Case Study for India

BRIDGE TO INDIA

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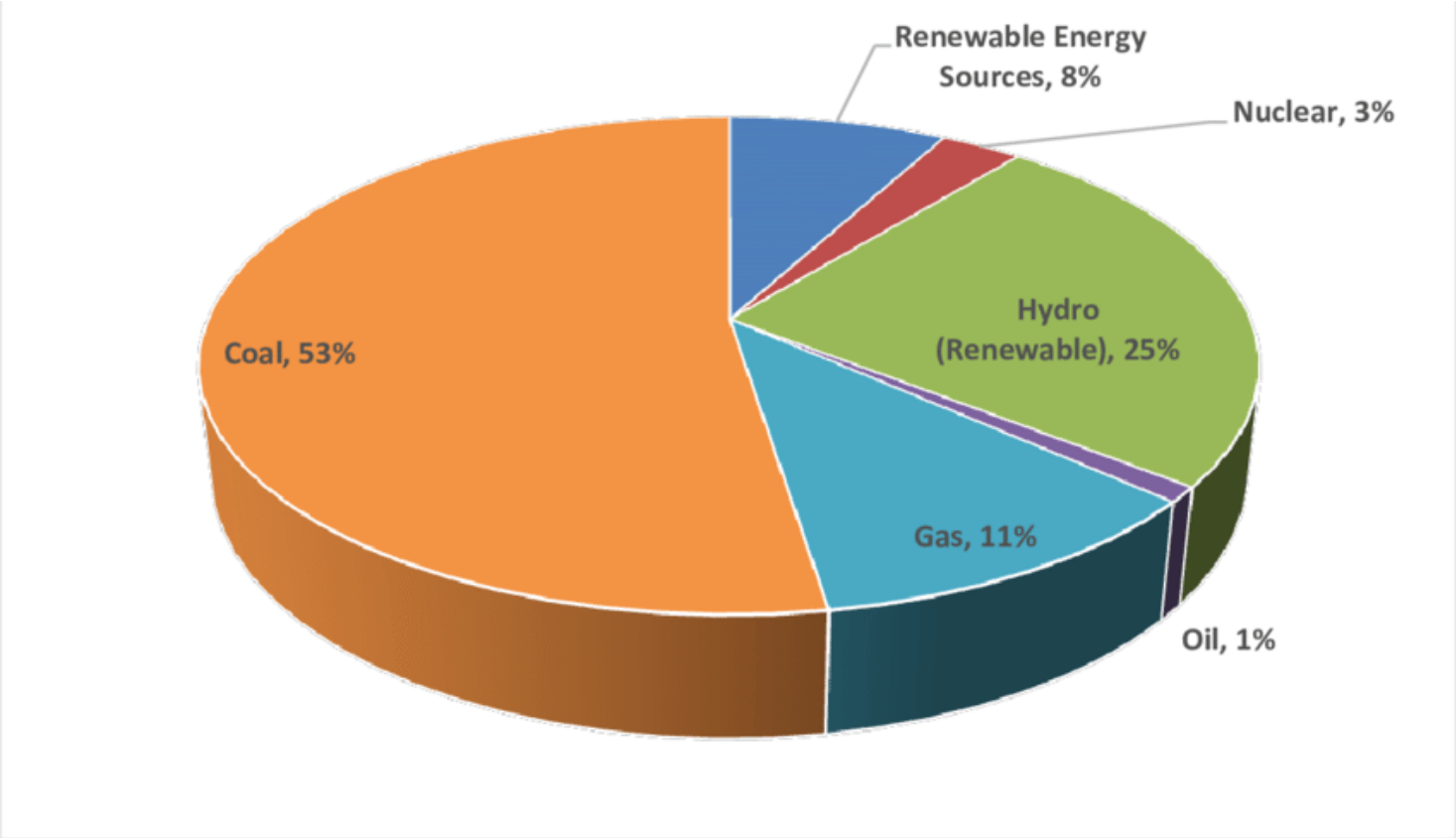
One of the Largest Solar Hubs

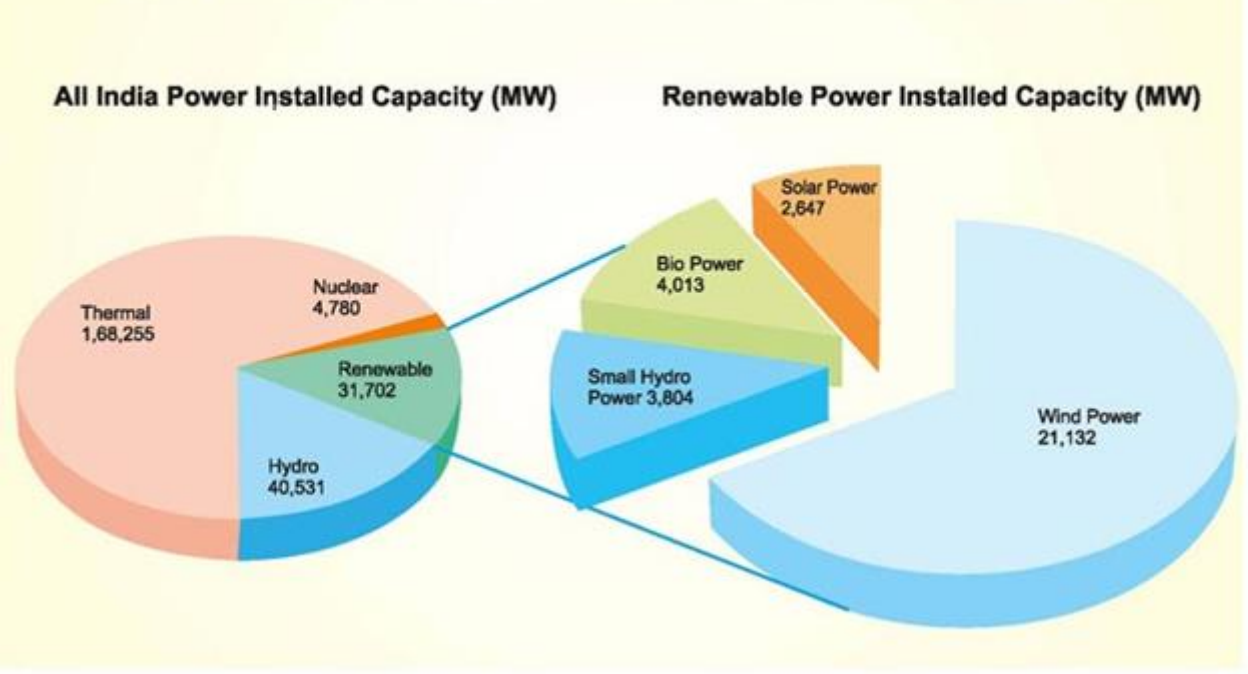
- The Indian growth story no longer needs to be validated and verified as India is set to become one of the largest solar hubs globally. Driving on the surge is the growing renewable energy industry with vision on the future and systematic year on year growth. The expo boasts of unparalleled collaborations amongst the international stakeholders with cutting-edge technology and products.
- India is on the ambitious path to implement the world's largest renewable energy expansion program. Its growing stature and successful leadership position at the International Solar Alliance has prompted even the countries outside of the tropics in entering the alliance. The ISA is conceived as a coalition of solar resource rich countries to address their special energy needs and provide a platform to collaborate on addressing the identified gaps through a common, agreed approach.

