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Recent Trends in Energy Consumption in India

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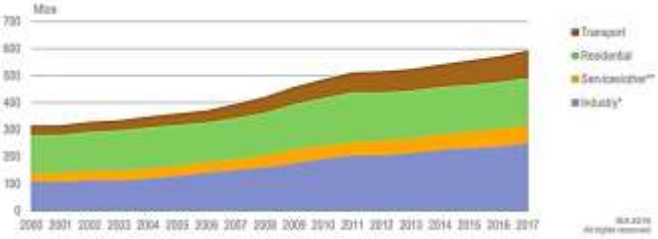
***Abstract*— As per the relative consumption of various energy sources as percent of the world total, India among the major Asian economies, occupies the second place immediately after China. In this context, this paper attempts to explore the possible impact of various forms of energy consumption sources and consumption pattern. And this study considers the annual data from 2009-2010 to 2019-2020 to using simple statistical methods of analysing data. Energy is required for the economic growth and development of a nation and improving the quality of life of its citizens. Energy consumption directly effects the economic growth of our country; besides it also examined the influence of various forms of energy consumption growth on growth of private consumption and private investment as different components of GDP growth.**

I. INTRODUCTION

Energy occupies a central position to achieve the overall economic, social and environmental aims of sustainable human development. The interconnection between energy and economic development has been a topic of greater research as energy is found out to be one of the most important driving forces for economic growth of all economies (Pokharel, 2006). As per the Energy Information Administration (EIA, 2006) "There is a strong two-way relationship between economic development and energy consumption. On one hand, growth of an economy, with its global competitiveness, hinges on the availability of cost effective and environmentally benevolent energy sources, and on the other hand, the level of economic development has been observed to be depended on energy demand. Energy intensity is used as an indicator to show how efficiently energy is being used in the economy. Energy Intensity in India, defined as the ratio of primary energy supply to gross domestic product (GDP), stood at 0.09 toe/USD 1000 (2018) in 2017, well below the world average of 0.107 toe/USD 1000. A decrease in energy intensity (Total primary Energy Demand TPED/GDP) of 27% over the past ten years has taken place against the backdrop of nearly doubling of India's energy demand, driven by strong economic growth rates of 6.8% on average since 2010. The IEA estimates that energy efficiency improvements in India since 2000 have avoided an additional 15% of energy use in 2018 (IEA, 2019c).

As per the relative consumption of various energy sources as percent of the world total, India among the major Asian economies, occupies the second place immediately after China. India's total final consumption of energy in different sectors is shown in figure 1. This led to concerns whether India's energy consumption levels will be proportional with the economic growth levels similar of other high and low energy consuming nations of the Asian region. In this context, this paper explores the feasible various sources of energy consumption and the pattern of consumption. The main objective of the study is to address the increasing levels of energy consumption to induce economic growth in comparison with the increasing cost associated with it with respect to its sustained supply in future.

Figure 1 – India's Total Final Consumption of Energy by Sector, 2000-2017



(Source: International Energy Agency – India 2020 Energy Policy Review)

Energy is an important part of all production and consumption sectors. As per existing technologies, to increase in per capita production for increasing per capita income requires increase in amounts of energy. The truth is without an assured supply of energy the rapid economic development of any nation is not possible.

II. LITERATURE REVIEW

Energy always play a significant role in economic development (Horn 1999) as the energy consumption per GDP unit and energy consumption per capita in relation to GDP per capita were extremely high for Ukraine, as compared to Russia and other transition countries. He

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ascribed these factors to technical infectiveness, structural flaws (high share of basic industry) as well as the ongoing economic crisis. Ediger and Huvaz (2006) showed that even though the primary energy consumption has a nearly linear relationship between the total GDP of Turkey in the 1980-1990, the most important development of consumption of energy and economic production exhibits constant fluctuations, evolving in a cyclic pattern. There is a close relationship between Turkey's energy and economy and the average rate of change in GDP and consumption of primary energy is 4.5 and 4.9 respectively. Therefore, whether or not the reduction in the rate of energy consumption is related to the peak of energy intensity depends on rates of GDP in the future (Ediger and Huvaz, 2006). If the causes of energy consumption run into GDP in the future, and energy consumption rates and their past trends in GDP continue, any reduction in energy consumption is expected to slow economic growth over the forecast period.

