Energy

India was the third-largest energy consumer in the world after China and the United States in 2013, and its need for energy supply continues to climb as a result of the country's dynamic economic growth and modernization over the past several years.[1] India's economy has grown at an average annual rate of approximately 11% between 2004 and 2014, and it proved relatively resilient following the 2008 global financial crisis.

The latest slowdown in growth of emerging market countries and higher inflation levels, combined with domestic supply and infrastructure constraints, reduced India's annual inflation-adjusted gross domestic product (GDP) growth from a high of 10.3% in 2010 to 5.1% in 2012, according to the World Bank. India's GDP growth rebounded to 7.3% in 2014 and 2015.[2] India was the third-largest economy in the world in 2014, as measured on a purchasing power parity basis.[3] Current risks to economic growth in India include continued fiscal deficits, infrastructure deficiencies, delays in structural reforms, and global energy price volatility.[4] Overall, the low energy prices during the past two years have been beneficial for India, a major energy consumer, by reducing overall expenses and government subsidies. On the other hand, persistent lower energy prices could affect the capital investment needed to develop India's more technically challenging upstream oil and natural gas projects.

The Bharatiya Janata Party (BJP), elected as the majority party in May 2014 to govern India in the following five years, faces several challenges to meet the country's growing energy demand including securing affordable energy supplies and attracting investment for upstream projects and transmission infrastructure. Highly regulated fuel prices for consumers, fuel subsidies that are shouldered by the government and state-owned upstream companies, transmission bottlenecks, a complex regulatory environment, and inconsistent energy sector reform currently hinder energy project investment. Some parts of the energy sector, chiefly coal production, remain relatively closed to private and foreign investment, while others such as electric power, petroleum and other liquids, and natural gas have had regulated price structures that have discouraged private investment in the recent past. Insufficient and aging infrastructure impedes the flow of energy supply to meet India's growing demand. Along with its pledge for deeper economic reforms, the new administration is supporting several energy reforms such as reducing petroleum product subsidies, reforming natural gas pricing policy, reducing electricity transmission and distribution losses and theft, alleviating regulatory burdens, and providing fiscal incentives to attract energy supply investment and to reduce infrastructure constraints.

Despite having large coal reserves and overall growth in coal and natural gas production over the past two decades, India is increasingly dependent on imported fossil fuels. India's current administration under Narendra Modi has a goal of reducing India's import dependency on oil and natural gas to two-thirds by 2022 and to half by 2030.[5] India is also looking to further develop and harness its coal and various renewable energy sources. These actions would effectively increase India's energy supply and create more efficiency in energy consumption. India has already begun implementing oil and natural gas pricing reforms since 2013 to foster sustainable investment and help lower subsidy costs.

Primary energy consumption in India more than doubled between 1990 and 2013, reaching an estimated 775 million tons of oil equivalent.[6] The country has the second-largest population in the world, at nearly 1.3 billion people in 2014, growing about 1.4% each year since 2004, according to World Bank data.[7] At the same time, India's per capita energy consumption is one-third of the global average, according to the International Energy Agency (IEA), indicating room for higher energy demand in the long term as the country continues its economic development.[8]

As shown in Figure 2, India's largest energy source is coal (44%), followed by traditional biomass and waste (24%) and petroleum and other liquids (23%). Other renewable fuel sources make up a small portion of primary energy consumption, although the capacity potential is significant for several of these resources such as solar, wind, and hydroelectricity. Since the beginning of the

New Economic Policy in 1991, India's population has increasingly moved to cities, and urban households have shifted away from using traditional biomass and waste for cooking and lighting to using electricity sourced from other energy sources such as hydrocarbons, nuclear, biofuels, wind, and solar.

India's power sector is one of the largest and fastest-growing areas of energy demand, rising from 11% to 15% of total energy consumption between 2000 and 2013, according to IEA.[9] Although electrification rates in India vary by source based on definitional differences of electricity access, the IEA estimates that 19% of the population (240 million people) lacked basic access to electricity in 2013, while electrified areas still suffer from rolling electricity blackouts.[10] The government seeks to balance the country's growing need for electricity with environmental concerns from the use of coal to produce electricity. India's transportation sector, primarily fueled by petroleum products, is set to expand as the country focuses on improving road and railway transit.

The **energy policy of India** is largely defined by the country's expanding energy deficit and increased focus on developing alternative sources of energy, particularly nuclear, solar and wind energy. India attained 63% overall energy self-sufficiency in 2017.

The primary energy consumption in India grew by 2.3% in 2019 and is the third biggest after China and USA with 5.8% global share. The total primary energy consumption from coal (452.2 Mtoe; 55.88%), crude oil (239.1 Mtoe; 29.55%), natural gas (49.9 Mtoe; 6.17%), nuclear energy (8.8 Mtoe; 1.09%), hydro electricity (31.6 Mtoe; 3.91%) and renewable power (27.5 Mtoe; 3.40%) is 809.2 Mtoe (excluding traditional biomass use) in the calendar year 2018. In 2018, India's net imports are nearly 205.3 million tons of crude oil and its products, 26.3 Mtoe of LNG and 141.7 Mtoe coal totaling to 373.3 Mtoe of primary energy which is equal to 46.13% of total primary energy consumption. India is largely dependent on fossil fuel imports to meet its energy demands – by 2030, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. About 80% of India's electricity generation is from fossil fuels. India is surplus in electricity generation and also marginal exporter of electricity in 2017. Since the end of calendar year 2015, huge power generation capacity has been idling for want of electricity demand. India ranks second after China in renewables production with 208.7 Mtoe in 2016.