Fuel Sources, 2009



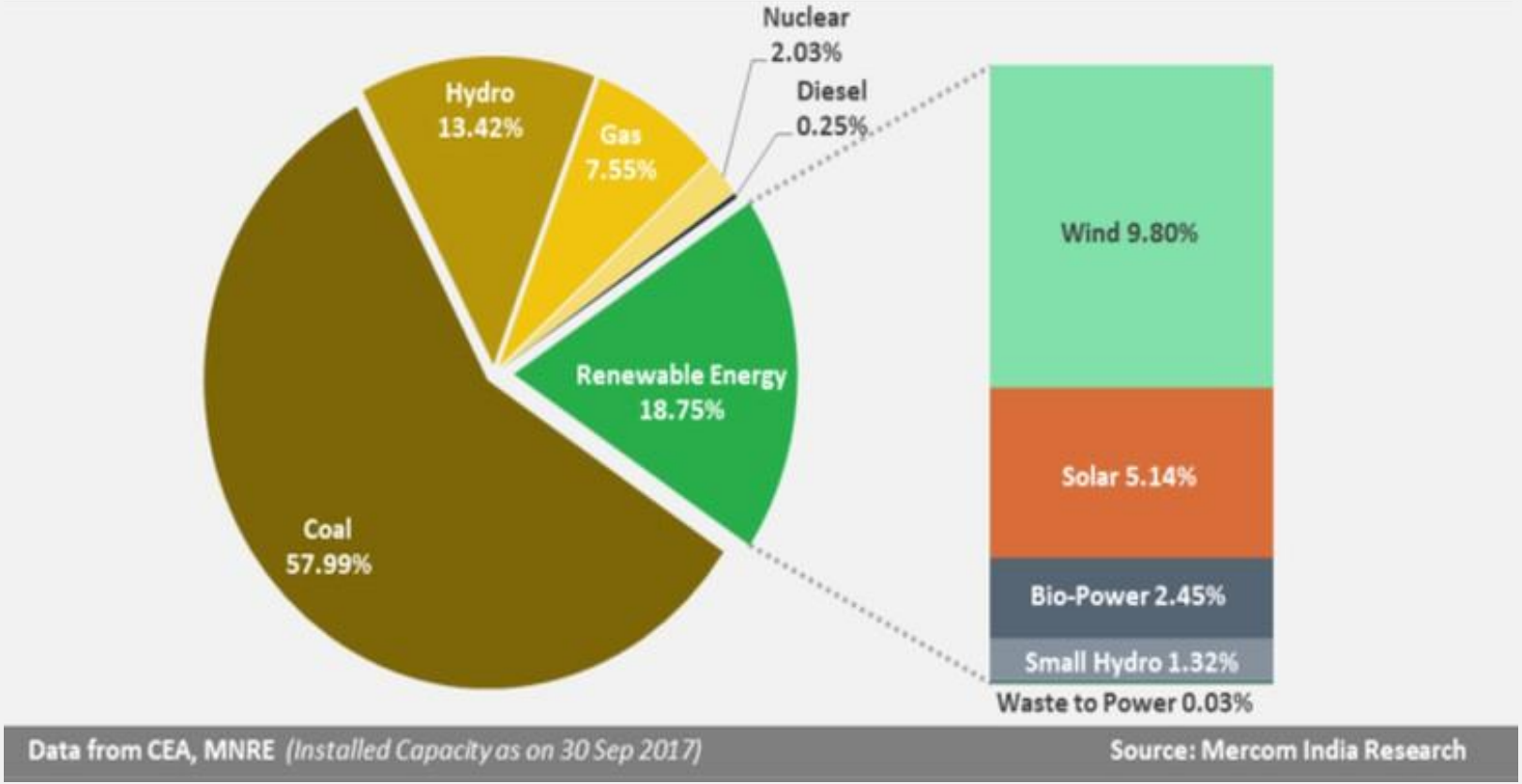
https://www.researchgate.net/figure/India-current-renewable-energy-sources-as-of-July-2009-Source-India-Energy-Data_fig6_318431767

Installed Power Capacity Mix, 2014



http://www.insightsonindia.com/2014/11/02/indias-energy-security-renewable-sources-of-energy/110214_1043_indiasenerg2-png/

Installed Power Capacity Mix, 2017



https://renewablesnow.com/news/india-reaches-19-share-of-renewables-in-power-mix-mercom-590532/

19% Share of Renewables in Power Mix

- Renewables accounted for 19% of India's installed power capacity at the end of September. India's renewable energy generation capacity has reached 62.5 GW at the end of September 2017 while the total installed power capacity stood at 333.5 GW.
- Coal remained the leading source with a 58% share, while renewables ranked 2nd. The 3rd was taken by hydro with a 13% share and total installed capacity of 44.8 GW. The total renewables capacity included 32.7 GW of wind, which corresponds to almost 10% of India's overall capacity. Next comes solar with more than 17 GW and a 5% share of the total mix.
- In the first nine months of 2017, newly-commissioned photovoltaic capacity exceeded 7 GW, accounting for 39% of the new power capacity, followed by wind with a 21.8% share. Renewable energy capacity additions are growing, while thermal generation is gradually declining.

