Is Sustainable Energy Transition in India on Track?

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India's energy transition trajectory is complex, encompassing myriads of factors. Some factors are endogenous to Indian economy and some are exogenous (of global origin); some are conventional and some are emerging; some hinder as constraints and some pose as opportunities. Energy systems and structure, both from the demand and supply side, are undergoing transformations, under the compulsions of three d's, namely democracy (thriving and evolving), demography (young) and development (vibrant). While energy consumption has exhibited a secular trend, the energy basket is set to undergo a different composition. The uncertainties are so much that reality at any point of time defies prediction.

The dominant features of energy systems management and challenges in India have undergone paradigm shift in recent years. Energy security from the supply side has given space to concern for energy sustainability. Energy scarcity management as a policy goal has given space to provision for energy abundance and reliability. Affordability by consumers has been replaced by demand for availability and accessibility by consumers. Energy distribution has encountered disruption by technology and smart delivery system. Market has become competitive and players have proliferated together with growth of regulatory institutions. Consumers and producers are trying to find their identity and assert their economic value, giving rise to a new set of players, known as *prosumers*. Forces of geopolitical developments and trade wars are threatening to unsettle the market equilibrium. Overall, Indian energy systems are passing through the vortex of regulation, policy, technology, investment in capacity of production, distribution and storage, pricing, digitization and move towards de-carbonization. More than the volume of energy consumed, what is becoming of significance is the efficiency and intensity of application of energy. Today, Indian energy Industry is more integrated with the world and there is a collaborative view that energy industry has to fuel the economy, enabling millions of people to lift their quality of life.

Innovation is one new factor, which is going to be the primary cause of disruption in transition. Innovation will largely help cause the decarbonisation of energy industry. Innovation will bring new business models, particularly in electricity sector, featured by decentralization and digitalization. Another emerging factor, to be ushered in energy sector is IoT (Internet of Things). This will leverage connected devices so that these devices smart trade with each other with very low transaction cost.

This paper is an assessment of the transition process that is underway in terms of its direction, intensity and actualization. The paper is structured under following seven headings:

1. Energy transition measured
2. Physical energy transition
3. Energy transition: target vs. accomplishment
4. Green energy programs
5. Future green energy initiatives
6. Business provisions for green energy
7. What more needs to be done?

1. Energy Transition Measured

1.1 India's Energy Consumption

India is world's third largest consumer of energy (724 MTOE in 2016), after China (3053 MTOE) and USA (2272 MTOE). Keeping pace with its fast GDP growth and urbanization, the country's energy consumption grew at 5.75 CAGR during last decade (2006-2016). Almost 30% of increase in energy consumption in the world will come from India. (IEA, 2017)

Table: Per-capita Energy Consumption and Energy Intensity

Year	Energy Consumption in peta joules	Midyear population (in Million)	GDP (Rs. crore)	Per Capita Energy Consumption (in Mega Joules)	Energy Intensity (Mega Joules per Rupee)
2005-06	14286	1118	3253073	12778	0.4392
2006-07	16571	1134	3564364	14613	0.4649
2007-08	17878	1148	3896636	15573	0.4588
2008-09	18936	1161	4158676	16310	0.4553
2009-10	21408	1175	4516071	18220	0.4740
2010-11	22458	1182	4918533	19000	0.4566
2011-12	23872	1219	8736329	19579	0.2732
2012-13	25128	1237	9213017	20307	0.2727
2013-14	25755	1256	9801370	20513	0.2628
2014-15	27589	1274	10527674	21660	0.2621
2015-16	28337	1292	11386145	21935	0.2489
2016-17	29279	1310	12196006	22351	0.2401

Note: GDP data till 2010-11 are estimated at 2004-05 price and from 2011-12 onwards, the same is estimate at 2011-12 price. Therefore, there is a discontinuity between the GDP and GDP derived figures between 2010-11 and 2011-12.
Source: Energy Statistics, MOSPI, GOI, 2018 and previous issues.

Significant to observe that per capita energy consumption in the country is growing and the energy intensity per unit of output on average is on a declining path. This is primarily explained by increasing share of national income from service sector and deployment of energy saving equipment and programs.

1.2 Transition in energy basket

Transition in energy consumption is to be seen from the points of view of: a) significant increase in energy demand and b) shift towards low carbon energy mix.

We have in this paper taken projection done by International Energy Agency (IEA) in World Energy Outlook 2017 in their sustainable development scenario. That scenario 'outlines an integrated approach to achieve energy related aspects of United Nation's Development Goals: determined action on climate change, universal access to modern energy by 2030, and a dramatic reduction in air pollution'. (IEA, 2017) The architecture of India's current energy policy and action plan is aligned with this scenario of IEA,

Table below presents total primary energy consumption of world and of India from 1965 till 2016 and presents projection till 2040 as per above stated sustainable development scenario made by IEA.

Table: Total Primary Energy Consumption: Actual up to 2016 and Projection thereafter- India vs. World

Fig - MTOE

	1965	1970	1980	1990	2000	2014	2015	2016	2025	2030	2040
	Actual – Historical								Projection		
World	3731	4912	6642	8142	10035	13684	13633	13760	13921	13836	14084
India	53	65	102	195	441	824	851	897	1118	1236	1479
% of India to World	1.4	1.3	1.5	2.4	4.4	6.0	6.2	6.5	8.1	9.2	10.8

Source: Figure till 1990 – BP Statistical Review of World Energy, 2017, by BP
Figure from 2000 onwards – World Energy Outlook, 2017, by IEA

India is poised to occupy the centre stage of world energy consumption, as its share goes on increasing from 6.5% of world consumption in 2016 to 10.8% in 2040, which is CAGR growth of 2.67%.

1.3 Move towards sustainability

Sustainability in energy consumption has been captured by two indices: 1. Energy Trilemma Index, formulated and estimated every year by World Energy Council, and 2. Energy Architecture Performance Index, formulated and estimated by World Economic Forum every year.

Beauty of these two indices is that these provide a composite score together with individual element wise ranking for all the countries (125 / 127) year after year. A country can find its relative position amongst other equal profiled countries and also observe how it is faring on each individual element year after year.