In 2017-18, the per-capita energy consumption is 23.355 Giga Joules (0.558 Mtoe) excluding traditional biomass use and the energy intensity of the Indian economy is 0.2332 Mega Joules per INR (56 kcal/INR). Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. Given India's growing energy demands and limited domestic oil and gas reserves, the country has ambitious plans to expand its renewable and most worked out nuclear power programme. India has the world's fourth largest wind power market and also plans to add about 100,000 MW of solar power capacity by 2020. India also envisages to increase the contribution of nuclear power to overall electricity generation capacity from 4.2% to 9% within 25 years The country has five nuclear reactors under construction (third highest in the world) and plans to construct 18 additional nuclear reactors (second highest in the world) by 2025. During the year 2018, the total investment in energy sector by India was 4.1% (US$ 75 billion) of US$ 1.85 trillion global investment.

Indian solar power PV tariff has fallen to ₹2.44 (3.4¢ US) per kWh in May 2017 which is lower than any other type of power generation in India. In the year 2020, the levelized tariff in US dollars for solar PV electricity has fallen to 1.35 cents/kWh. Also the international tariff of solar thermal storage power plants has fallen to US$0.063/kWh, which is cheaper than fossil fuel plants. The cheaper hybrid solar power (mix of solar PV and solar thermal storage power) need not depend on costly and polluting coal/gas fired power generation for ensuring stable grid operation. Solar electricity price is going to become the benchmark price for deciding the other fuel prices (petroleum products, natural gas/biogas/LNG, CNG, LPG, coal, lignite, biomass, etc.) based on their ultimate use and advantages.

Oil and gas :- India ranks third in oil consumption with 212.7 million tons in 2016 after USA and China.During the calendar year 2015, India imported 195.1 million tons crude oil and 23.3 million tons refined petroleum products and exported 55 million tons refined petroleum products. India has built surplus world class refining capacity using imported crude oil for exporting refined petroleum products. The net imports of crude oil is lesser by one fourth after accounting exports and imports of refined petroleum products.Natural gas production was 29.2 billion cubic meters and consumption 50.6 billion cubic meters during the calendar year 2015.

During the financial year 2012–13, the production of crude oil was 37.86 million tons and 40,679 million standard cubic meters (nearly 26.85 million tons) natural gas. The net import of crude oil & petroleum products is 146.70 million tons worth of Rs 5611.40 billions. This includes 9.534 million tons of LNG imports worth of Rs. 282.15 billions.Internationally, LNG price (One million Btu of LNG = 0.1724 barrels of crude oil (boe) = 24.36 cubic meters of natural gas = 16 kg of natural gas = 29.2 litres diesel = 21.3 kg LPG) is fixed below crude oil price in terms of heating value. LNG is slowly gaining its role as direct use fuel in road and marine transport without regasification. By the end of June 2016, LNG price has fallen by nearly 50% below its oil parity price making it more economical fuel than diesel/gas oil in transport sector. In 2012-13, India consumed 15.744 million tons petrol and 69.179 million tons diesel which are mainly produced from imported crude oil at huge foreign exchange out go. Use of natural gas for heating, cooking and electricity generation is not economical as more and more locally produced natural gas will be converted into LNG for use in transport sector to reduce crude oil imports. In addition to the conventional natural gas production, coal gasification, coal bed methane, coal mine methane and Biogas digesters / Renewable natural gas will also become source of LNG forming decentralised base for production of LNG to cater to the widely distributed demand. There is possibility to convert most of the heavy duty vehicles (including diesel driven rail engines) into LNG fuelled vehicles to reduce diesel consumption drastically with operational cost and least pollution benefits. Also, the break even price at user end for switching from imported coal to LNG in electricity generation is estimated near US$6 per million British thermal units ($20/MWh). The advent of cheaper marine CNG transport will restrict LNG use in high end transport sector to replace costly liquid fuels leaving imported CNG use for other needs. As the marine CNG transport is economical for medium distance transport and has fast unloading flexibility at many ports without costly unloading facilities, they have become alternate solution to submarine gas pipelines. Natural gas/methane can also be converted cheaply in to hydrogen gas and carbon black without emitting any green house gas for use in transport sector with fuel cell vehicle technology.

The state-owned Oil and Natural Gas Corporation (ONGC) acquired shares in oil fields in countries like Sudan, Syria, Iran, and Nigeria – investments that have led to diplomatic tensions with the United States. Because of political instability in the Middle East and increasing domestic demand for energy, India is keen on decreasing its dependency on OPEC to meet its oil demand, and increasing its energy security. Several Indian oil companies, primarily led by ONGC and Reliance Industries, have started a massive hunt for oil in several regions in India, including Rajasthan, Krishna Godavari Basin and north-eastern Himalayas. India has nearly 63 tcf technically recoverable resources of shale gas which can meet all its needs for twenty years if exploited. India is developing an offshore gas field in Mozambique. The proposed Iran-Pakistan-India pipeline is a part of India's plan to meet its increasing energy demand.

Coal : - India has the world's 5th largest proven coal reserves. In India, coal is the bulk primary energy contributor with 56.90% share equivalent to 452.2 Mtoe in 2018 India's coal production has only fallen once in the last 30 years when the figure fell from 319 mt in 1997 to 316 mt in 1998.

India is also the second-largest importer of coal 141.7 Mtoe in 2018 and the second-largest consumer of coal with 452.2 Mtoe in 2018. India is also home to the world's largest coal company, Coal India Ltd, which controls 85% of the country's coal production with 7.8% production share of coal (including lignite) in the world. Top five hard and brown coal producing countries in 2013 (2012) are (million tons): China 3,680 (3,645), United States 893 (922), India 605 (607), Australia 478 (453) and Indonesia 421 (386). However, India ranks fifth in global coal production at 228 mtoe (5.9%) in 2013 when its inferior quality coal tonnage is converted into tons of oil equivalent. Coal-fired power plants account for 59% of India's installed electricity capacity. After electricity production, coal is also used for cement production in substantial quantity. In 2013, India imported nearly 95 Mtoe of steam coal and coking coal which is 29% of total consumption to meet the demand in electricity, cement and steel production. Pet coke availability, at cheaper price to local coal, is replacing coal in cement plants.