Energy Policy

- The policy is defined by its expanding energy deficit and increased focus on developing alternative sources of energy, particularly nuclear, solar and wind. India's overall energy self sufficiency stood at 66% in 2014.
- The primary energy consumption is the 3rd largest after China and the U.S. with 5.6% global share in 2017. The total primary energy consumption from crude oil (221.1 Mtoe; 29.34%), natural gas (46.6 Mtoe; 6.18%), coal (424 Mtoe; 56.26%), nuclear (8.7 Mtoe; 1.15%), hydro (30.7 Mtoe; 4.07%) and renewables (21.8 Mtoe; 2.89%) is 753.7 Mtoe excluding biomass use in 2017.
- In 2017, India's net imports were nearly 198.8 Mtoe and its products, 25.7 Mtoe of LNG and 129.8 Mtoe coal totaling to 354.3 Mtoe of primary energy which is equal to 47% of total primary energy consumption. About 75% of India's electricity generation is from fossil fuels. India is surplus in electricity generation and also marginal exporter of electricity in 2017.

https://en.wikipedia.org/wiki/Energy_policy_of_India

Fossil Fuel Import

- India is largely dependent on fossil fuel imports to meet its energy demands. India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption by 2030. In 2009~10, the country imported 159.26 Mtoe and 31% of its total imports are oil imports. By the end of 2015, India has become a power surplus country with huge power generation capacity idling for want of electricity demand. It ranks 2nd after China in renewables production with 208.7 Mtoe in 2016.
- In 2015~16, the per-capita energy consumption was 22.042 GJ (0.527 Mtoe) excluding biomass use and the energy intensity is 0.271 MJ per INR (65 kcal/INR). Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the 2nd largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption.

https://en.wikipedia.org/wiki/Energy_policy_of_India

Changing Energy Scenes

- Given its growing energy demands and limited domestic oil and gas reserves, India has ambitious plans to expand its renewable and most worked out nuclear power program. 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 (3rd highest in the world) and plans to construct 18 additional nuclear reactors (2nd highest in the world) by 2025.
- 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 2016, the levelized tariff in US$ for solar PV electricity has fallen below 2.42¢/kWh.

https://en.wikipedia.org/wiki/Energy_policy_of_India

Oil & Gas

- Also the international tariff of solar thermal storage power plants has fallen to US$6.3 cents/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 based on their ultimate use and advantages.
- India ranks 3rd in oil consumption with 212.7 Mtoe in 2016 after the U.S. and China. In 2015, India imported 195.1 Mtoe crude oil and 23.3 Mtoe refined petroleum products and exported 55 Mtoe 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 1/4 after accounting exports and imports of refined petroleum products.

https://en.wikipedia.org/wiki/Energy_policy_of_India

Oil & Gas

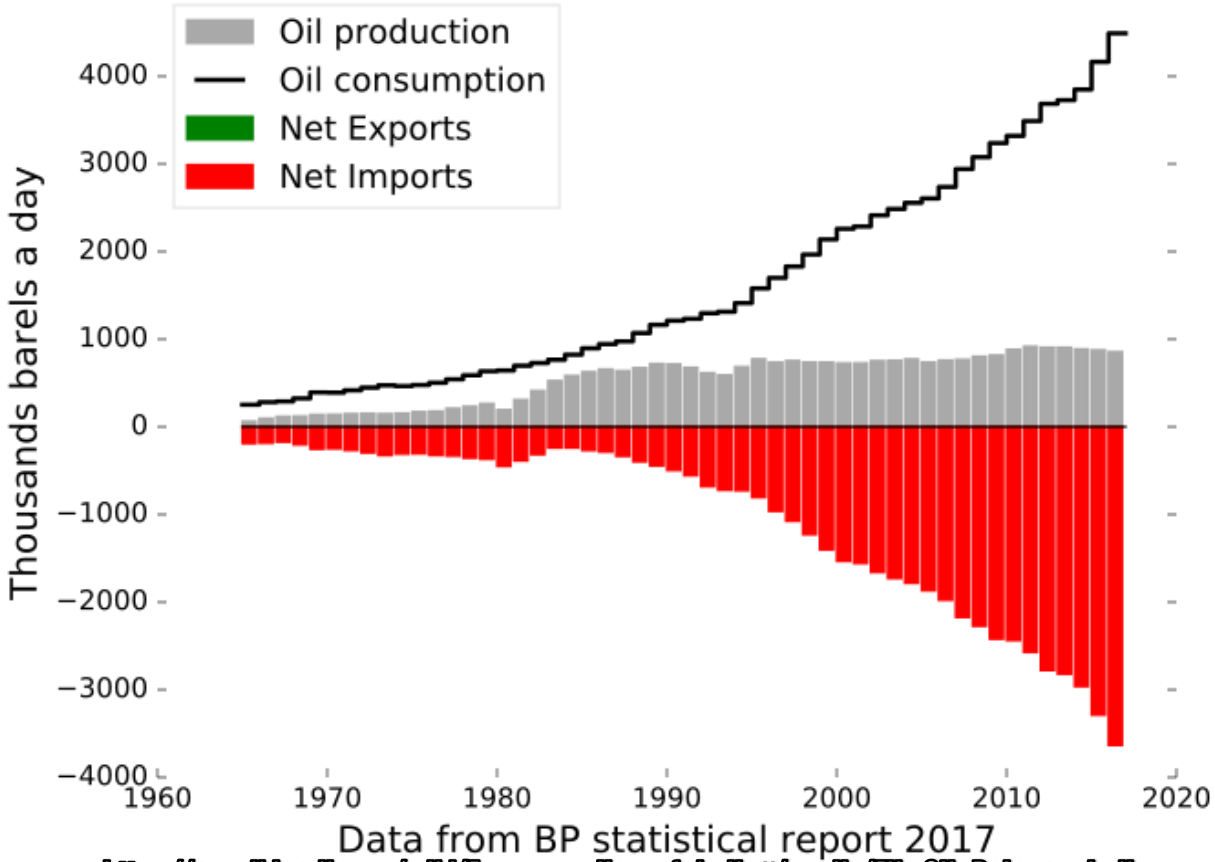
- Natural gas production was 29.2 B m^3 and consumption 50.6 B m^3 in 2015. In 2012~13, the production of crude oil is 37.86 Mtoe and 40,679 Mtoe standard m^3 (nearly 26.85 Mtoe) natural gas. The net import of crude oil & petroleum products is 146.70 Mtoe worth of Rs 5611.40 B. This includes 9.534 Mtoe of LNG imports worth of Rs. 282.15 B. Internationally, LNG price (1 mmBtu of LNG = 0.1724 barrels of crude oil (boe) = 24.36 m^3 of natural gas = 29.2 liters 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.