Energy Trilemma Index

Energy Trilemma Index of World Energy Council (WEC), computed since 2010, considers 3 dimensions of a country's energy system: a) Energy Security, b) Energy Equity and c) Environmental Sustainability.

Each of the 3 indicators represents an aspect of policy and performance of energy systems of a country. Each indictor is vital for the economic and social wellbeing of the country. 'Energy security' represents 'effective management of primary energy supply from domestic and external sources, reliability of energy infrastructure and ability of energy providers to meet the current and future demand'. 'Energy equity' measures 'accessibility and affordability of energy supply across the population'. 'Environmental sustainability' measures 'achievement of supply and demand side energy efficiencies and development of energy supply from renewable and other low carbon sources'.

Energy Trilemma Index (ETI) is a comparative ranking based on scores which is outcome of analysis of 60 data sets used to develop 23 indicators.

Each dimension has been given a score ranging from 'A' to 'D', reflecting where energy leaders may want to direct initiatives to achieve better performance. The balance score highlights how well a country manages the trade-offs between the three energy trilemma and identifies the top performing country with 'AAA' score.

WEC also measures 'Contextual Performance Indicator' that considers 'the broader circumstances of energy performance, including a country's ability to provide coherent, predictable and stable policy and regulatory framework, initiate R&D and innovation and attract investment' and also the country's economic, societal and political stability.

India has moved up in overall rank from 122 in 2014 (was better placed at 115 in 2013) to 92 in 2017. The improvement has come from all the three indicators and is more pronounced with respect to environmental sustainability. This indicates that transition towards low carbon economy is indeed happening in India, though it has long way to move further from the level 'C' to level 'A'. The 'context' indictor reflecting policy, regulatory and economic and political stability shows remarkable improvement in 2013 and in 2017. (There was a methodological change in 2016 in computing the Trilemma index by WEC, leading to discontinuity of data prior to 2015.)

Table: Energy Trilemma Indicators for India

Figures indicate Rank, except the balance score, which is a composite Score

	2012	2013	2014	2015	2016	2017
Energy Security	86	76	76	60	51	66
Energy Equity	110	110	105	93	93	96
Environmental Sustainability	123	121	123	96	97	92
Contextual Performance	-	76	90	105	100	86
Overall Rank	117	115	122	92	91	92
Balance Score	-	CDD	CDD	BDD	BCC	CCC

Source: World Energy Trilemma Index 2017 & 2014, World Energy Council

Energy Architecture Performance Index

World Economic Forum, since 2013, devised a composite index, 'Energy Architecture Performance Index' (EAPI), as a measure of 3 key indicators of a country's energy system, which are again split into 18 sub indicators. EAPI index ranks 127 countries in descending order and gives score to the 3 key indicators on a scale of 0 – 1.

3 Broad Index	What the Sub-indices indicate
Economic Growth and Development	This sub-index measures the extent to which a country's energy architecture adds or detracts from economic growth
Environmental Sustainability	This sub-index measures the environmental impact of energy supply and consumption
Energy Access and Security	This sub-index measures the extent to which an energy supply is secure, accessible and diversified

Table: Energy Architecture Performance Index for India (score on the scale of 0 – 1)

	Rank out of 127 Countries	Composite Score	Economic Growth & Development	Environmental Sustainability	Energy Access & Security
2017	87	0.55	0.54	0.49	0.62
2016	90	0.53	0.51	0.49	0.61
2015	95	0.51	0.50	0.42	0.61
2014	69	0.48	0.49	0.41	0.54

Source: Global Energy Architecture Performance Index, World Economic Forum

Above table brings out the fact that India has improved score on all fronts, during last 4 years, particularly with respect to energy access and security and environmental sustainability. There is marginal improvement in composite score over the years, though the rank scrolled down in 2015 and went up in 2016 and further up in 2017. India has much to travel up the ladder to reach anywhere closer to the highest score of Switzerland, where environmental sustainability is 0.77 and energy access and security is 0.88.

Energy Transition Index

World Economic Forum in 2018 has formulated concept of Energy Transition Index (ETI) and computed value (in terms of percentage) for 114 countries. (WEF, 2018) In addition to measuring country's energy system performance, ETI evaluates the extent to which countries have created the conditions for being future ready for becoming sustainable energy economy. ETI is a composite index consisting of two sub-index, namely; energy subsystem performance score and transition readiness score. The system performance score is computed with 17 indicators, which are defined using three imperatives of energy triangle (EAPI); energy system that supports: a) economic development and growth, b) environmental sustainability and c) energy security and access. The transition readiness score is calculated using 23 indicators, which define six enabling dimensions: a) capital and investment, b) regulation and political commitment, c) institutions and governance, d) infrastructure and innovative business environment, e) human capital and consumer participation, and f) energy system structure.

Table: Energy Transition Index for India

Figures in Percentage

	India Score	Highest Score – Country
Energy Transition Index	49	76 - Sweden
System Performance Index	52	84 – Norway
Transition Readiness Index	47	73 - Finland

Source*:* WEF, 2018

Inter-temporal comparison of this index is not available; therefore we are not in a position to observe the movement (improvement) over the years. However, the fact that overall transition index remains below 50% and less by 27 percentage point from the highest, speaks that India has to do a lot to experience the transition that India is aiming at.

Readiness for Solar Household Systems

McKinsey has identified 39 countries in sub Saharan Africa and South Asia where 90% of world's estimated 870 million un-electrified population would habitat by 2020. Based on projected grid expansion, population growth and consumer's ability to pay, McKinsey has assessed that 150 million households in those 39 countries could benefit solar household system (SHS) by 2020. India is placed in the highest category (out of 4 categories), and third in position from top after Kenya and Philippines, as most SHS ready in index of 'readiness for solar household system'. (Kendall, 2018)

2. Physical Energy Transition

2.1 India's Resolve for Energy Transition

India ratified its Nationally Determined Contribution (NDC) commitment made in Paris Agreement in COP 21 of United Nations Framework Convention on Climate Change (UNFCCC) on 2nd October 2016.