Gasification of coal or lignite or pet coke produces syngas or coal gas or coke oven gas which is a mixture of hydrogen, carbon monoxide and carbon dioxide gases. Coal gas can be converted into synthetic natural gas (SNG) by using Fischer–Tropsch process at low pressure and high temperature. Coal gas can also be produced by underground coal gasification where the coal deposits are located deep in the ground or uneconomical to mine the coal. CNG and LNG are emerging as economical alternatives to diesel oil with the escalation in international crude oil prices. Synthetic natural gas production technologies have tremendous scope to meet the transport sector requirements fully using the locally available coal in India. Dankuni coal complex is producing syngas which is piped to the industrial users in Calcutta. Many coal based fertiliser plants which are shut down can also be retrofitted economically to produce SNG as LNG and CNG fetch good price by substituting imports. Recently, Indian government fixed the natural gas

price at producer end as US$5.61 per million British thermal units ($19.1/MWh) on net calorific value (NCV) basis, which is at par with the estimated SNG price from coal.

Bio-fuels:- Gasification of bio mass yields wood gas or syngas which can be converted into substitute natural gas by Methanation. Nearly 750 million tons of non edible (by cattle) biomass is available annually in India which can be put to higher value addition use and substitute imported crude oil, coal, LNG, urea fertiliser, nuclear fuels, etc. It is estimated that renewable and carbon neutral biomass resources of India can replace present consumption of all fossil fuels when used productively.

Huge quantity of imported coal is being used in pulverised coal-fired power stations. Raw biomass can not be used in the pulverised coal mills as they are difficult to grind into fine powder due to caking property of raw biomass. However biomass can be used after Torrefaction in the pulverised coal mills for replacing imported coal. North west and southern regions can replace imported coal use with torrefied biomass where surplus agriculture/crop residual biomass is available. Biomass power plants can also get extra income by selling the Renewable Purchase Certificates (RPC).

In cement production, carbon neutral biomass is being used to replace coal for reducing carbon foot print drastically.

Biogas or natural gas or methane produced from farm/agro/crop/domestic waste can also be used for producing protein rich feed for cattle/fish/poultry/pet animals economically by cultivating *Methylococcus capsulatus* bacteria culture in a decentralised manner near to the rural / consumption areas with tiny land and water foot print. With the availability of CO_2 gas as by product from these units, cheaper production cost of algae oil from algae or spirulina particularly in tropical countries like India would displace the prime position of crude oil in near future.

India's three Oil Marketing Companies (OMCs) are currently setting up 12 second-generation ethanol plants across the country which will collect agriculture waste from farmers and convert it into bio-ethanol. In 2018, India has set target to produce 15 million tons of biogas/bio-CNG by installing 5,000 large scale commercial type biogas plants which can produce daily 12.5 tons of bio-CNG by each plant.

The former President of India, Dr. A. P. J. Abdul Kalam, was a strong advocate of Jatropha cultivation for production of bio-diesel. He said that out of the 6,00,000 km^2 of waste land that is available in India over 3,00,000 km^2 is suitable for Jatropha cultivation. Once the plant is grown, it has a useful lifespan of several decades. A plan for supplying incentives to encourage the use of Jatropha has been coloured with green stripes. Biopropane is also produced from non-edible vegetable oils, used cooking oil, waste animal fats, etc.

Nuclear power :- India boasts a quickly advancing and active nuclear power programme. It is expected to have 20 GW of nuclear capacity by 2020, though it currently stands as 9th in the world in terms of nuclear capacity.

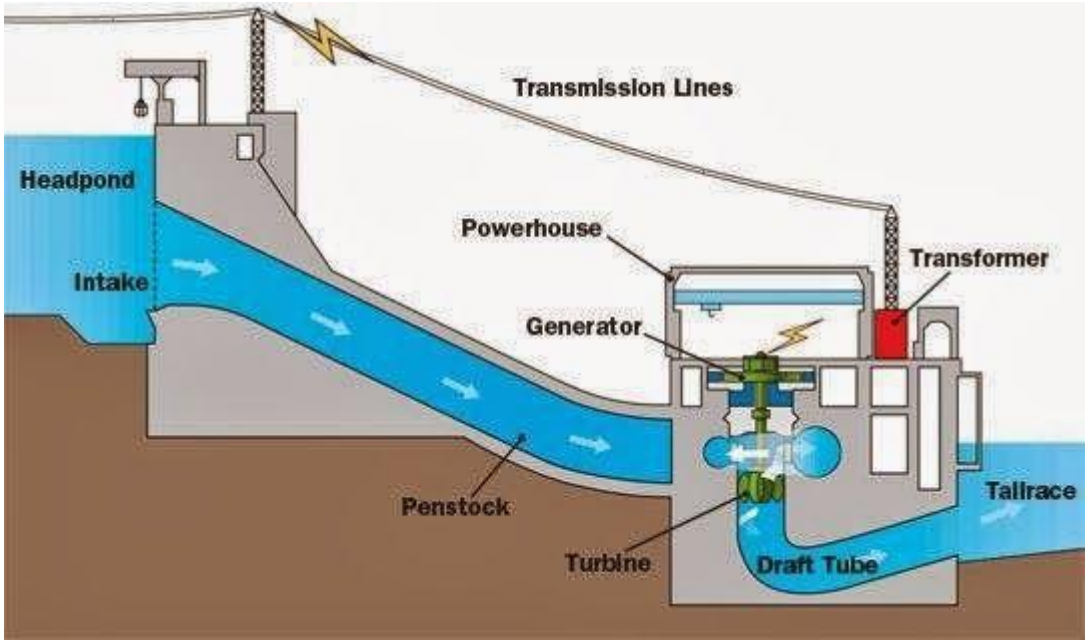
An Achilles' heel of the Indian nuclear power programme, however, is the fact that India is not a signatory of the Nuclear Non-Proliferation Treaty. This has many times in its history prevented it from obtaining nuclear technology vital to expanding its nuclear industry. Another consequence of this is that much of its programme has been domestically developed much like its nuclear weapons programme. The United States-India Peaceful Atomic Energy Cooperation Act seems to be a way to get access to advanced nuclear technologies for India.