The multivariate structure examines the relationship between total consumption of energy and real income in an Asian economy like India, Pakistan, Malaysia, Singapore, Indonesia, Philippines, Korea, and while Taiwan, Malaysia, Singapore and the Philippines seemed to be neutral in terms of energy expenditure, the GNP for India had a one-sided effect on energy consumption, the opposite was true for Indonesia and the reciprocity was in favour of Pakistan (Masih and Masih 1996, 1997).

Paul and Bhattacharya (2004) applied alternative econometric time series models: Engle-Granger co-integration, Granger causality test, and Johnsen's multivariate co-integration technique on Indian data for the period 1950-1996, to show the result of integration. While long-term economic growth leads to energy consumption, the standard Granger causality shows that energy consumption leads to economic growth. The results of the Granger causal relationship also match those of Johnsen's error correction. In the survey, they found that Cheng (1999) had a one-sided effect from economic growth to energy consumption, but Adjaya (2000) found a causal relationship in the opposite direction. Ghosh (2005), using a joint integration and error correction modelling approach, found a long-term equilibrium relationship between total consumption of petroleum products in India and economic growth from 1970-1971 to 2001-2002. Kraft and Kraft (1978) provide evidence to support the one-way causal relationship leading from Gross National Product (GNP) to energy consumption in the United States from 1947 to 1974. The results mean that the GNP can implement energy saving policies without affecting growth. Payne (2010) has used a significant number of time series, and in recent years panel studies have tried to establish the relationship between power consumption and economic growth in developing countries. From the perspective of policy makers, if electricity consumption is negatively or insignificantly affecting the rate of economic growth, then saving policies are much needed to avoid negative effects on the economy.

Anupama Das, et al. (2012) in their article, a panel of 45 developing countries for the period 1971–2009 is used to examine the dynamic relationship between consumption of electricity and development of economy. They employed the system of moment approach proposed by Biundell and Bond (1998) as a generalized method, an information-efficient means for obtaining coherent coefficient estimates. Their results suggest a positive relationship between the consumption of electricity and growth in the economy when estimated in the full panel. Regional analysis indicates a positive growth-power link for Asia and the Pacific and sub-Saharan Africa, although levels and levels of importance are different.

III. DATA BASE

The study considers the annual data from 2009-2010 to 2019-2020. The data relating to different forms of energy consumption and GDP at constant prices have been collected from Indian Petroleum and Natural Gas Statistics, Ministry of Petroleum Natural Gas Economics and Statistics division, Government of India, and Energy Statistics, Ministry of Statistics and program Implementation, Central Electricity Authority (CEA), Planning Commission, World Energy Outlook.

3.1 Indian Energy Scenario

India is one of the largest electricity market areas in the world, comparable to the power systems of the European Union, the People's Republic of China (''China''), the Russian Federation ("Russia'') and the United States. The national grid of India is the largest national synchronous grid in the world. India has an annual energy production of about 1389 BU as well as the third largest energy consumer in the world and the demand is expected to reach 4 trillion units by 2030. Growth in the industrial sector, economy, population, living standards and urbanization along with rising demands in energy consumption had led to the winding of energy gap access across the country.

Energy plays a vital role in the economic development of any country. Access to energy services which is affordable as well as reliable plays a vital part for the development of economy. Modern services of energy are generally provided in the form of liquid fuels, gaseous fuels and electricity. These are crucial for infrastructure development and maintaining the growth rate of an economy in order to ensure overall development. Growth along with some structural changes is termed as development. Demand of energy has a directly proportional relationship with the economic growth i.e. demand of energy always increases with the rise of economic activity. In recent times, which is

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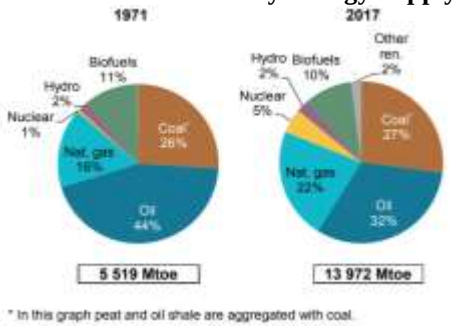
the most advanced stage of social and economic development, the pattern of energy usage has moved towards electricity showing the increase in energy dependence for ensuring growth and development of a nation.