https://en.wikipedia.org/wiki/Energy_policy_of_India

An ONGC Platform at Bombay High in the Arabian Sea

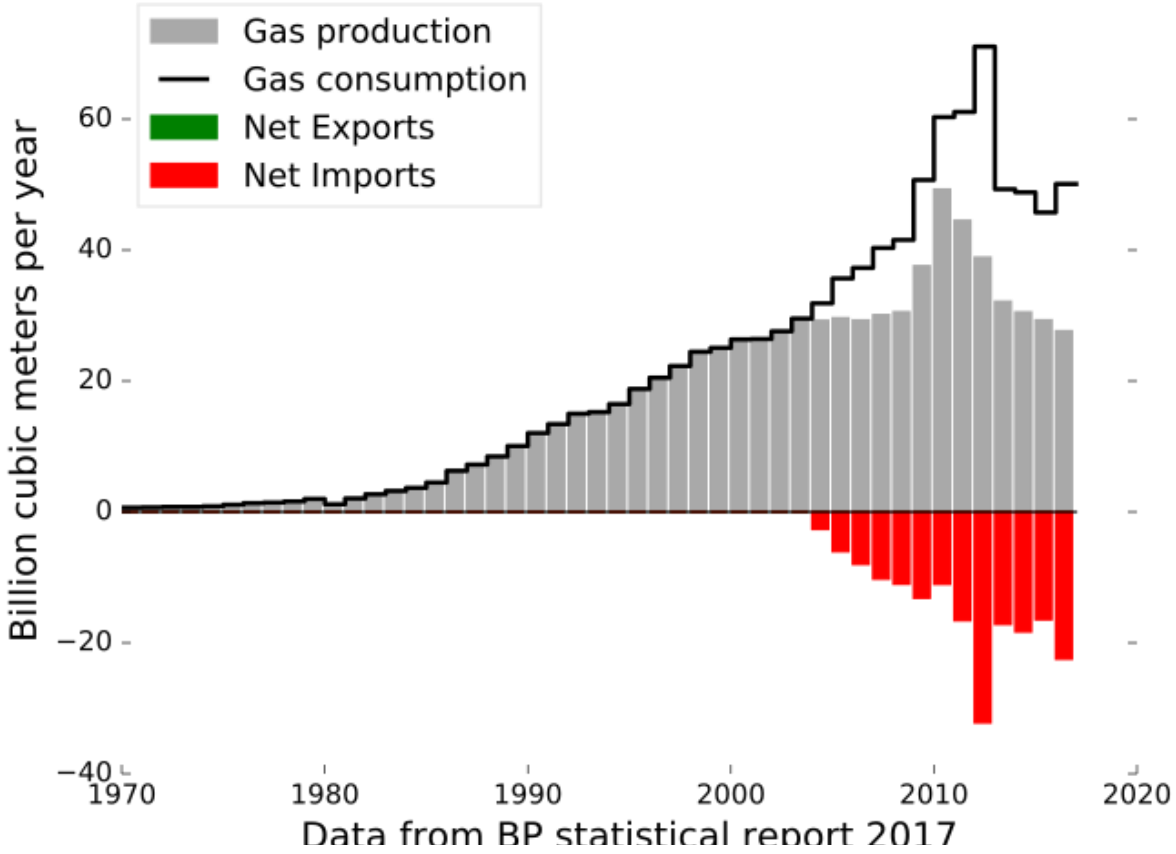
https://en.wikipedia.org/wiki/Energy_policy_of_India#/media/File:ONGC_Oil_Platform.jpg

India's Oil Deficit



https://en.wikipedia.org/wiki/Energy_policy_of_India#/media/File:Oil_Balance_India.svg

Gas Balance of India



https://en.wikipedia.org/wiki/Energy_policy_of_India#/media/File:Gas_Balance_India.svg