India has been using imported enriched uranium and is under International Atomic Energy Agency (IAEA) safeguards, but it has developed various aspects of the nuclear fuel cycle to support its reactors. Development of select technologies has been strongly affected by limited imports. Use of heavy-water reactors has been particularly attractive for the nation because it allows uranium to be burnt with little to no enrichment. India has also done a great amount of work in the development of a thorium-centred fuel cycle. While uranium deposits in the nation are extremely limited, there are much greater reserves of thorium, and it could provide hundreds of times the energy with the same mass of fuel. The fact that thorium can theoretically be utilised in heavy water reactors has tied the development of the two. A prototype reactor that would burn uranium-plutonium fuel while irradiating a thorium blanket is under construction at the Madras/Kalpakkam Atomic Power Station.Uranium used for the weapons programme has been separate from the power programme using uranium from scant indigenous reserves.

Hydro electricity:- India is endowed with economically exploitable and viable hydro potential assessed to be about 125,570 MW at 60% capacity factor. India ranked fourth globally by underutilized hydro power potential. In addition, 6,780 MW in terms of installed capacity from Small, Mini, and Micro Hydel schemes have been assessed. Also, 56 sites for pumped storage schemes (PSS) with an aggregate installed capacity of 94,000 MW have been identified for catering to peak electricity demand and water pumping for irrigation needs. It is the most widely used form of renewable energy but the economically exploitable hydro power potential keeps on varying due to technological developments and the comparable cost of electricity generation from other sources. The hydro-electric potential of India ranks 5th in terms of exploitable hydro-potential on global scenario.

The installed capacity of hydro power is 45,315 MW as of 31 May 2018. India ranks sixth in hydro electricity generation globally after China, Canada, Brazil, USA and Russia. During the year 2017-18, the total hydro electricity generation in India is 126.123 billion kWh which works out to 24,000 MW at 60% capacity factor. Till now, hydroelectricity sector is dominated by the state and central government owned companies but this sector is going to grow faster with the participation of private sector for developing the hydro potential located in the Himalaya mountain ranges including north east of India. However the hydro power potential in central India forming part of Godavari, Mahanadi and Narmada river basins has not yet been developed on major scale due to potential opposition from the tribal population.

Pumped storage schemes are perfect centralized peaking power stations for the load management in the electricity grid. PSS would be in high demand for meeting peak load demand and storing the surplus electricity as India graduates from electricity deficit to electricity surplus. They also produce secondary /seasonal power at no additional cost when rivers are flooding with excess water. Storing electricity by other alternative systems such as batteries, compressed air storage systems, etc is more costlier than electricity production by standby generator. India has already established nearly 4785 MW pumped storage capacity which is part of its installed hydro power plants.



Wind power: - India has the fourth largest installed wind power capacity in the world. As of 31 December 2017, the installed capacity of wind power was 32,848 MW an increase of 4148 MW over the previous year Wind power accounts nearly 10% of India's total installed power generation capacity and generated 52.666 billion kWh in the fiscal year 2017-18 which is nearly 3% of total electricity generation. The capacity utilisation factor is nearly 16% in the fiscal year 2017-18. The Ministry of New and Renewable Energy (MNRE) of India has announced a revised estimation of the potential wind power resource (excluding offshore wind power potential) from 49,130 MW assessed at 50m Hub heights to 102,788 MW assessed at 80m Hub height at 15% capacity factor.

Solar energy: India's solar energy insolation is about 5,000 T kWh per year (i.e. ~ 600 TW), far more than its current total primary energy consumption. India's long-term solar potential could be unparalleled in the world because it has the ideal combination of both high solar insolation and a big potential consumer base density. Also a major factor influencing a region's energy intensity is the cost of energy consumed for temperature control. Since cooling load requirements are roughly in phase with the sun's intensity, cooling from intense solar radiation could make perfect energy-economic sense in the subcontinent located mostly in the tropics.

Installation of solar power PV plants require nearly 2.0 hectares (5 acres) land per MW capacity which is similar to coal-fired power plants when life cycle coal mining, consumptive water storage & ash disposal areas are also accounted and hydro power plants when submergence area of water reservoir is also accounted. 1.6 million MW capacity solar plants can be installed in India on its 1% land (32,000 square km). There are vast tracts of land suitable for solar power in all parts of India exceeding 8% of its total area which are unproductive barren and devoid of vegetation. Part of waste lands (32,000 square km) when installed with solar power plants can produce 2400 billion kWh of electricity (two times the total generation in 2013-14) with land productivity/yield of 0.9 million Rs per acre (3 Rs/kWh price) which is at par with many industrial areas and many times more than the best productive irrigated agriculture lands. Moreover, these solar power units are not dependent on supply of any raw material and are self productive. There is unlimited scope for solar electricity to replace all fossil fuel energy requirements (natural gas, coal, lignite and crude oil) if all the marginally productive lands are occupied by solar power plants in future. The solar power potential of India can meet perennially to cater per capita energy consumption at par with USA/Japan for the peak population in its demographic transition.