The significant measurable commitments are:

- To reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level.
- To achieve about 40 percent cumulative electricity installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).
- To create additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030.

Government of India announced in 2014 its intention to have cumulative renewable power generation capacity of 175 GW by 2022 (excluding large hydropower). Out of this, solar will be 100 GW, wind 60 GW, biomass 10 GW and small hydro projects will be 5 GW.

India launched international solar alliance of 120 countries in 21st Conference of Parties (COP21) at Paris in December 2015, with commitment to contribute $27 million and headquarter in India.

2.2 Energy Basket for India

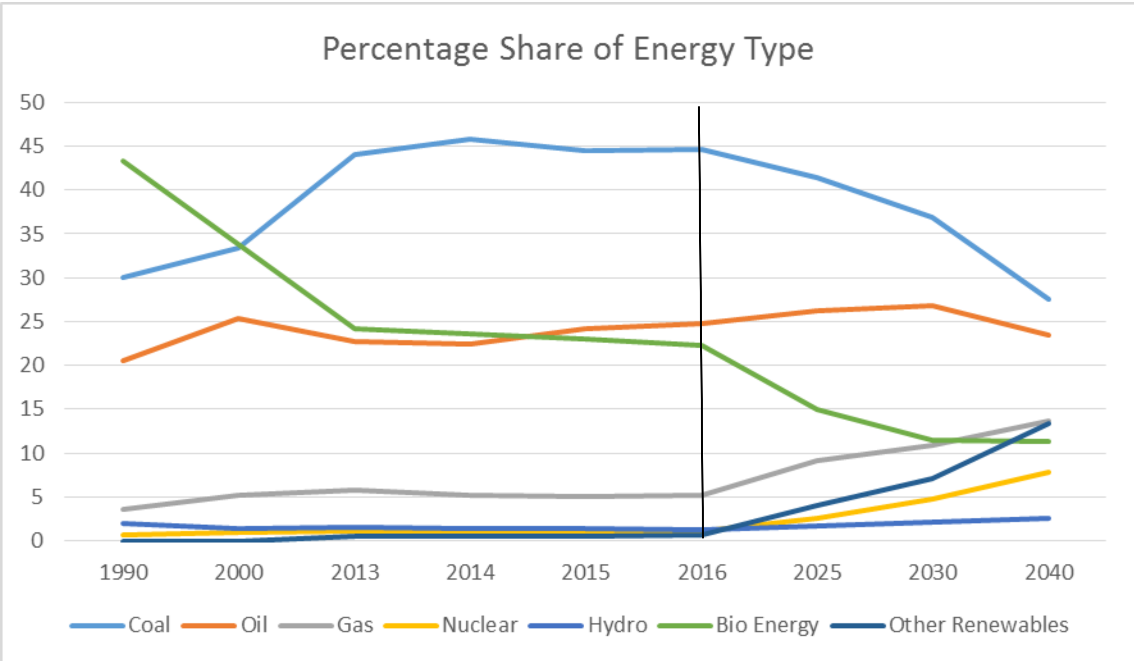
Table: Energy Type Mix (Actual till 2016 and projection till 2040)

Fig - MTOE

	1990	2000	2013	2014	2015	2016	2025	2030	2040
	Actual						Projection		
Coal	92	147	341	378	379	401	463	456	408
Oil	63	112	176	185	206	222	293	331	348
Gas	11	23	45	43	43	47	102	135	203
Nuclear	2	4	9	9	10	10	28	59	116
Hydro	6	6	12	11	12	11	19	26	38
Bio Energy	133	149	188	194	196	200	168	142	167
Other Renewables	0	0	4	4	5	6	45	87	199
Total	307	441	775	824	851	897	1118	1236	1479

Source: World Energy Outlook, International Energy Agency

The above projection of energy type mix done by IEA, 2017 takes into account India's ambitious clean energy plan, including massive electrification plan and providing clean cooking gas in rural and below poverty line households. Further, the projection under sustainable development scenario also considers improved energy efficiency and deployment of renewable energy sources across all sectors.



The trend that is clearly visible in the above projection (table and graph) is that share of two polluting fuels are taking plunge, which are coal and solid bio-fuel (2015 is seen as tipping point). The share of low carbon emitting fuels, namely gas and renewables is rising. (2016 and 2015 are seen to the tipping years, respectively). The trend that has shown signs of reversal in 2015-2016 continues unabated till 2040.

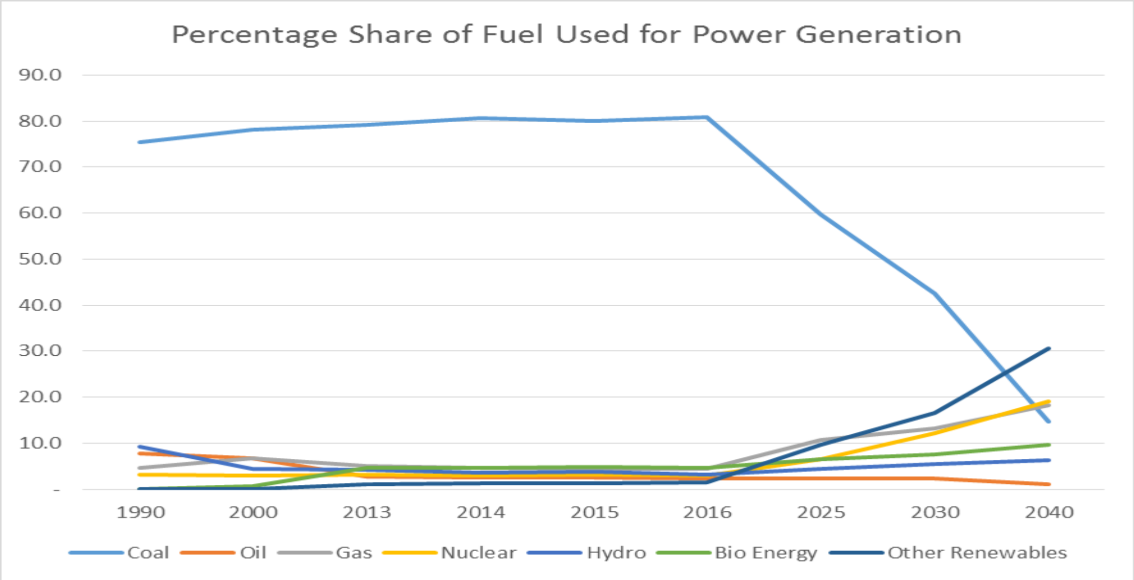
One significant indicator of transition in the sphere of energy is the mix of fuel used for electricity generation. Table below presents the changing combination of fuel types used for power generation.