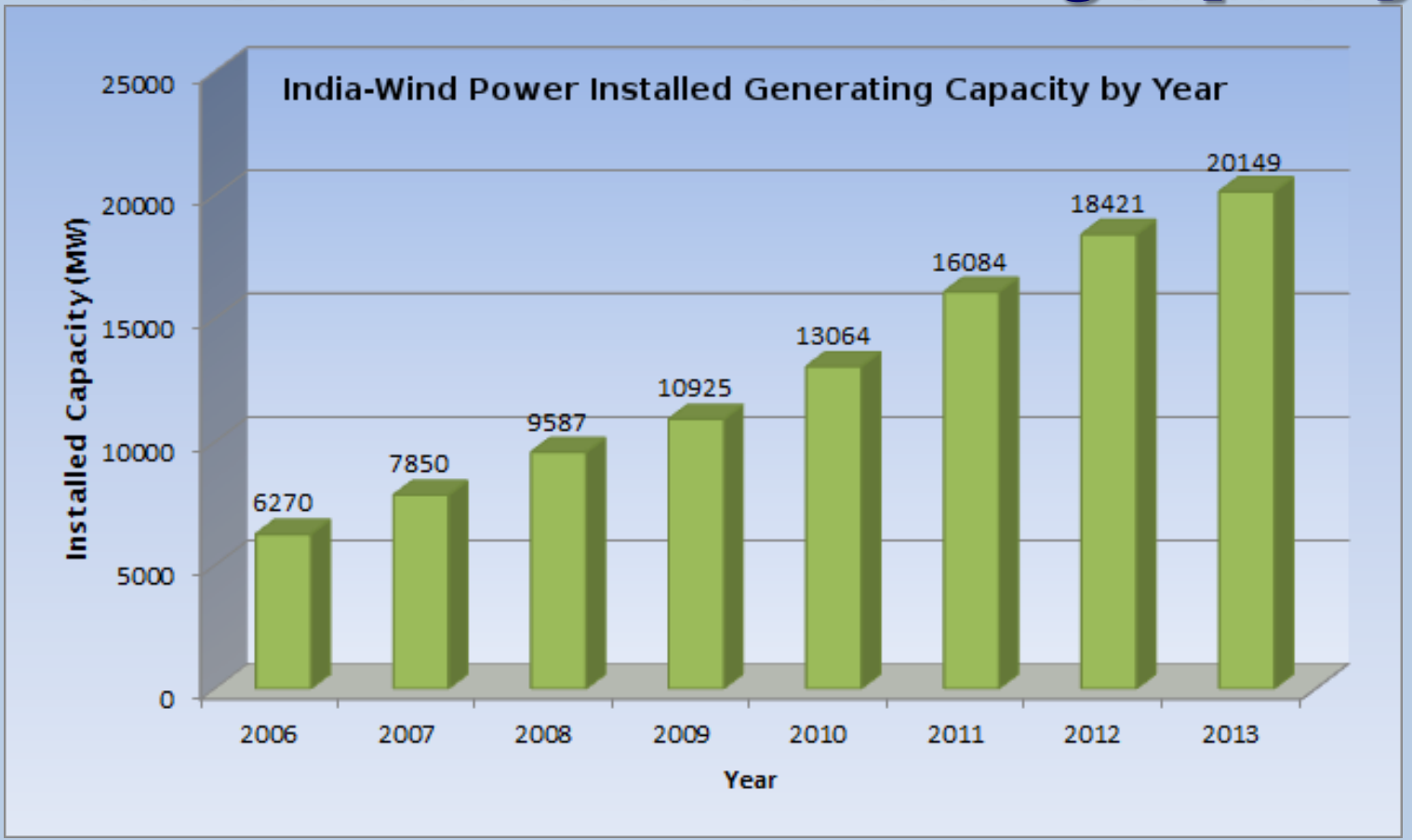
A Coal Mine in Jharkhand State

https://en.wikipedia.org/wiki/Energy_policy_of_India#/media/File:Coal_mine_in_Dhanbad,_India.jpg

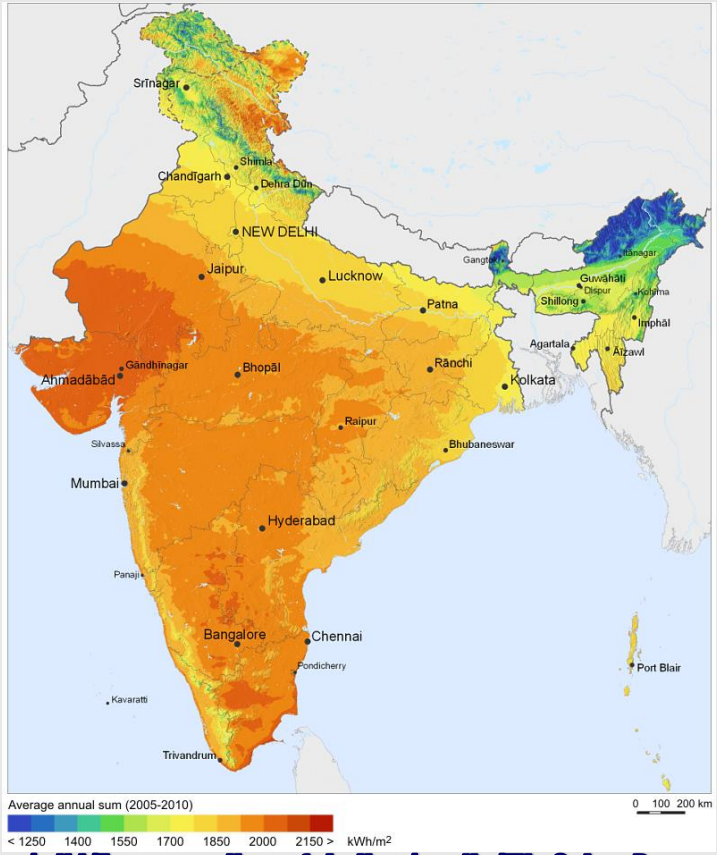
Kudankulam Nuclear Plant (2x1000 MW) in Tamil Nadu

https://en.wikipedia.org/wiki/Energy_policy_of_India#/media/File:Kudankulam_NPP.jpg