The installed capacity of commercial solar thermal power plants in India is 227.5 MW with 50 MW in Andhra Pradesh and 177.5 MW in RajasthanSolar thermal plants are emerging as cheaper (6 Euro ¢/kWh) and clean load following power plants compared to fossil fuel power plants. They can cater the load/ demand perfectly and work as base load power plants when the extracted

solar energy is found excess in a day. Proper mix of solar thermal and solar PV can fully match the load fluctuations without the need of costly battery storage.

Synergy with irrigation water pumping and hydro power stations

The major disadvantage of solar power (PV type only) is that it can not produce electricity during the night time and cloudy day time also. In India, this disadvantage can be overcome by installing pumped-storage hydroelectricity stations. Ultimate electricity requirement for river water pumping (excluding ground water pumping) is 570 billion kWh to pump one cubic meter of water for each square meter area by 125 m height on average for irrigating 140 million hectares of net sown area (42% of total land) for three crops in a year. This is achieved by utilising all the usable river waters by interlinking Indian rivers by envisaging coastal reservoirs. These river water pumping stations would also be envisaged with pumped-storage hydroelectricity features to generate electricity when necessary to stabilise the grid. Also, all existing and future hydro power stations can be expanded with additional pumped-storage hydroelectricity units to cater night time electricity consumption. Most of the ground water pumping power can be met directly by solar power during daytime. To achieve food security, India needs to achieve water security which is possible only by energy security for harnessing its water resources.

Electric vehicles:- The retail prices of petrol and diesel are high in India to make electricity driven vehicles more economical as more and more electricity is generated from solar energy in near future without appreciable environmental effects. During the year 2018, many IPPs offered to sell solar power below 3.00 Rs/kWh to feed into the high voltage grid. This price is far below the affordable retail electricity tariff for the solar power to replace petrol and diesel use in transport sector.

The retail price of diesel is 53.00 Rs/litre in 2012-13. The affordable electricity retail price (860 kcal/kWh at 75% input electricity to shaft power efficiency) to replace diesel (lower heating value 8572 kcal/litre at 40% fuel energy to crank shaft efficiency) is 9.97 Rs/kWh. The retail price of petrol is 75.00 Rs/litre in 2012-13. The affordable electricity retail price (860 kcal/kWh at 75% input electricity to shaft power efficiency) to replace petrol (lower heating value 7693 kcal/litre at 33% fuel energy to crank shaft efficiency) is 19.06 Rs/kWh. In 2012-13, India consumed 15.744

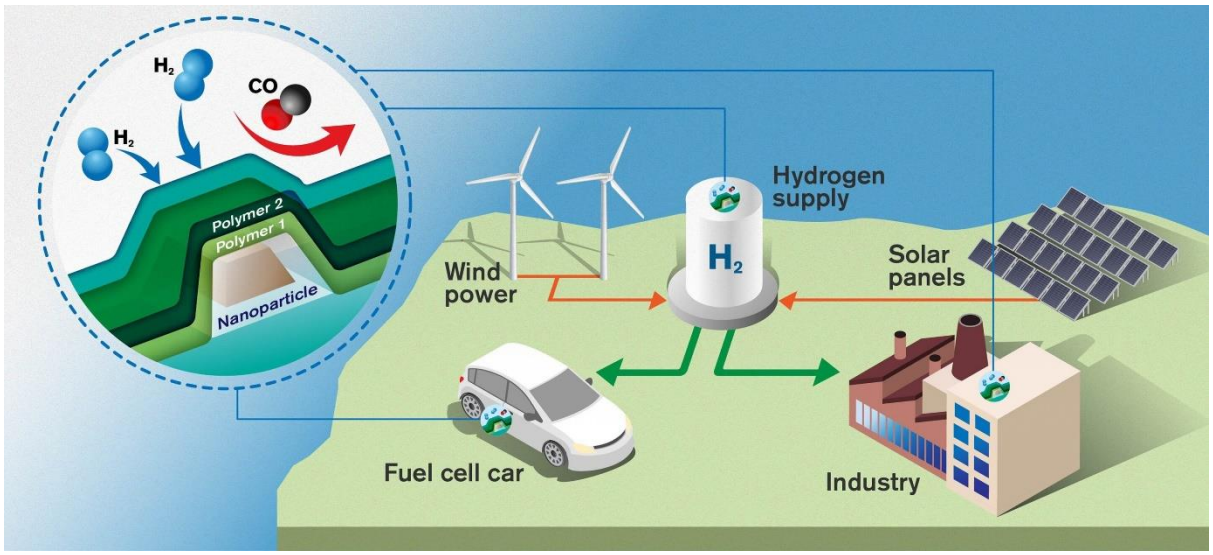
million tons petrol and 69.179 million tons diesel which are mainly produced from imported crude oil at huge foreign exchange out go.

V2G is also feasible with electricity driven vehicles to contribute for catering to the peak load in the electricity grid. The electricity driven vehicles would become popular in future when its energy storage / battery technology becomes more compact, lesser density, longer lasting and maintenance free.

Hydrogen energy:- Hydrogen Energy programme started in India after joining the IPHE (International Partnership for Hydrogen Economy) in the year 2003. There are nineteen other countries including Australia, United States, UK, Japan, etc. This global partnership helps India to set up commercial use of Hydrogen gas as an energy source. Ministry of New and Renewable Energy (MNRE) is the focal government agency associated with hydrogen energy development in India.

Hydrogen is a carbon neutral fuel. Solar electricity prices in India have already fallen below the affordable price (≈ INR 5.00 per Kwh to generate 0.041 lb/Kwh hydrogen which is equivalent to 0.071 litres of petrol in terms of lower heating value) to make hydrogen economical fuel by sourcing from electrolysis of water to replace petrol/gasoline as transport fuel. Vehicles with fuel cell technology based on hydrogen gas are nearly twice more efficient compared to diesel/petrol fueled engines. Hydrogen can be generated cheaply by splitting methane using electricity without emitting any green house gas and also extracted from wood gas produced from carbon neutral biomass. A luxury FCEV car generates one litre of bottled quality drinking water for every 10 km ride which is a significant by product. Also FCEV does not emit any particulate matter but removes particulate matter up to PM2.5 from the ambient air. Any medium or heavy duty vehicle can be retrofitted in to fuel cell vehicle as its system power density (watts/litre) and system specific power (watts/kg) are comparable with that of internal combustion engine. The cost and durability of fuel cell engines with economies of scale production line are comparable with the petrol/diesel engines.