Table: Energy Types used for Power Generation

Fig - MTOE

	1990	2000	2013	2014	2015	2016	2025	2030	2040
	Actual						Projection		
Coal	49	104	223	249	253	274	255	205	89
Oil	5	9	8	8	8	8	10	11	7
Gas	3	9	14	14	14	15	46	64	111
Nuclear	2	4	9	9	10	10	28	59	116
Hydro	6	6	12	11	12	11	19	26	38
Bio Energy	0	1	13	14	15	16	28	36	59
Other Renewables	0	0	3	4	4	5	41	80	185
Total	65	133	282	309	316	339	427	481	605

Source: World Energy Outlook 2017, International Energy Agency



A striking observation is that the percentage of coal used for power generation has plummeted from the current level of 80.8 percent to 14.7 percent in 2040. Since power generation has consistently been projected to increase at 2.44 percent CAGR (for 24 years; from 2016 to 2040), all types of fuels will be used more and more. Remarkably, percentage of gas (with least carbon emission) will increase from 4.4 percent in 2016 to 18.3 percent in 2040. Percentage of renewable source will increase from the level of 1.5 percent in 2016 to 30.6 percent in 2040.

3. Energy Transition: Target vs. Accomplishment

3.1 Status of India's Transition Trajectory

In this section, we will critically evaluate the progress that India has achieved on the path of transition, in terms of volume and de-carbonization. All these will be explored taking into account on-ground realities, potential, financial investment and technology front. Major policy and schemes also will be reviewed, on the yardstick of progress and performance.

3.2 How Much Renewable Energy Capacity Built in India?

Table: Trend of Renewable Energy Capacity

Fig in MW

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Hydro	32432	33493	34393	35307	36734	37571	38097	39570	41471	42801	44596
Wind	7845	9655	10926	13065	16084	18421	20150	22465	25088	28700	32878
Solar	4	10	12	37	565	926	1336	3518	5396	9647	19275
Bio	1586	2016	2453	3023	3758	4019	4280	5148	5605	9024	9533
Total	41867	45174	47784	51432	57141	60937	63863	70701	77560	90172	106282

Source: IRENA, 2018

India till 2017 has renewable energy capacity of 106 GW including 40 GW of large hydro projects, forming 4.88 percent of world capacity. There has been substantial addition of renewable capacity in India, growing at 9.76 CAGR during last decade. The capacity addition has been accelerated during last 3 years, when it grew at 14.55 CAGR. There has been 5 fold increase in solar capacity from 3.5 GW in 2014 to 19.3 GW in 2017. Wind energy capacity has increased by 14% in 2017.

3.3 Green (Renewable) Power Generation Capacity as per India's Commitment in Paris Agreement

Table: Target vs Accomplishment of Renewable Electricity

Figure - GW

Source of Power	Estimated Potential As on 31. 03. 2017. @1	Target Capacity as per INDC committed in Paris COP 21 in Oct. 2015, to be created by 2022	Actual Capacity as on 31. 03. 2018. @2	Capacity added in 3.5 years (Apr 2014-Dec 2017)	Balance to reach the target in 4 years
Solar	649.3	100	21.6	12.87	78.4
Wind @ 100 mt. height	302.2	60	34	11.70	26
Biomass	18.6	10	0.7	0.79	0.6
Bagasse Cogeneration	7.3		8.7		
Small Hydro	21.1	5	4.5	0.59	0.5
Waste to Energy	2.5	-	0.1	-	-
Total Renewable	1001	175	69.6	27.07	105.5

Sources:
@1. – Energy Statistics, 2018, CSO, MOSPI, GOI
@2. – mnre.gov.in, accessed on 15.05.2018 (Physical Progress-Achievement)

Number of schemes are in place and regulatory environment has been created for taking the country's generation and use of renewable energy on fast forward mode. Still there are micro issue centring on technology, investment and functioning of State Electricity Distribution Companies (DISCOMs) which are being addressed.

In the table below capacity addition during last 4 years has been compared with the 2022 target.

Table: Grid Connected Renewable Electricity – Target vs Addition in Capacity

Fig in GW

Source	As on end March						
	2014	2015	2016	2017	2018	Addition during 4 years	Target 2022
Wind	21.1	25.1	27.7	32.3	34.0	12.9	60
Solar	2.5	4.9	8.1	12.3	21.6	19.1	100
Biomass @1	4.01	4.45	4.88	8.83	9.36	5.35	10
Waste to Power	0.11	0.13	0.12	0.11	0.14	0.03	
Small Hydro	3.8	4.2	4.3	4.4	4.5	0.7	5
Total	31.5	38.8	45.1	57.9	69.7	38.2	175

@1 – Biomass & Gasification and Bagasse Cogeneration
Source: Author's own record for historical data

From the above 2 tables, looking at the actualization during last 4 years, the target for power generation from solar and wind appear to be daunting. However, reviewing the progress of several initiatives underway, the targets are not outside the zone of realization.

There has been substantial addition of renewable energy, particularly from solar and wind source during last 4 years. For the first time during 2017-18, the country added more production capacity from renewable energy (11,788 MW) in a year than from conventional sources like thermal and hydro (5,400 MW). The transition is visible in the table below.