Figure 2 – World Total Primary Energy Supply by Fuel



(Source: International Energy Agency – World Energy Balances Overview 2019)

Problems faced by the developing or emerging economies are generally of three types. First is to meet the energy demand to the people who are still deprived of basic energy service which is electricity. Second is to fulfil the increasing demand of energy required for economic growth in the form of developing infrastructure and growing industrialization. The last one is to address the problem of the high levels of emission which is causing environmental problems and health hazard among humans. The world total primary energy supply by fuel is shown in Figure 2 and world total final energy consumption by sector and source is shown in Table 1.

Table 1: World Total Final Energy Consumption by Sector and Source

Sector	Coal	Oil	Natural Gas	Biofuels and Waste	Electricity	Heat	Total
Total final consumption	41.5	164.8	60.1	41.7	74.8	12.3	395.1
- Total energy consumption	38.7	138	53.1	41.7	74.8	12.3	358.7
- Industry	32.9	12.7	22.5	9.2	31.4	5.7	114.4
- Transport	0.1	103.9	4.5	3.2	1.3	0.03	112.9
- Of which intl. bunkers	-	16.3	0	-	-	-	16.3
- Households	2.8	10.8	18	25.4	20.5	4.4	81.9
- Others	2.9	10.7	8.2	3.9	21.6	2.2	49.4
- Non-energy use	2.8	26.8	6.9	-	-	-	36.5

(Source: 2019 Energy Statistics Pocketbook – United Nations Statistics Division)

India's energy intensity is more than twice of the matured economies, which are known as OECD (Organization of Economic Co-operation and Development) member countries. The energy intensity of India is also much more than the Asian countries which are emerging economies, such as the member countries of ASEAN and China. The primary energy use in India is estimated to increase heavily in order to support a GDP growth rate of 9 percent in 2031-2032 even after considering a substantial reduction in energy intensity (Eleventh Plan report 2007-2012). To support this on a sustained basis, around 5.8 percent increase in the supply of primary energy per year which includes gathered non-commercial like wood and dung would be required. Supply of commercial energy would be required to grow at about 6.8 percent per annum as it will replace non-commercial energy, but this will involve around 20 percent reduction in energy use per unit of GDP nearly a decade. By 2031-2032, there will be increase in the primary energy use by 4 to 5 times and six-folds increase in power generation capacity from the 2006-2007 level of around 1,60,000 MW which covers all captive plants.

In a global perspective, considering India's likely energy demand in 2031-2032, with the current energy consumption of China is 3063 Mtoe and current consumption of USA is 2155 million or mega tonnes of oil equivalent (Mtoe), India's total production of energy is shown in table 2. In comparison, India consumed about 882 Mtoe of commercial energy in 2017. Having an estimated population of just under 1.47 billion within 2031-2032, per capita energy consumption of India will be slightly above China's current per capita consumption. The United States consumed almost 16% of world energy, with 4.3% of the world's population. Conversely, China and India consumed 22% and 6% of global energy respectively, but each accounted for 18% of the global population. Further, per capita energy consumption of India which currently is less than 27 percent in 2017 level of global average energy consumption shall in 2031-2032 also remain just about 74 percent of the current global average.