The excess power generation capacity available in India is nearly 500 billion units/year presently and another 75,000 MW conventional power generating capacity is in pipeline excluding the targeted 175,000 MW renewable power by 2022. The hydrogen fuel generated by 500 billion units of electricity can replace all diesel and petrol consumed by heavy and medium duty vehicles in India completely obviating the need of crude oil imports for internal consumption. Use of hydrogen as fuel to replace jet fuel by the aircraft's is also promising proposition. Converting petrol/diesel driven road vehicles in to fuel cell electric vehicles on priority would save the huge import cost of crude oil and transform the stranded electricity infrastructure in to productive assets with major boost to the overall economic growth.



Electricity as substitute to imported LPG and kerosene:

The net import of LPG is 6.093 million tons and the domestic consumption is 13.568 million tons with Rs. 41,546 crores subsidy to the domestic consumers in 2012-13. The LPG import content is nearly 40% of total consumption in India. The affordable electricity retail price (860 kcal/kWh at 90% heating efficiency) to replace LPG (lower heating value 11,000 kcal/kg at 75% heating efficiency) in domestic cooking is 6.47 Rs/kWh when the retail price of LPG cylinder is Rs 1000 (without subsidy) with 14.2 kg LPG content. Replacing LPG consumption with electricity reduces its imports substantially.The domestic consumption of Kerosene is 7.349 million tons with Rs. 30,151 crores subsidy to the domestic consumers in 2012-13. The subsidised retail price of Kerosene is 13.69 Rs/litre whereas the export/import price is 48.00 Rs/litre. The affordable electricity retail price (860 kcal/kWh at 90% heating efficiency) to replace Kerosene (lower heating value 8240 kcal/litre at 75% heating efficiency) in domestic cooking is 6.00 Rs/kWh when Kerosene retail price is 48 Rs/litre (without subsidy).

During the year 2013-14, The plant load factor (PLF) of coal-fired thermal power stations is only 65.43% whereas these stations can run above 85% PLF comfortably provided there is adequate electricity demand in the country. The additional electricity generation at 85% PLF is nearly 240 billion units which is adequate to replace all the LPG and Kerosene consumption in domestic sector. The incremental cost of generating additional electricity is only their coal fuel cost which is less than 3 Rs/kWh. Enhancing the PLF of coal-fired stations and encouraging domestic electricity consumers to substitute electricity in place of LPG and Kerosene in household cooking, would reduce the government subsidies and idle capacity of thermal power stations can be put to use economically. The domestic consumers who are willing to surrender the subsidised LPG / Kerosene permits or eligible for subsidized LPG / Kerosene permits, may be given free electricity connection and subsidized electricity tariff.

In December 2018, IPPs are offering to sell solar power below 2.90 Rs/kWh to feed into the high voltage grid. This price is below the affordable electricity tariff for the solar power to replace LPG and Kerosene use at subsidized price of LPG or Kerosene in domestic sector. Two wheelers and three wheelers consume 62% and 6% of petrol respectively in India. The saved LPG/Autogas replaced by electricity in domestic sector can be used by two and three wheelers with operational cost and least pollution benefits. LPG is also used in heavy duty vehicles / boats / trains / off road construction or mining or farming or other equipment to replace diesel or petrol with economy and environmental advantages. It is also possible to convert the existing heavy duty diesel engines to dual fuel with LPG for reducing the PM10 particulate emissions. Existing petrol engines can be converted at low cost in to 100% LPG or dual fuel with LPG for achieving enhanced fuel efficiency and economy with drastically reduced emissions. Non-subsidy LPG prices are below the diesel or petrol prices in India in terms of heat content (heat content wise one kg of LPG is equal to 1.85 liters of LPG or 1.37 liters of diesel oil or 1.48 liters of petrol). Cheaper butane, a constituent of LPG (propane and butane mixture), can be directly mixed with petrol/gasoline for better use in vehicles. Instead of using LPG as heating fuel in domestic sector, for higher end usage, propane can also be converted into alkylate which is a premium gasoline blending stock because it has exceptional antiknock properties and gives clean burning. Propane can be used in hydrogen/Ammonia production with advantages compared to natural gas and also can be transported much cheaper than LNG or natural gas.

Energy trading with neighbouring countries:- The per capita electricity consumption is low compared to many countries despite cheaper electricity tariff in India. Despite low electricity per capita consumption in India, the country is going to achieve surplus electricity generation during the 12th plan (2012 to 2017) period provided its coal production and transport infrastructure is developed adequately India has been exporting electricity to Bangladesh and Nepal and importing excess electricity in Bhutan. Surplus electricity can be exported to the neighbouring countries in return for natural gas supplies from Pakistan, Bangladesh and Myanmar.

Bangladesh, Myanmar and Pakistan are producing substantial natural gas and using for electricity generation purpose. Bangladesh, Myanmar and Pakistan produce 55 million cubic metres per day (mcmd), 9 mcmd and 118 mcmd out of which 20 mcmd, 1.4 mcmd and 34 mcmd are consumed for electricity generation respectively. Whereas the natural gas production in India is not even adequate to meet its non-electricity requirements.