3.4 Non fossil fuel share in power generation

India has committed to enhance generation of electricity from non-fossil fuel sources from 30% in 2015 to 40% in 2030. As of 31.03.2018, total installed percentage of renewable energy for generating power in utilities has reached 35% (MOP, 2018) The demand from renewable sources is projected to touch 42% in 2030 and 66% in 2040. (IEA, 2017)

Table: Installed Capacity of for Power Generation (Utilities)

Fig GW

As on	Coal	Diesel	Gas	Hydro	Nuclear	Other Renewables @ 1	Total
31. 03. 2008	76.0	1.2	14.7	35.9	4.1	11.1	143.1
31. 03. 2009	77.6	1.2	14.9	36.9	4.1	13.2	148.0
31. 03. 2010	84.1	1.2	17.0	36.9	4.5	15.5	159.3
31. 03. 2011	94.0	1.2	17.7	37.5	4.7	18.4	173.6
31. 03. 2012	112.0	1.2	18.3	39.0	4.7	24.5	199.8
31. 03. 2013	130.2	1.2	20.1	39.4	4.7	27.5	223.3
31. 03. 2014	145.2	1.2	21.7	40.5	4.7	35.0	248.5
31. 03. 2015	164.6	1.2	23.0	41.2	5.7	38.9	275.0
31. 03. 2016	185.1	1.0	24.5	42.7	5.7	46.0	305.1
31. 03. 2017	192.1	0.8	25.3	44.4	6.7	57.2	326.8
31. 03. 2018	197.1	0.8	24.8	45.2	6.7	69.0	344.0

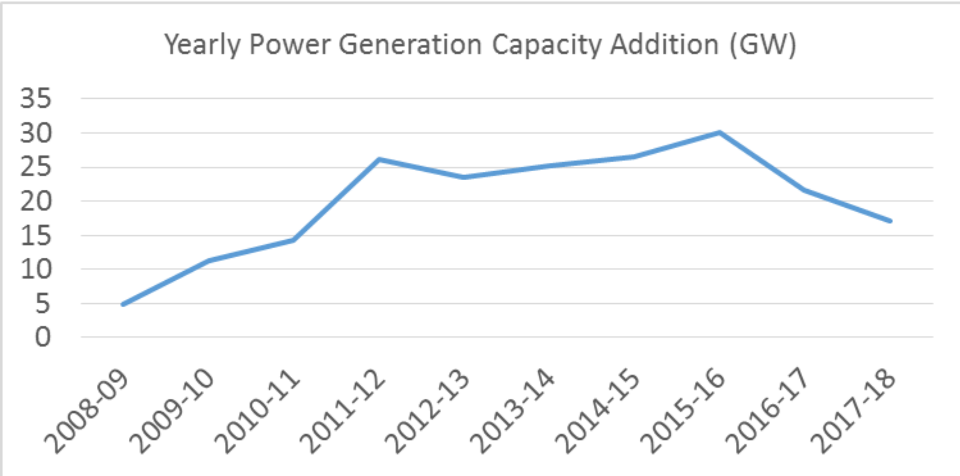
@ 1 - Other Renewables include Small Hydro, Wind, Bagasse (Cogeneration), Waste to

Energy and Solar, details as on 31. 03. 2018 provided in the table below: (Fig in GW)

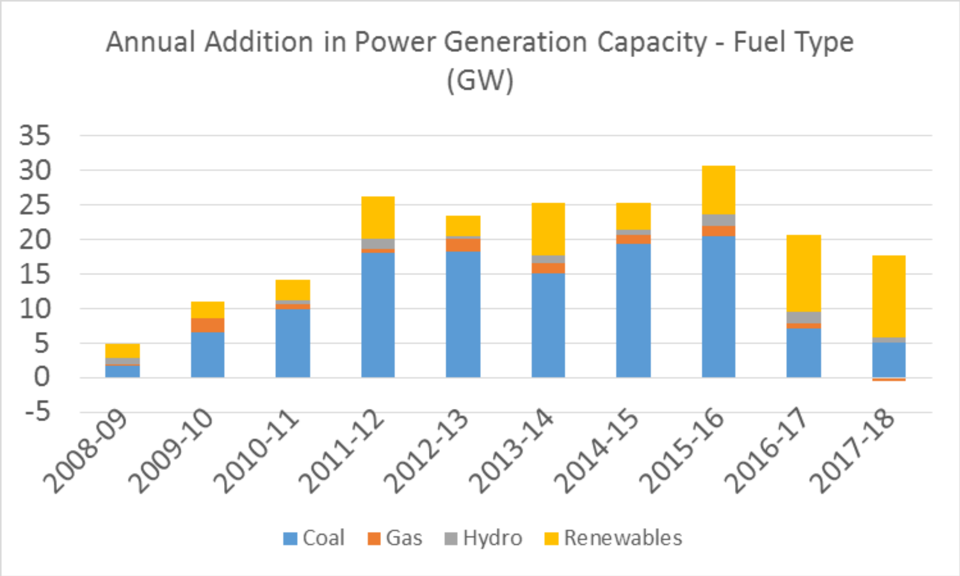
Small Hydro Power	Wind Power	Bio-Power		Solar Power	Total Capacity
		Biomass (Bagasse) / Cogeneration	Waste to Energy		
4.485	34.046	8.7	0.138	21.651	69.022

Source: Till 2017 – Energy Statistics, 2018
For 2018 – MOP-2018 & Central Electricity Regulator, accessed 15.05.2018

With urbanization and spurred by economic growth, there has been increase in power consumption in the country, experiencing 9.17% CAGR growth during last decade (2008-2018), reflected in substantial increase in per-capita consumption of electricity from 883 kWh in 2012 (end March) to 1122 kWh in 2017 (end March). Capacity addition has been consistently building up year after year, taking substantial leap from 2011-12 onwards, peaking in the year 2015-16.



Capacity addition has happened largely in coal based power generation capacity. However, from the year 2016-17 onwards, addition has largely taken in renewables, showing a clear symptom of green power.



4. Green Energy Programs

4.1 National Mission for Enhanced Energy Efficiency

India put in place a 'National Mission for Enhanced Energy Efficiency' (NMEEE), as part of 8 point National Action Plan for Climate Change' in 2008.

