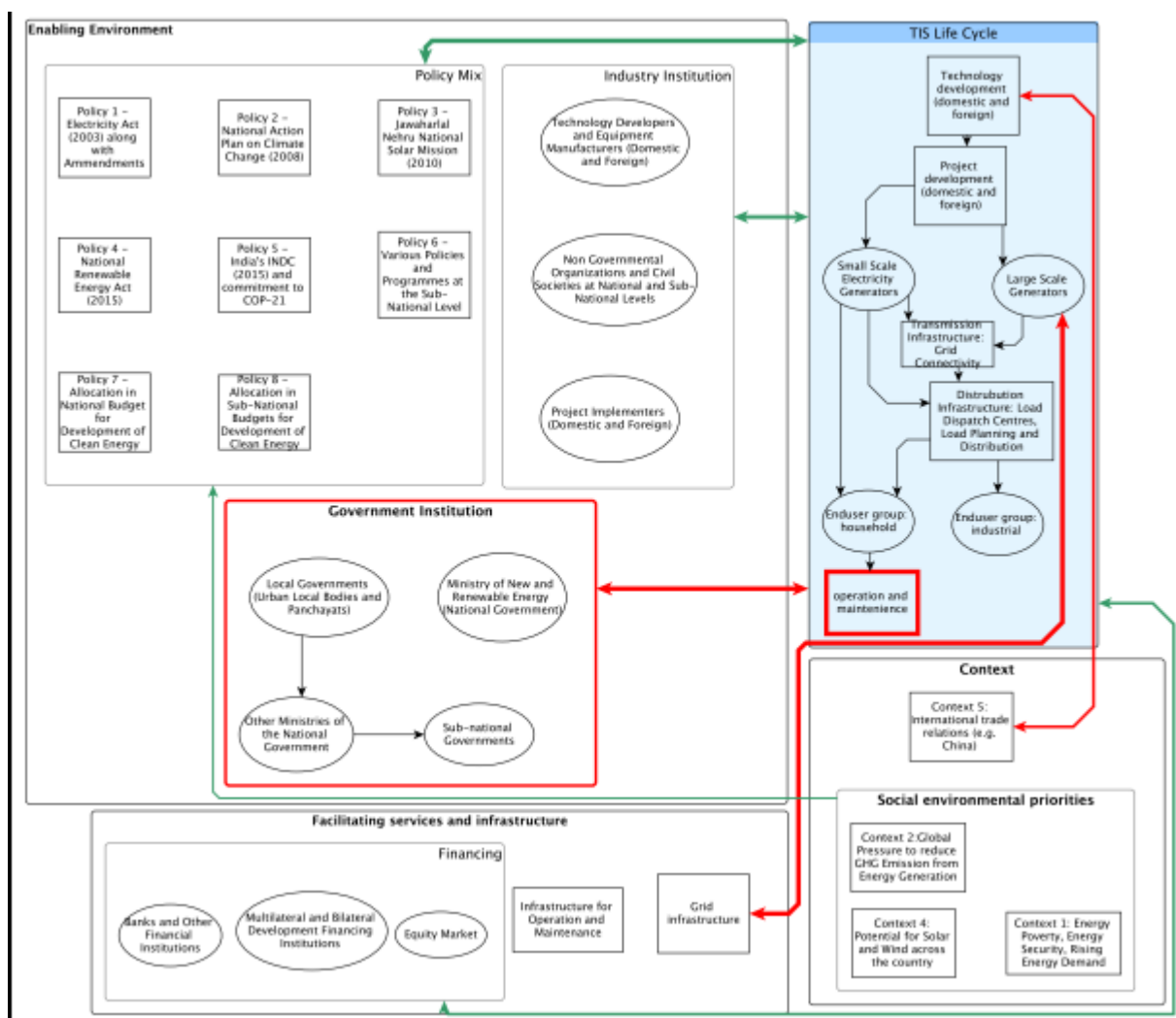


Figure 10 Innovation System Map: Solar and Wind Power in India

Hence, although India is marked with a policy mix and institutional arrangements for scaling up solar and wind energy in the country, there are challenges which pose risk to the intended trajectories. It is important to identify such risks and formulate risk mitigation mechanisms to achieve the intended goal of mainstreaming renewable energy as has been expressed in the INDC of India in 2015. Needless to say, such risks differ across scale of projects and type of projects. Thus it is important that strategies factor in these considerations before implementation. The task, although not impossible, is daunting.

## 1.5 Stakeholder engagement

The Indian case study is a “limited” case study in the project. However, to understand various complexities of RE in India, a range of stakeholders have been consulted. Simultaneously a rigorous review of the literature and analysis of various policies have been done. The present report is based on the findings from the literature review and inputs received from the stakeholders during consultation of stakeholders. An indicative list of stakeholders consulted during the process is shown below.

**Table 12: Stakeholders Consulted**

	Type of stakeholder	Position in the organization	Economic sector	Type of engagement	Month and year contacted
1	Policy maker	Government National	- Energy	Interview	August 2016
2	Policy maker	Government subnational	- Energy	Interview	July, 2016
3	Policy maker	Government subnational	- Energy	Interview	March-April, 2016
4	Policy maker	Government Subnational	- Energy	Interview	March - April, 2016
5	Industry Association	Business	Energy	Interview	March, 2016
6	Academic	Researcher	Energy	Interview	March-October, 2016
7	Academic	Researcher	Energy	Interview	October, 2016
8	Academic	Researcher	Energy	Interview	March-October, 2016
9	Users		Energy	Survey	January-March, 2016



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