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Table 2: Production of Energy in India

Year	Coal (million tonnes)	Lignite (million tonnes)	Crude Oil (million tonnes)	Natural Gas (Billion Cubic Metres)	Electricity* (GWh)
1	2	3	4	5	6
2009-2010	532.04	34.07	33.69	47.5	159,643.84
2010-2011	532.69	37.73	37.68	52.22	179,926.46
2011-2012	539.95	42.33	38.86	47.56	214,024.08
2012-2013	556.4	46.45	37.79	40.68	204,035.31
2013-2014	565.77	44.27	37.79	35.41	234,595.01
2014-2015	612.44	48.27	37.46	33.66	238,908.43
2015-2016	639.23	43.84	36.94	32.25	224,571.11
2016-2017	657.87	45.23	36.01	31.9	241,841.64
2017-2018	675.4	46.64	35.68	32.65	266,308.30
2018-2019(P)	728.72	44.28	34.2	32.87	299,465.00
Growth rate of 2018-2019 over 2017-2018(%)	7.89	-5.06	-4.15	0.67	12.45
CAGR 2009-2010 to 2018-2019(%)	3.2	2.66	0.15	-3.61	6.49

(P): provisional

**Electricity from Hydro, Nuclear and other Renewable energy sources.*
Sources: 1. Ministry of Coal
2. Ministry of Petroleum & Natural Gas
3. Central Electricity Authority
(Source: Energy Statistics 2020 – National Statistical Office – Ministry of Statistics and Programme Implementation, Government of India)

In 2035, the demand of primary energy in the world is anticipated to grow at an average annual growth rate of 1.5 per cent and that of Asia is assumed to reach 2.5 per cent. The demand for energy of the world is expected to reach 16.9 Billion tonnes of oil equivalent (Btoe), a 1.5-fold increase from 11.1 Btoe in 2010. While that for Asia is expected to reach at 7.1 Btoe by 2035 from 3.5 Btoe 2010. By 2035, Asia would be responsible for nearly sixty per cent of the increased energy demand of the world, showing sharp economic growth within the developing countries in the continent. Rapid growth in the economy of Asian nations, particularly India and China will have the maximum percentage of the increasing demand in energy. India's gross generation of electricity is shown in table 3.

Table 3: Gross Generation of Electricity in India

Year	Non-Utilities							
	Thermal							
	Steam	Diesel	Gas	Total	Hydro	Nuclear	RES*	Total
1	2	3	4	5	6	7	8	9
2009-2010	539,586	4,248	96,373	640,208	104,059	18,636	36,947	799,851
2010-2011	561,298	3,181	100,342	664,822	114,416	26,266	39,245	844,748
2011-2012	612,497	2,649	93,281	708,427	130,511	32,287	51,226	922,451
2012-2013	691,341	2,448	66,664	760,454	113,720	32,866	57,449	964,489
2013-2014	745,533	1,998	44,522	792,054	134,848	34,228	65,520	1,026,649
2014-2015	835,291	1,576	41,075	877,941	129,244	36,102	73,563	1,116,850
2015-2016	895,340	551	47,122	943,013	121,377	37,414	65,781	1,167,584
2016-2017	944,022	401	49,094	993,516	122,378	37,916	81,548	1,235,358
2017-2018	986,591	348	50,208	1,037,184	126,123	38,346	101,839	1,303,493
2018-2019(P)	1,022,265	215	49,834	1,072,314	134,894	37,813	126,759	1,371,779
Growth rate of 2018-2019 over 2017-2018(%)	3.62	-38.19	-0.74	3.39	6.95	-1.39	24.47	5.24
CAGR 2009-2010 to 2018-2019(%)	6.6	-25.79	-6.38	5.29	2.63	7.33	13.12	5.54