NMEEE has the following 4 operating tools:

i. A market based mechanism to enhance cost effectiveness, of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded. (Perform Achieve and Trade)
ii. Accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable. (Market Transformation for Energy Efficiency)
iii. Creation of mechanisms that would help finance demand side management programmes in all sectors by capturing future energy savings. (Energy Efficiency Financing Platform)
iv. Developing fiscal instruments to promote energy efficiency (Framework for Energy Efficient Economic Development)

The energy efficiency tools including promotion of renewable energy are happening through the following 3 institutional platforms:

a) Indian Renewable Development Agency (IRDA), set up in 1987 as a non-banking financial institution, is engaged in promoting, developing and extending financial assistance for setting up projects relating to new and renewable sources of energy and for energy efficiency and conservation.
b) Indian Energy Exchange (IEX) has been set up in 2008 for trading electricity and power based derivatives.
c) Solar Energy Corporation of India (SECI), set up in 2011, is meant to facilitate implementation of national solar mission. SECI is responsible for administering Viability Gap Funding, for large scale grid connected projects, solar park scheme and grid connected solar rooftop scheme, along with host of other

specialized schemes, such as defense scheme, canal top scheme, Indo-Pak boarder schemes.

4.2 Carbon Sink

India committed in COP 21 at Paris creating additional carbon sink the equivalent of 2.5 to 3 billion tonnes carbon dioxide by 2030.

The carbon stock in India (as in January 2018) is roughly 7 billion tonnes, equivalent to 25.66 billion tonnes of carbon dioxide. The average annual increment of carbon stock is 35 million tonnes, which is equivalent to 128.33 million tonnes carbon dioxide.

By 2030, the increment is expected to be equivalent of 1.92 billion of carbon dioxide, which would mean shortfall of 0.6 to 1.1 billion tonnes.

Besides increasing forest cover, India is looking at soil of catchment areas as additional means. Catchment area can be natural carbon sinks that can sequester substantial amount of atmospheric carbon dioxide in the soil.

4.3 Emission Intensity of GDP

India aims to reduce emission intensity of GDP by 33 to 35% by 2030 from 2005 level. India is attempting to achieve this by two ways: a) by tapping non fossil energy source and, b) by creating additional carbon sink.

On the issue of reduction of GHG, India has two types of policy instruments: (CDP, 2017)

a) Domestic market mechanism, such as, renewable energy certificates market (REC) and energy efficiency certificates market (PAT)
b) Carbon pricing policies, such as carbon tax in the form of coal cess.

In 2005, India's emission intensity was 0.47 metric tonnes of carbon dioxide per $1000 of GDP. (Charles Frank, 2016) By 2010, the emission intensity has reportedly reduced by 12%.

Climate Action Tracker's analysis shows that India can achieve its NDC target with currently implemented policies. Under current policy projections, GHG emission (excluding LULUCF) are projected to reach a level of 3.4 GtCO2e in 2020 and 5.0-5.2 GtCO2e in 2030. This is 64-66% increase in emission from 2010 level by 2020 and a more than doubling of 2010 levels by 2030. While this growth is in line with both the 2020 and 2030 intensity pledges, the achievement of India's target depends on actual economic growth levels.

India's total emissions have been growing steadily since 1990. The overall growth slowed down around 2000 as land use changed from being a small source emissions in the first inventory year – 14 MtCO2e in 1994 – to a large sink, with removals of 223 MtCO2e in 2000 and 253 MtCO2e in 2010. (climateactiontracker.org)

4.4 UDAY Scheme

Ministry of Power, Government of India in November 2015 launched a scheme for the State Electricity Boards (Electricity Distribution Companies), named as Ujwal DISCOM Assurance Yojana (UDAY). Objective of the scheme were to provide support for: a) financial turnaround, b) operational improvement, c) reduction of cost of generation of power, d) development of renewable energy and e) energy efficiency and conservation. Under the scheme, State Governments were to takeover up to 75% of their respective DISCOM's debt by issuing sovereign bonds to pay back the lenders. So far, 32 States and Union Territories have become partner of the UDAY scheme. Rs 2.32 lakh crores worth bonds have been issued to 16 States and estimated Rs 2.69 lakh crores will be issued.

Notwithstanding above, Indian State Electricity Boards are not in their pink of health. Problem has been identified as lack of political will primarily to set the tariff right and, for that purpose, carrying out purposeful reforms.

"In terms of per capita consumption, India is a power starved country. At the same time, going by the generation capacity that is underutilized or even left stranded, India is power surplus country. The apparent paradox stems from political unwillingness to charge consumers realistic tariffs and make the sector financially viable." (ET, 2018)

4.5 International Solar Alliance

International Solar Alliance (ISA) is open to 121 countries located between the Tropic of Cancer and Tropic of Capricorn, of which 61 countries have joined the ISA framework agreement and 32 countries have ratified it. Following are 10 points action charted in the founding conference held at New Delhi on 11. 03. 2018:

i. Ensure that better and affordable solar technology is available and accessible to everyone.
ii. Need to increase the solar proportion in energy mix.
iii. Encourage innovation so that solar solutions can be provided for various needs.
iv. Provide concessional financing and low risk finance for solar projects.
v. Developing regulatory aspects and standards which will speed up adoption and development of solar solutions.
vi. Developing countries will have to develop consultancy support for bankable solar projects.
vii. Emphasis on greater inclusiveness and participation in our efforts.
viii. Building extensive network of centres of excellence that can take care of the local conditions and factors.
ix. Solar energy policy may be viewed from the angle of the totality of development so that we get more and more contribution towards achievement of SDGs.
x. To strengthen ISA secretariat and make it professional.

5. Future Green Energy Initiatives

5.1 Floating Solar Plant

India has started building floating solar plant as alternative to conventional ground mounted photo voltaic systems which are land intensive. It has benefits like conserving water through reduction of evaporation, increased generation due to cooling effect on the panels and requires lesser installation time than conventional land mounted ones.