Installed Wind Power Generating Capacity



Solar Resource Map



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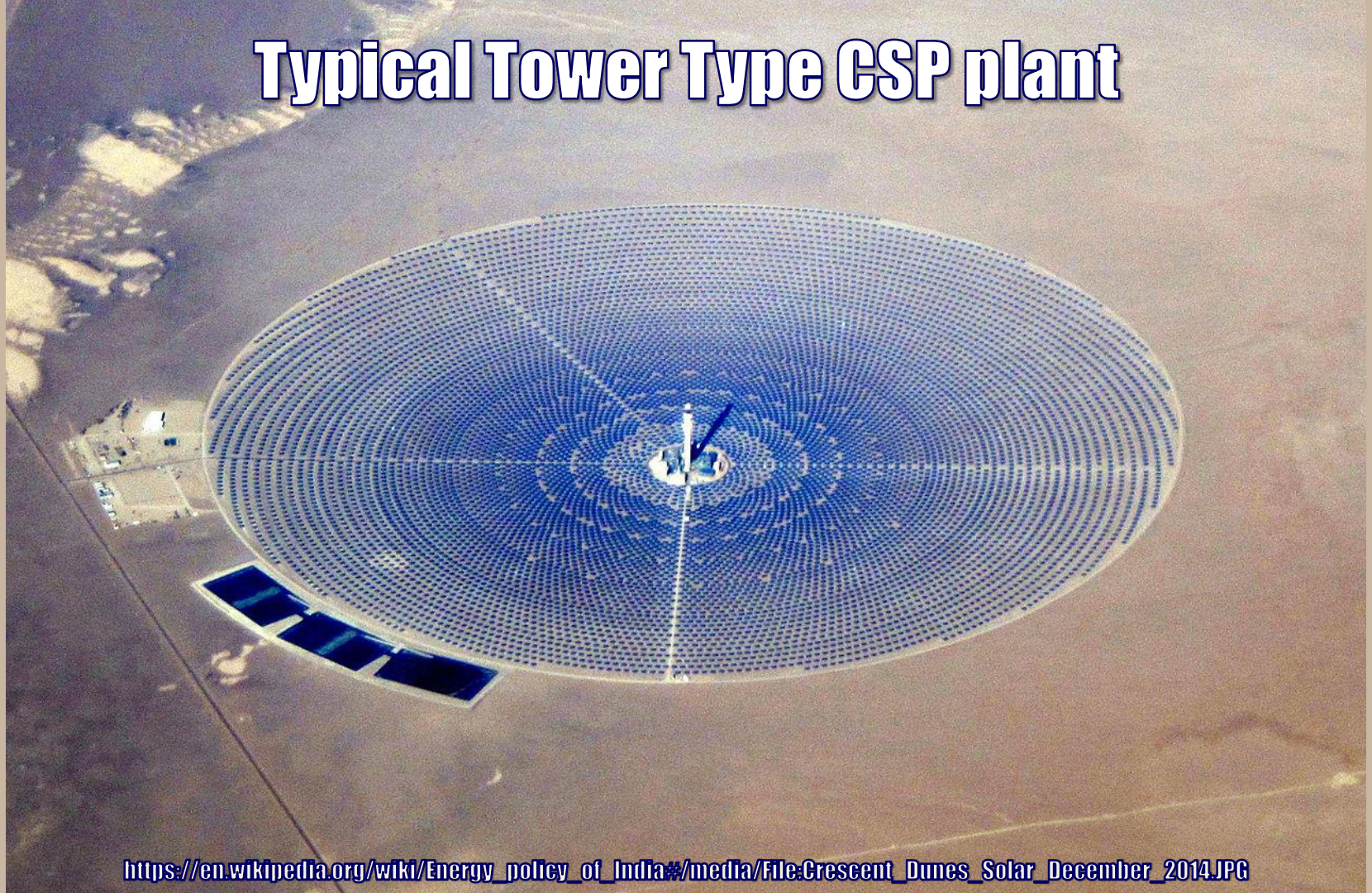
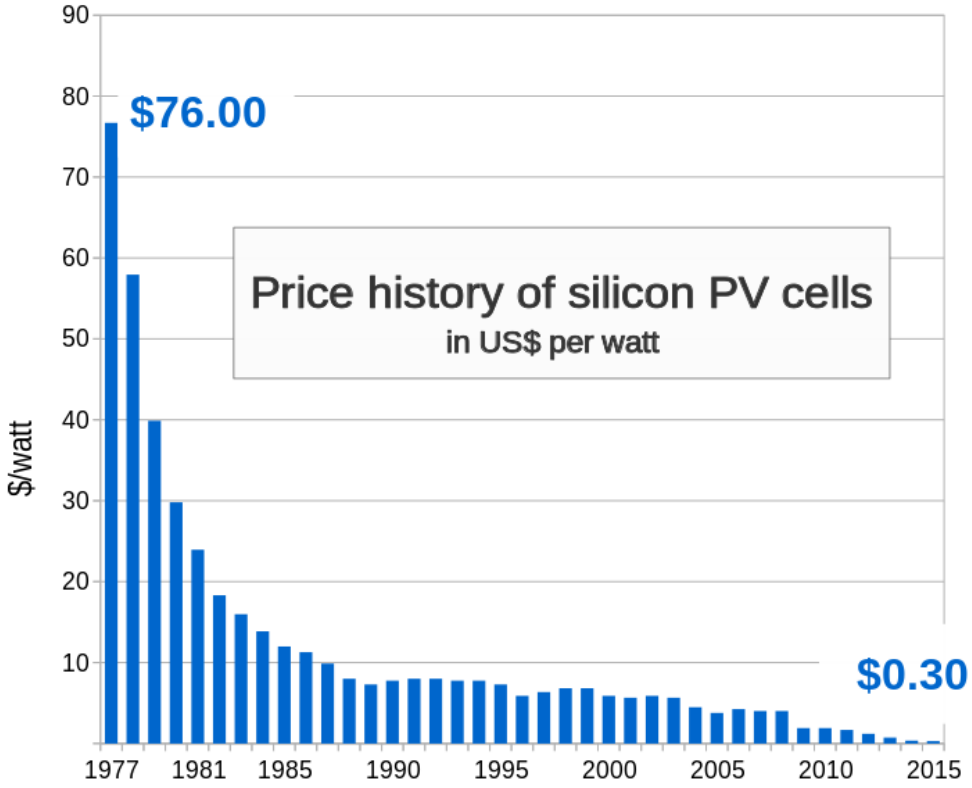
Typical Tower Type CSP plant



https://en.wikipedia.org/wiki/Energy_policy_of_India#/media/File:Crescent_Dunes_Solar_December_2014.JPG

Pay for PV Cells



Source: Bloomberg New Energy Finance & pv.energytrend.com

https://en.wikipedia.org/wiki/Energy_policy_of_India#/media/File:Price_history_of_silicon_PV_cells_since_1977.svg

Rural Areas in India

https://en.wikipedia.org/wiki/Energy_policy_of_India#/media/File:Indian_girls_making_tea_over_open_fire.jpg/

Ramagundam Thermal Power Station (2600 MW)

https://en.wikipedia.org/wiki/Energy_policy_of_India#/media/File:Rstps4.jpg

Energy in India

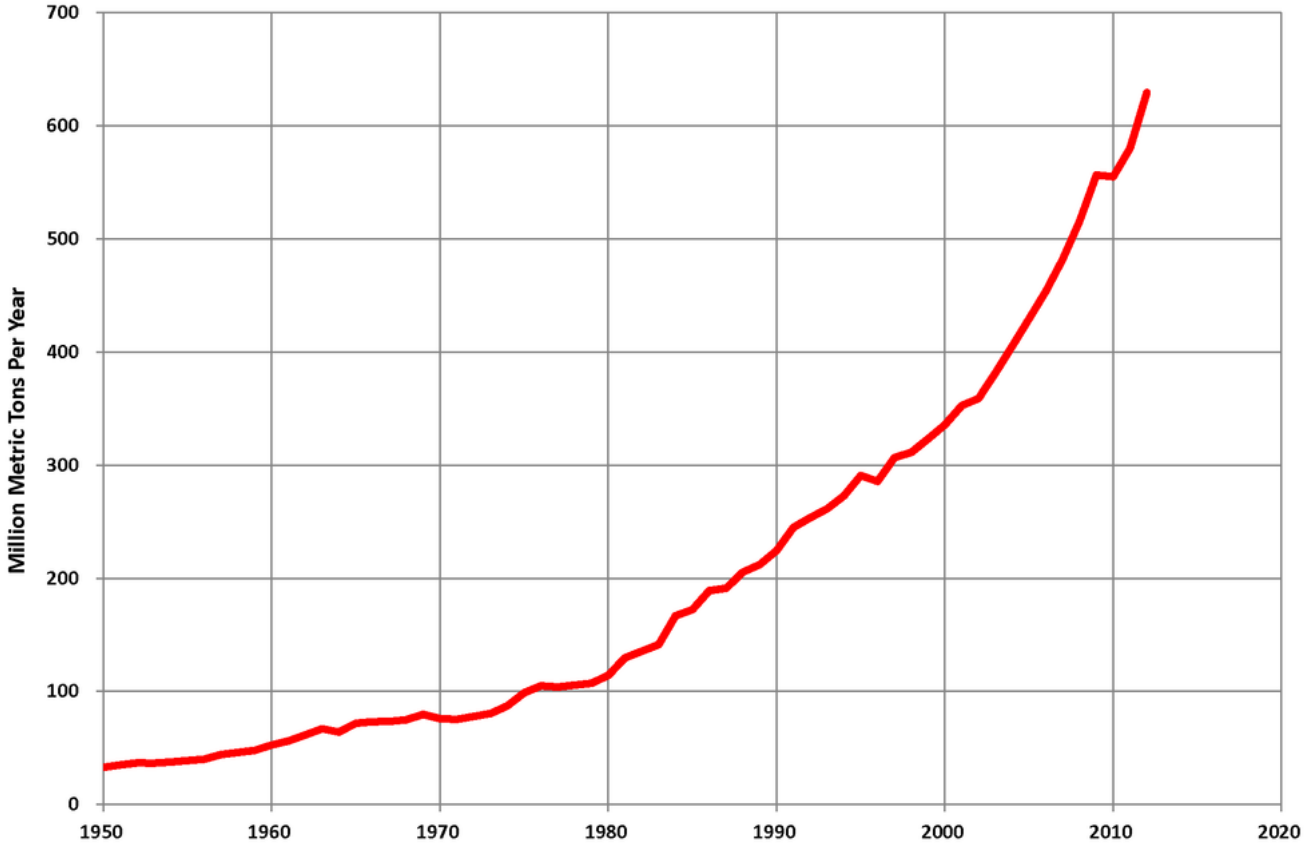
https://en.wikipedia.org/wiki/Energy_in_India