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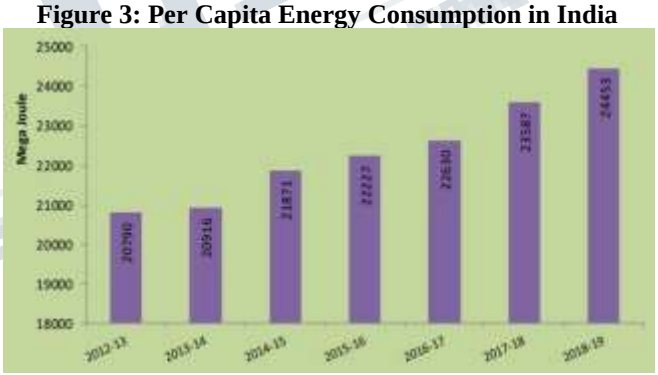
Year	Non-Utilities							Grand Total
	Thermal				Hydro	RES*	Total	
	Steam	Diesel	Gas	Total				
1	10	11	12	13	14	15	16	
2009-2010	77,416	8,217	19,739	105,372	152	609	106,133	905,984
2010-2011	96,657	7,754	15,435	119,846	149	922	120,917	965,665
2011-2012	104,863	6,244	21,972	133,079	131	1,178	134,388	1,056,839
2012-2013	113,167	8,205	20,769	142,141	118	1,750	144,010	1,108,499
2013-2014	118,178	8,866	19,912	146,957	129	1,903	148,988	1,175,637
2014-2015	128,401	9,720	21,135	159,256	145	2,656	162,057	1,278,907
2015-2016	136,721	8,412	21,083	166,216	110	2,046	168,372	1,335,956
2016-2017	137,588	9,182	22,855	169,625	144	2,277	172,046	1,407,404
2017-2018	143,868	8,107	25,362	177,337	112	2,328	179,777	1,483,270
2018-2019(P)	141,137	7,723	23,785	172,645	97	2,258	175,000	1,546,779
Growth rate of 2018-2019 over 2017-2018(%)	-1.9	-4.74	-6.22	-2.65	-13.76	-3.01	-2.66	4.28
CAGR 2009-2010 to 2018-2019(%)	6.19	-0.62	1.88	5.06	-4.38	14	5.13	5.49

(Source: Energy Statistics 2020 – National Statistical Office – Ministry of Statistics and Programme Implementation, Government of India)

3.2 Demand and supply scenario

India currently ranks as one of the top energy consumers in the world. India's per capita energy consumption is shown in figure 3. With India's population and GDP expected to grow in the future, energy demand will see a significant rise as well. Total primary energy will increase almost 3 times between 2017 and 2042, equivalent to an annual growth rate of approximately 4% (NITI Aayog 2020). India ranks third in the world in total primary energy consumption, having a share of about 6 percent in the world commercial energy demand in the year 2017. India's energy consumption has almost doubled since 2000 and the potential for further rapid growth is enormous (IEA, India Energy Outlook, 2015). Per capita final energy consumption in India is very low and there is wide disparity between urban and rural areas. In 2015-2016, India's per capita energy and electricity consumption stood at 1075 KWh/year (GOI, Power Sector Executive Summary, 2015), which was just one third of the world average (IEA, WEO Factsheet, 2015).

Figure 3: Per Capita Energy Consumption in India



(Source: Energy Statistics 2020 – National Statistical Office – Ministry of Statistics and Programme Implementation, Government of India)

India is well-endowed with both conventional as well as renewable energy resources. Coal, oil, and natural gas are the most common primary commercial energy sources. Given the scale of demand in the country and availability of low-cost coal, coal will remain be primary source of electricity followed by other cost-effective sources like hydro, gas, nuclear and renewable energy. In usage of coal for power generation, however a gradual transition towards clean coal technologies like super critical and ultra-super critical power plants could be seen. This is reflected in the diminishing coal capacity in the near term, despite increasing levels of electricity from coal. As far as solar and

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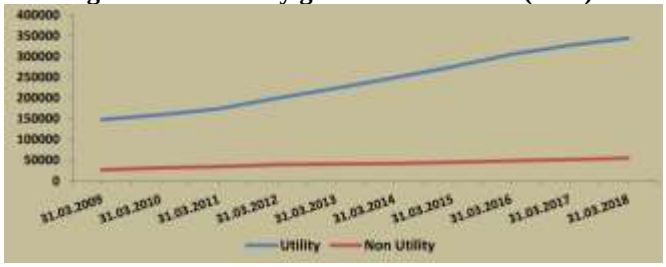
wind capacity is concerned, without any significant improvement in cost, capacity addition of these renewables in baseline scenario is limited. This is reflected in the renewable share of total electricity generation, as without improvement in technical efficiency capacity addition in solar and wind translates into a lesser than proportionate increase in generation from these sources.