Bangladesh, Myanmar and Pakistan have proven reserves of 200 billion cubic metres (bcm), 1200 bcm and 500 bcm respectively. There is ample opportunity for mutually beneficial trading in energy resources with these countries. India can supply its surplus electricity to Pakistan and Bangladesh in return for the natural gas imports by gas pipe lines. Similarly India can develop on BOOT basis hydro power projects in Bhutan, Nepal and Myanmar. India can also enter into long term power purchase agreements with China for developing the hydro power potential in Brahmaputra river basin of Tibet region. India can also supply its surplus electricity to Sri Lanka by undersea cable link. There is ample trading synergy for India with its neighbouring countries in securing its energy requirements.

Policy framework: In general, India's strategy is the encouragement of the development of renewable sources of energy by the use of incentives by the federal and state governments. With the abundant solar energy resource combined with adequate high head pumped hydroelectric energy storage potential, India is capable to meet its ultimate energy requirements of its peak population from its renewable energy sources alone.

A long-term energy policy perspective is provided by the Integrated Energy Policy Report 2006 which provides policy guidance on energy-sector growth. Increasing energy consumption associated primarily with activities in transport, mining, and manufacturing in India needs rethinking on India's energy production.

The following trends are manifested in the energy policy to achieve self sufficiency, least pollution and long term sustainability.

Purpose	Preferred fuel	Next preferred fuel	Least preferred fuel
Mobile military hardware	Indigenous diesel, Indigenous petrol	Ethanol, Biodiesel	Nil
Air transport	LNG	Biodiesel, Bioethanol, Ammonia	ATF, HSK

Marine transport	LNG, FCEV, CNG	Pyrolysis oil, Nuclear fuel, Biodiesel, Bioethanol	LDO, HFO, Bunker fuel, Diesel
Heavy duty road vehicles	LNG, FCEV, CNG, LPG	Biodiesel	Diesel, Animal draught power
Passenger four wheel vehicles	LPG, LNG, Battery power, FCEV	Biodiesel	Diesel, Petrol
Passenger two/three wheel vehicles	LPG, CNG, Battery power	Biodiesel	Petrol, Animal draught power
Railways	Electricity, LNG, LPG, FCEV	Biodiesel	Diesel
Illumination/ lighting	Electricity	CNG, LPG	Kerosene
Cooking	Electricity	CNG, Biochar	Kerosene, LPG, Fire wood
Space & water heating	Electricity, Pyrolysis oil, Biochar, Solar energy	CNG	Kerosene, LPG, Fire wood
Commercial / Domestic - appliances	Electricity	Battery power	Diesel, Petrol, LPG, CNG
Industrial- motive power	Electricity	Bio diesel, Pyrolysis oil	CNG, LPG, Diesel, Petrol

Industrial-heating	Biomass, Pyrolysis oil, Biochar, Solar thermal energy, Electricity	Biogas, PNG	Kerosene, LPG, Fire wood
Urea fertilizer	Biogas / synthetic gas, Biochar,	Natural gas, Electricity, Indigenous petcock	Naphtha, Coal
Water pumping	Electricity	LPG	Kerosene, Diesel, Petrol
Agriculture-heating & drying	Biomass, Pyrolysis oil, Solar energy	LPG, Electricity	Diesel, Petrol
Agriculture-appliances	Electricity, LPG	Bio diesel, Pyrolysis oil	CNG, Diesel, Petrol
Electricity Generation	Solar Power, Wind, Hydro power, biomass, Torrifacted biomass, Biochar, Biogas plant residue, pumped-storage hydroelectricity	CNG, Animal draught power (peaking power only), Battery energy storage system	Petrol, Diesel, NGL, LPG, LDO, HFO, Naptha, Nuclear, Coal, Petcoke
Steel production	Renewable electricity, Charcoal, Biochar	Renewable hydrogen, LPG, CNG	Coke, Coal
Cement production	Indigenous petcock, Biomass, Waste organic matter, Renewable electricity	LPG, CNG	Coal
Feed stock for Petrochemicals	Acetylene and hydrogen generated by renewable electricity, Biogas, Hydrogen from wood gas	BioLPG, Bioethanol, Biodiesel	Ethane, Naptha

Protein rich cattle/fish feed	CNG, PNG, Biogas, LNG	SNG from coal, Coalbed methane, Coal mine methane, SNG from renewable electricity, SNG from indigenous petcock	Nil
Industrial- raw materials	As economically required	Nil	Nil

Electricity generation:- The installed capacity of utility power plants is 314.64 GW as on 31 January 2017 and the gross electricity generated by utilities during the year 2015-16 is 1168.359 billion kWh which includes auxiliary power consumption of power generating stations. The installed capacity of captive power plants in industries (1 MW and above) is 50,289 MW as on 31 March 2017 and generated 197 billion kWh in the financial year 2016-17. In addition, there are nearly 75,000 MW aggregate capacity diesel generator sets with units sizes between 100 KVA and 1000 KVA. All India per capita consumption of Electricity is nearly 1,122 kWh during the financial year 2016-17.

Total installed Power generation Capacity (end of April 2017)

Source	Utilities Capacity (MW)	%	Captive Power Capacity (MW)	%
Coal	194,402.88	59.9	29,888.00	59.43
Hydroelectricity	44,594.42	14.0	64.00	0.11
Renewable energy source	50,018.00	15.9	Included in **Oil**	-
Natural Gas	25,329.38	8.1	6,061.00	12.05
Nuclear	6,780.00	1.8	-	-
Oil	837.63	0.3	14,285.00	28.41
Total	**329,204.53**		**50,289.00**	100

The total installed utility power generation capacity as on 30 April 2017 with sector wise & type wise break up is as given below.