Population million	Prim. energy TWh	Production TWh	Import TWh	Electricity TWh	CO_2-emission Mt	
2004	1,080	6,662	5,430	1,230	494	1,103
2007	1,123	6,919	5,244	1,745	610	1,324
2008	1,140	7, 222	5,446	1,836	645	1,428
2009	1,155	7,860	5,844	2,116	690	1,586
2010	1,171	8,056	6,032	2,110	755	1,626
2012	1,241	8,716	6,291	2,483	835	1,745
2012R	1,237	9,166	6,333	2,829	940	1,954
2013	1,250	9,018	6,086	2,962	979	1,869
Change 2004–10	8.4%	20.9%	11.1%	72%	53%	47%
Mtoe = 11.63 TWh, Prim. energy includes energy losses that are 2/3 for nuclear power[6]2012R = CO2 calculation criteria changed, numbers updated						

Coal Mining

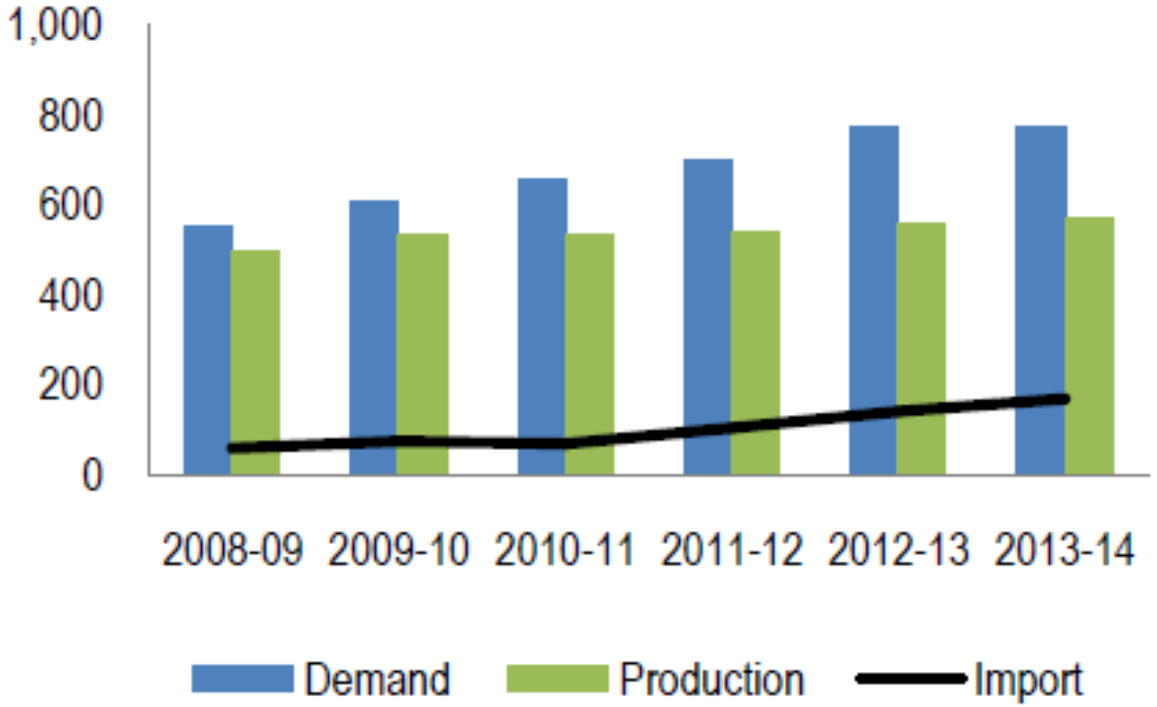
- Coal mining in India began in 1774 when John Sumner and Suetonius Grant Heatly of the East India Company commenced commercial exploitation in the Raniganj Coalfield along the Western bank of Damodar river. Growth remained slow for nearly a century due to low demand. The introduction of steam locomotives in 1853 boosted demand, and coal production rose to an annual average of 1 million metric tons (1.1 million short tons).
- India produced 6.12 million metric tons (6.75 million short tons) of coal per year by 1900 and 18 million metric tons (20 million short tons) per year by 1920. Coal production rose steadily over the next few decades, and was boosted by demand caused by World War I. Production slumped in the interwar period, but rose to 30 million metric tons (33 million short tons) by 1946 largely as a result of World War II. In the regions of British India, the Indians pioneered Indian involvement in coal mining from 1894.