3.3 Power sector in India

Power plays a vital role in both infrastructural as well as economic development of a nation. Among the major economies, India takes the sixth position regarding the share of fossil fuels in the electricity mix. The share of coal in the electricity mix is one of the highest in the world, after South Africa, and ahead of China and Australia. The GoI is targeting 175 GW of renewable power capacity by 2022, with 100 GW of solar (60 GW of utility-scale solar PV, 40 GW of rooftop solar), 60 GW of wind power, 5 GW of small hydro and 10 GW of bioenergy. By end of November 2019 grid-connected renewable electricity capacity reached 80 GW, with 32 GW from solar PV and 37 GW from onshore wind. Total electricity generation in India (MW) is shown in figure 4. Moreover, India has an objective to reach 63 GW of nuclear power capacity by 2032, a large increase compared to today's installed capacity of around 7 GW in 2019 (see nuclear energy section below). Under the Electricity Act of 2003, the CEA prepares a National Electricity Plan in accordance with the National Electricity Policy once every five years. The 2018 Plan outlines that 23 GW of coal-fired capacity is set to retire during 2017-2022 and another 26 GW during 2022-2027. The GoI is aiming for the replacement of old inefficient coal-fired thermal units with supercritical units and the addition of gas, hydro, nuclear and renewables. By the end of 2022, 46.8% of India's installed capacity is expected to come from non-fossil sources such as nuclear, hydro and renewables, and 56.5% by 2027, which would take India far above the 40% stated in its NDC. In 2027 the country is expected to have 275 GW of installed solar and wind capacity, 72 GW of hydro and 15 GW of nuclear (CEA, 2018a).

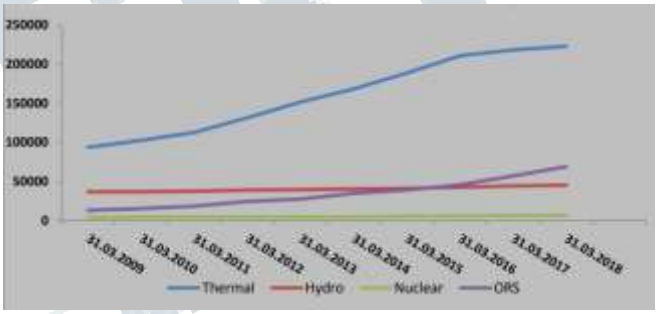
Figure 4: Electricity generation in India (MW)



(Source: Energy Statistics 2020 – National Statistical Office – Ministry of Statistics and Programme Implementation, Government of India)

India's installed generation capacity is composed of 365 GW, coal (55.8%), hydro (13.7%), wind (10.1%), solar PV (8.8%), natural gas (6.8%), bioenergy and waste (2.7%), nuclear (2%) and oil (0.1%) Solar installed capacity in India has increased rapidly from 2.63 GW in 2013 to 32.5 GW in 2019. While the share of renewables (wind, solar and bioenergy) was around 8% of generation in 2017, these sources made up around 21.8% of the installed capacity in 2017. Installed electricity generation capacity (MW) of different sources of power is shown in figure 5 and annual gross generation of power by source in India is shown in table 4. The largest power markets within India are the states of Maharashtra, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Gujarat, Tamil Nadu, West Bengal, Andra Pradesh, Rajasthan and Karnataka.

Figure 5: Installed Electricity Generation Capacity (MW) of Different sources of Power during the period 2008-2009 to 2017-2018



(Source: Energy Statistics 2020 – National Statistical Office – Ministry of Statistics and Programme Implementation, Government of India)

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Table 4: Annual Gross Generation of Power by Source in India