The largest such plant with 500 kWp was launched in December 2017 on 1.25 acres of water surface of Banasura Sagar reservoir in Wayanad. The plant has been set up by Kerala State Electricity Board at a cost of Rs 9.25 crores. A 500 KVA (Kilo volt ampere) transformer, 17 inverters, a supervisory control and data acquisition (SCADA) system to control and monitor power generation and an anchoring system are part of the floating solar project.

5.2 Hybrid Solar and Wind Plant

The Ministry of New and Renewable Energy (MNRE) has issued the national wind solar hybrid policy on May 14, 2018. The key objective of this policy is to provide a framework for promotion of large grid connected wind-solar PV hybrid system for optimal and efficient utilization of transmission infrastructure and land, reducing the variability in renewable power generation and achieving better grid stability.

5.3 Corporate Renewable Energy Leadership

Corporate sourcing of renewable energy has become a global phenomenon and the market is growing, currently at 645 TWh in 2017 in 75 countries. There are 35 companies in India who have got into this mode. (IRENA, 2018 a)

Mumbai metro committed to buy 50 MW in April 2018 from the solar plant to be set up in Dhule district of Maharashtra. Delhi metro committed to buy power from the 750 MW Rewa solar plant in Madhya Pradesh. Microsoft in Bengaluru has signed to purchase 3 MW solar powered electricity, which is 80% of its electricity need for its office building, from Atria Power. Three companies have so far committed to be hundred percent renewable energy powered; Infosys, Tata Motors and Dalmia Cement.

40 Indian companies are setting price on their internal carbon emission. (wri-india.org, accessed on 24. 10. 2018)

5.4 National Bio Fuel Policy

India had a national bio fuel policy 2009. A new national bio fuel policy 2018 has been approved by the Government in May 2018.

The policy that calls for usage and production of ethanol from damaged food grains and farm products has paved way for optimal utilization of agricultural waste to produce bio-power (1st, 2nd and 3rd Generation bio-fuel, bio-CNG). It has also made provisions to convert waste/plastic and municipal solid waste to fuel. The Policy expands the scope of raw material for ethanol production by allowing use of Sugarcane Juice, Sugar containing materials like Sugar Beet, Sweet Sorghum, Starch containing materials like Corn, Cassava, Damaged food grains like wheat, broken rice, Rotten Potatoes, unfit for human consumption for ethanol production.

With a thrust on Advanced Biofuels, the Policy indicates a viability gap funding scheme for 2G ethanol Bio refineries of Rs.5000 crore in 6 years in addition to additional tax incentives, higher purchase price as compared to 1G biofuels.

The technology for manufacturing biofuel from cellulosic and lignocellulosic biomass and solid litter is still in evolution stage and needs to be upgraded and refined to make it commercially lucrative.

5.5 Green Energy Corridor

India commenced work on the ground its first green energy corridor project with an ultra-high-voltage direct current link over 1800 km passing through five States. The link is a key element of integrating renewable energy with main grid. It will integrate thermal and wind energy for transmission of power from high consumption centre located thousands of kilometre away, supporting electricity demands in the south (Pugalur in Southern State of Tamil Nadu) and transmitting clean energy to the central India (Raigarh), when there is excess wind power. The project is worth over Rs 4,350 crores, partly funded by Asian Development Bank and is part of Indo-German Energy Program.

5.6 Electric Mobility

India has all the compelling reasons (like imported fossil fuel dependent and poor air quality in the cities) and all the favourable factors (like electrification, shared mobility and connectivity) to leapfrog into the electric mobility bandwagon that is out to disrupt automobile industry world over. (McKinsey, 2017) India has expressed policy intent and has taken drive to fast forward the transition to electric vehicle. Few factors like cost of vehicle, cost of battery and charging infrastructure are being awaited. Public transport and two wheelers are first to join in this transition.

As estimated by Bloomberg New Energy Finance (BNEF-2017) battery prices are expected to fall 73% between 2016 and 2030, driven by lower costs of financing, improved manufacturing capabilities, material efficiency and a more efficient supply chain. Improvement in battery energy density will also play a major role, which is expected to improve by 93% between 2016 and 2030. In the largest automobile segment (petrol cars and two wheelers), based on total cost of ownership analysis, it is expected that electric vehicle will achieve cost parity with conventional vehicle during 2023 – 2028.

Under Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME) scheme, Government of India subsidizes 60% of total cost of an electric bus (each bus costs Rs 1.7 to 2.5 crores) and has already sanctioned 390 buses in 11 cities (as on April 6, 2018).

6. Business Provision for Green Energy

6.1 Investment Potential / Proposed

FDI up to 100% is permitted under the automatic route for renewable energy generation and distribution projects, subject to provisions of the Electricity Act, 2003.

FDI inflows in the Indian non-conventional energy sector between April 2000 and December 2017 stood at US$ 6.26 billion. (www.ibef.org, accessed on 24. 05. 2018)

The Central Electricity Authority (CEA) expects investment in India's power transmission sector to reach Rs 2.6 trillion (US$ 40.3 billion) during 2017-22, and to enhance the transmission capacity of the inter-regional links by 45,700 megawatt (MW).

Some major investments and developments in the Indian renewable energy sector are as follows:

- In March 2018, ReNew Power finalised a deal estimated at US$ 1.55 billion to acquire Ostro Energy and make it the largest renewable energy company in India.
- World's largest solar park named 'Shakti Sthala' was launched in Karnataka in March 2018 with an investment of Rs 16,500 crore (US$ 2.55 billion).
- Solar sector in India received investments of over US$ 10 billion in 2017.
- Private Equity (PE) investments in India's wind and solar power have increased by 47 per cent in 2017 (January 1 to September 25) to US$ 920 million, across nine deals, as compared to US$ 630 million coming from 10 deals during the corresponding period in 2016.
- In December 2017, IL&FS Financial Services Ltd partnered with Jammu and Kashmir (J&K) Bank Ltd to finance nine hydropower projects in J&K with a total capacity of 2,000 MW, which require financing of around Rs 20,000 crore (US$ 3.12 billion).
- The Asian Development Bank and the Punjab National Bank have signed a financing loan worth US$ 100 million, which will be used to support solar rooftop projects on commercial and industrial buildings across India.