Sector	Thermal (MW)				Nuclear (MW)	Renewable (MW)		Total (MW)	%
	Coal	Gas	Diesel	Sub-Total Thermal		Hydro	Other Renewable		
Central	55,245.00	7,490.83	0.00	62,735.83	6,780.00	11,651.42	0.00	81,167.25	25
State	65,145.50	7,257.95	363.93	72,767.38	0.00	29,703.00	1,963.80	104,447.28	32
Private	74,012.38	10,580.60	473.70	85,066.68	0.00	3,240.00	55,283.33	143,590.01	43
All India	194,402.88	25,329.38	837.63	220,569.88	6,780.00	44,594.42	57,260.23	329,204.53	100

Yearly gross electricity generation – mode wise (GWh)

Year	Fossil Fuel			Nuclear	Hydro	Sub total	RES						Utility and Captive Power			
	Coal	Oil	Gas				Minihydro	Solar	Wind	Biomass	Other	Subtotal	Utility	Captive	Misc	Total
2019-20	995,840	108	48,497	46,381	155,970	1,246,796	9,366	50,103	64,639	13,843	366	138,318	1,385,114	na	na	na
2018-19	1,021,997	129	49,886	37,706	135,040	1,244,758	8,703	39,268	62,036	16,325	425	126,757	1,371,517	175,000	na	1,546,517

2017-18	986,591	386	50,208	38,346	126,123	1,201,653	5,056	25,871	52,666	15,252	358	101,839	1,303,493	183,000	na	1,486,493
2016-17	944,850	262	49,100	37,663	122,313	1,154,188	7,673	12,086	46,011	14,159	213	81,949	1,236,137	197,000	na	1,433,392
2015-16	896,260	406	47,122	37,413	121,377	1,102,578	8,355	7,450	28,604	16,681	269	65,781	1,168,359	183,611	na	1,351,970
2014-15	835,838	1,407	41,075	36,102	129,244	1,043,666	8,060	4,600	28,214	14,944	414	61,780	1,105,446	166,426	na	1,271,872
2013-14	746,087	1,868	44,522	34,228	134,847	961,552	na	3,350	na	na	na	59,615	1,021,167	156,643	na	1,177,810
2012-13	691,341	2,449	66,664	32,866	113,720	907,040	na	na	na	na	na	57,449	964,489	144,009	na	1,108,498
2011-12	612,497	2,649	93,281	32,286	130,511	871,224	na	na	na	na	na	51,226	922,451	134,387	na	1,056,838

Notes: Coal includes lignite; Misc: includes contributions from emergency diesel generator sets; *Hydro includes pumped storage generation; na = data not available.

In 2019-20, the total generation from all renewable energy sources is nearly 20% of the total electricity generation (utility and captive) in India.

Energy conservation: - Energy conservation has emerged as a major policy objective, and the Energy Conservation Act 2001, was passed by the Indian Parliament in September 2001. This Act requires large energy consumers to adhere to energy consumption norms; new buildings to follow the Energy Conservation Building Code; and appliances to meet energy performance standards and to display energy consumption labels. The Act also created the Bureau of Energy Efficiency to implement the provisions of the Act. In 2015, Prime Minister Mr. Modi launched a scheme called Prakash Path urging people to use LED lamps in place of other lamps to drastically cut down lighting power requirement. Energy efficient fans at subsidised price are offered to the electricity consumers by the electricity distribution companies (DisComs) to decrease peak electricity load.

Rural electrification: As on 28 April 2018, all Indian villages were electrified. India has achieved 100% electrification of all rural and urban households. As of 4 January 2019, 211.88 million rural households are provided with electricity, which is nearly 100% of the 212.65 million total rural households. Up to 4 January 2019, 42.937 million urban households are provided with electricity, which is almost 100% of the 42.941 million total urban households. 89% of house holds in the country use LPG drastically reducing the use of traditional fuels – fuelwood, agricultural waste and biomass cakes – for cooking and general heating needs.

Gujarat Energy and Petro chemicals Department :- Energy & Petrochemicals Department has a very important contribution to the state all-round development with a vision to provide quality power and piped natural gas at sustainable rates to the people of Gujarat through increased generation, efficient and distribution transmission, private sector participation, energy conservation, power sector reforms and use of alternative sources of non-conventional energy. The Department is associated with various companies engaged in the field of power, gas, fertilizers and non-conventional energy.

The glimpses of these companies are shown here under:

- Gujarat Urja Vikas Nigam Limited (GUVNL)
- Gujarat State Electricity Corporation Ltd. (GSECL)
- Gujarat Energy Transmission Corporation Ltd. (GETCO)
- Paschim Gujarat Vij Co. Ltd.,(PGVCL)
- Uttar Gujarat Vij Co. Ltd. (UGVCL)
- Madhya Gujarat Vij Co. Ltd. (MGVCL)
- Daxin Gujarat Vij Co. Ltd. (DGVCL)
- Gujarat Industry Power Co. Ltd. (GIPCL)
- Gujarat Electricity Regulatory Commission (GERC)
- Gujarat Power Corporation Ltd. (GPCL)
- Gujarat State Petroleum Corporation Ltd. (GSPC)

- Gujarat State Petronet Ltd. (GSPL)
- Gujarat Gas Ltd. (GGL)
- Gujarat State Fertilizers and Chemicals Ltd (GSFC)
- Gujarat Alkalis and Chemicals Co. Ltd. (GACL)
- Gujarat Narmada Valley Fertilizers and Chemicals Ltd.(GNFC)

The Government's Power Schemes related to Energy & Petrochemical department

- Electrification Under Sub Scheme Of The Tribal Area
- Power Connection For Agriculture
- Kutir Jyoti Scheme
- Scheme for Electrification of Huts
- Sub Schemes For Schedule Castes
- Schemes For Over All Development Of Fishermen
- Programs For Makeover Of Power Development (RAPDRP)
- Scheme For Energy Power For Farmers Interest (KHUSI)
- Pump Sets Working On Solar Energy

Gujarat Energy and Petro chemicals Department Scheme

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