Fuel Category	2013	2014	2015	2016	2017	2018	2019*****
Coal*	145 273	164 636	185 173	192 163	197 171	200 704	204 224
Gas	21 782	23 062	24 509	25 329	24 897	24 937	24 937
Diesel	1 199	1 199	993	838	838	638	510
Nuclear	4 780	5 780	5 780	6 780	6 780	6 780	6 780
Hydro**	44 335	45 323	47 057	48 858	49 779	49 992	50 047
Wind	21 043	23 354	26 777	32 280	34 046	35 626	37 279
Solar	2 632	3 744	6 763	12 289	21 651	28 181	32 578
Biomass***	7 510	7 805	8 110	8 296	8 839	9 242	9 946
Total	248 554	274 903	305 162	326 833	344 001	356 100	365 891

**Includes lignite.*
***Include small hydropower.*
****Includes biomass power/co-generation and energy-from-waste.*
*****Preliminary data based on 30/11/2019*
Source: CEA (2019a), All India Installed Capacity.

3.4 Oil and Natural Gas

Oil remains an essential energy source for India. It is the second-largest source in the country's total primary energy supply (TPES) and the largest in its total final consumption (TFC). Oil demand has increased rapidly over the last several decades and India is now the third-largest oil-consuming country in the world. In the last decade, India's domestic oil production has remained relatively stable at an average of 862 thousand barrels per day (kb/d), with an annual average growth rate of 0.3%, but oil's share of total domestic energy production has declined. For refined products, India's production has increased steadily and the country is currently a net exporter. Over the same period, India's oil demand grew by more than 50%, mostly led by rapid growth in gasoline and diesel for transport, the largest oil-consuming sector, and liquefied petroleum gas (LPG) in cooking. While the rate varies, oil demand has been growing across all sectors and is expected to surpass that of the People's Republic of China ("China") in the mid-2020s as India becomes the leader of oil demand growth. With continued strong growth in oil demand against falling domestic production, India has become more reliant on oil imports, which hovered around 83% in 2018. At the same time, India's import bill for crude oil has increased by 27% from USD 88 billion in 2017 to USD 112 billion in 2018.

India's natural gas consumption is small but increasing. Most gas is used in the industrial sector and in power generation. Residential gas consumption is small, but India is expanding its gas distribution networks rapidly, an area where major growth is expected. Some states and cities also promote gas vehicles to reduce emissions from the transport sector. Domestic production covers just over half of India's gas supply. The rest is imported in the form of liquefied natural gas (LNG), which has increased rapidly in recent years, thanks to the decline in global gas prices. Investment in new LNG terminals is on a rapid rise. In 2014 India linked its domestic gas price to a basket of international LNG prices. Since domestic gas production has developed below expectations, gas use for power generation struggles to compete with cheap coal and renewables under the current contracted import prices. To stimulate more domestic production of oil and gas, the Government of India (GoI) has introduced a Hydrocarbon Exploration and Licensing Policy (HELP), which brought freedom of price setting and marketing for new gas production. India aims to increase the share of natural gas to 15% of the energy mix by 2030 (PNGRB, 2013), which suggests a doubling of current demand and infrastructure needs, as part of a gas trading hub. In 2017 total gas supply was almost 60 billion cubic metres (bcm). Domestic production accounted for 54% of total supply and imports of LNG for the remaining 43%. Except for the period 2009-2012, when production peaked at around 50 bcm, India's production has been stable at just above 30 bcm per year since the early 2000s. Gas imports began in 2003 and have increased stepwise since, as India has expanded its LNG terminal capacity. In 2017 total natural gas imports were 27 bcm, of which 49% came from Qatar. India has diversified its supply sources in recent years and imported from more than 13 countries in 2017, including large shares from Nigeria, Equatorial Guinea and Australia.

IV. CONCLUSION

Energy is the life blood for economic growth, improving the quality of life, infrastructural development and for increasing various opportunities in the future. Energy

consumption has a direct impact on the economic growth of our country, further it is also found out that various forms of energy consumption growth on growth of private consumption and private investment has an influence on the GDP growth. The study could suggest for reducing the use of conventional energy sources i.e. coal, oil and natural gas consumption particularly in the consumption sectors of the economy, in order to achieve higher growth in the economy as these sources not only contribute to the economic growth but also consumption of these could over a time could have adverse impact on the economy in the future.

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