6.2 Government Incentives and Support for Renewable Energy

Incentives offered by the Government since early 2000s have resulted in per unit cost of generation of wind and solar power cost competitive compared with other fossil fuels. Significant amongst the incentives are:

- Renewable Purchase Obligations (RPO) requires power distribution companies and large industries to source a fixed percentage of their requirement from renewables. Each State has set its own RPO requirement.
- 10 percent of power production from new coal and lignite capacity additions (upgrades or new generating units) must come from renewables, according to the Renewable Generation Obligation (RGO).
- Solar projects are accorded infrastructure status.

6.3 Tax Incentives Offered to Wind and Solar Energy Industry

The government's policy to enhance India's renewable energy portfolio has led to introduction of a slew of tax incentives to encourage investment.

- Firms are exempt from the payment of income tax on profits from power generation for the first 10 years of their operation.
- Some imported products are exempt from payment of excise duty. For instance, certain components of wind energy electricity generators and solar photovoltaic ribbons are liable for full exemption.
- Select components for the manufacture of solar modules, solar water heaters, and associated systems are granted complete or partial Basic Customs Duty waivers.
- Solar and wind power projects are excluded from inter-state transmission charges or taxes on transmission losses for 25 years from the date of commissioning.
- GST on solar and wind energy components is limited to 5 percent.

6.4 Financial Incentives for the Wind and Solar Energy Industry

Government of India follows auction based allocation of wind and solar capacity. The lowest wind and solar tariffs now is close to $ 0.04 (Rs 2.44 for solar and Rs 2.50 for wind).

The following incentives are provided to make solar and wind energy cost competitive:

- Wheeling charges (charges for transmission of electricity over the grid on a per megawatt hour basis) are comparable with those offered to fossil fuel based power.
- Viability Gap Funding (VGF) assistance, up to a maximum of US$153,846.2/MW, through reverse e-auction for ultra large solar power projects of 5,000 MW capacity, which will be implemented by the Solar Energy Corporation of India (SECI).
- A subsidy of 30 percent of project costs, after which off-grid solar projects can also avail soft loans.
- 40 percent accelerated depreciation in a written down value (WDV) basis.
- Rooftop solar installation as accommodated in housing loans provided by banks or National Housing Boards.

To protect against defaults by state distribution companies, solar power is included in the Tripartite Agreement between India's federal government, state governments, and the Reserve Bank of India (RBI) for payment security.

A combination of these incentives and other favourable policies helped attract about $ 2.05 billion (Rs 13,000 crores) in investments in India's renewable energy sector between April 2014 and December 2016.

Meanwhile, government support such as the ten year tax break and Generation Based Incentives (GBI) were withdrawn in 2017. In addition, the relaxed rate of 80 percent of accelerated depreciation was reduced by half. This is because federal regulators hope that the gradual withdrawal of support mechanisms will help create a market-run power industry.

6.5 India's energy market – Is a level playing field possible?

The rapid growth of renewables in India showcases the importance of incentives for an emerging industry to be able to compete with established energy players.

To illustrate this, an example from a recent business bid may be considered, where the lowest solar bid of US$0.04 (Rs 2.44) at Bhadla in Rajasthan was achieved through a combination of the following:
a) Viability Gap Funding (VGF);
b) A state-backed long term Power Purchase Agreement (PPA); and,
c) Land acquisition by the government of Rajasthan.

Incentives are key to reducing the prices of solar and wind power generation in a market dominated by an extensive and cheap coal-fired generation capacity. The incorporation of 'clean coal' technologies, having improved efficiency rates, within Ultra Mega Power Projects (UMPP) of 4,000 MW capacity poses a serious challenge to renewables. The coal industry also receives several subsidies like reduced freight rates for the transport of coal from mine to plant.

Hence, if a true level playing field is to be achieved, any withdrawal of incentives for the renewable energy industry should be commensurate with the withdrawal of subsidies granted to the coal industry.

7. What More Need to be done?

7.1 Energy Storage

Energy storage is the key component for creating sustainable energy systems. Current technologies, such as solar photovoltaic and wind turbines etc. can generate energy in a sustainable and environmentally friendly manner; yet their intermittent nature poses issues in power quality, dependability and grid stability. The increase in renewable energy generation can cause several issues in power grid. Firstly, in power grid operation, the fluctuation in the output of renewable generation makes system frequency control difficult, and if the frequency deviation becomes too wide, system operation can deteriorate. Renewable energy output is unreliable because it is affected by weather conditions. Energy storage technologies have the potential to offset the intermittency problem of renewable energy sources by storing the generated intermittent energy and then making it accessible upon demand.

The key challenge for reaching the government's RE targets would be the ability of the grid to integrate variability associated with these renewables and the investment required for upgrading the transmission and distribution (T&D) infrastructure. Energy storage can help in better integration of these renewable by providing multiple values to the system such as optimizing T&D investments, addressing forecasting errors in wind and solar generation for more accurate scheduling, addressing local reliability issues by providing reactive power support and also enabling end users for managing peak load and more efficient utilization of distributed renewables etc.

Conclusion

Energy transition in India signals India's sustainable and inclusive economic development and aids to the quality of living of one fifth of world population. In this paper, the transition has been assessed from various angles, namely, policy, technology and business. Indicators of energy transition has been analysed from historical perspective and future projection. Composite indices of energy architecture have been seen in historical timeframe to view the nature and quality of transition, impacting the quality of life of people and of environment.

What emerges is that India has indeed embarked on the path of sustainable energy transition, very much in synch with global trend. However, the complexities of India's socio-economic status and resource endowment have not allowed India to make a radical shift. Last four years have witnessed a massive thrust in right direction and results are visible in the form of green shoots.

Significant to note that India has taken leadership role with regard to renewable energy, particularly for the emerging and developing countries in the world.

Since the policy intent and resource deployment are appropriately placed, it is expected that the country will, in not so long distant future, progress and reap the results that it is looking for. Support in terms of technology transfer and multilateral aids as envisaged in various global treaties and conventions would enhance the country's movement.

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