Coal Production, 1950~2012



https://www.renewableenergyindiaexpo.com/

Demand, Production & Import of Coal (Mtoe)



https://en.wikipedia.org/wiki/Coal_mining_in_India#/media/File:Demand,_production_and_import_of_coal_(in_million_tonnes).png

Coal Reserves

- India has the 5th largest coal reserves in the world, and is the 4th largest producer of coal in the world, producing 662.79 million metric tons (730.60 million short tons) in 2016~17. As on 31 March 2017, India had 315.14 billion metric tons (347.38 billion short tons) of the resource. The estimated total reserves of lignite coal as on 31 March 2017 was 44.70 billion metric tons (49.27 billion short tons).
- India is forced to import high quality coal to meet the requirements of steel plants. Its coal imports have risen from 49.79 million metric tons (0.05488 billion short tons) in 2007~08 to 190.95 million metric tons (0.21049 billion short tons) in 2016~17. Its coal exports rose from 1.63 million metric tons (1.80 million short tons) in 2007~08 to 2.44 million metric tons (2.69 million short tons) in 2012~13, but subsequently declined to 1.77 million metric tons (1.95 million short tons) in 2016~17.

https://en.wikipedia.org/wiki/Coal_mining_in_India

Gondwana Coal

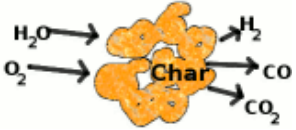
- As on 31 October, the installed capacity of coal power in India was 186,492.88 MW, accounting for 60.7% of the total installed capacity. Its electricity sector consumed 72% of the coal produced in 2013.
- A large part of Indian coal reserve is similar to Gondwana coal. It is of low calorific value and high ash content. The carbon content is low in India's coal, and toxic trace element concentrations are negligible. The natural fuel value of Indian coal is poor. On average, the Indian power plants using India's coal supply consume about 0.7 kg of coal to generate a kWh, whereas United States thermal power plants consume about 0.45 kg of coal per kWh. This is because of the difference in the quality of the coal, as measured by the Gross Calorific Value (GCV). On average, Indian coal has a GCV of about 4500 Kcal/kg, whereas the quality elsewhere in the world is much better.

https://en.wikipedia.org/wiki/Coal_mining_in_India

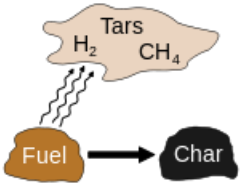
Coal Mafia

- The state-owned coal mines of Jharkhand were among the first areas in India to see the emergence of a sophisticated mafia, beginning with the mining town of Dhanbad. It is alleged that the coal industry's trade union leadership forms the upper echelon of this arrangement and employs caste allegiances to maintain its power. Pilferage and sale of coal on the black market, inflated or fictitious supply expenses, falsified worker contracts and the expropriation and leasing out of government land have allegedly become routine. A parallel economy has developed with a significant fraction of the local population employed by the mafia in manually transporting the stolen coal for long distances over unpaved roads to illegal mafia warehouses and points of sale.
- The coal mafia has had a negative effect on Indian industry, with coal supplies and quality varying erratically.

https://en.wikipedia.org/wiki/Coal_mining_in_India



Bio Fuels



- Gasification of bio mass yields wood gas or syngas which canbe converted into substitute natural gas by Methanation. Nearly 750 million tons of non edible (by cattle) biomass is available annually which can be put to higher value addition use and substitute imported crude oil, coal, LNG, urea fertilizer, nuclear fuels, etc. Renewable and carbon neutral biomass resources are estimated to replace present consumption of all fossil fuels.
- Huge quantity of imported coal is being used in pulverized coal fired power stations. Raw biomass cannot be used in the pulverized coal mills as they are difficult to grind into fine powder due to caking property. However biomass can be used after Torrefaction in the pulverized 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.

https://en.wikipedia.org/wiki/Energy_policy_of_India

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 program, 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 program has been domestically developed much like its nuclear weapons program. The U.S.-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 safeguards, but it has developed various aspects of the nuclear fuel cycle to support its reactors.

https://en.wikipedia.org/wiki/Nuclear_power_in_India

Three-Stage Nuclear Power Program

- It was formulated by Homi Bhabha in the 1950s to secure the country's long term energy independence, through the use of uranium and thorium reserves found in the monazite sands of coastal regions of South India. The ultimate focus of the program is on enabling the thorium reserves to be utilized in meeting its energy requirements. Thorium is particularly attractive for India, as it has only around 1~2% of the global uranium reserves, but one of the largest shares of global thorium reserves at 25% of the world's known thorium reserves. However, thorium is more difficult to use than uranium as a fuel because it requires breeding, and global uranium prices remain low enough that renders breeding unnecessary.
- As of August 2014, India's first Prototype Fast Breeder Reactor had been delayed, and India continued to import thousands of tons of uranium from Russia, Kazakhstan, France, and Uzbekistan.

https://en.wikipedia.org/wiki/India%27s_three-stage_nuclear_power_programme

Hydro Power

- India is endowed with economically exploitable and viable hydro potential assessed to be about 125,570 MW at 60% capacity factor. India ranked 4th 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 with an aggregate installed capacity of 94,000 MW have been identified for catering to peak electricity demand & 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 hydroelectric 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.

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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 ~10% of India's total installed power generation capacity and generated 52.666 B kWh in the fiscal year 2017~18 which is ~3% of total electricity generation. The capacity utilization factor is ~16% in the fiscal year 2017~18.
- The Ministry of New and Renewable Energy 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.

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Solar Energy

- India's solar energy insolation is ~5,000 T kWh per year (~ 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. With a major section of its citizens still surviving off-grid, India's grid system is considerably underdeveloped.
- Availability of cheap solar can bring electricity to people, and bypass the need of installation of expensive grid lines. 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, whenever the required technology becomes competitively cheaper.

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Solar Thermal Power

- 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 Rajasthan. Solar thermal plants are emerging as cheaper (US 6.1 ¢/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.
- The major disadvantage of solar power (PV type only) is that it cannot 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

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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 without appreciable environmental effects. During 2013, many IPPs offered to sell solar power below 6.50 Rs/kWh to feed into the low voltage (< 33 kV) grid. This price is below the affordable electricity retail tariff for the solar 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 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.

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Hydrogen Energy

- India joined the International Partnership for Hydrogen Economy in 2003. There are 19 other countries including Australia, the U.S., U.K. & Japan. This global partnership helps to set up commercial use of hydrogen gas. Ministry of New and Renewable Energy 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 are nearly twice more efficient than diesel/petrol fueled engines. A luxury hydrogen fuel cell car generates 1 liter of bottled quality drinking water for every 10 km ride.

https://en.wikipedia.org/wiki/Energy_policy_of_India

Total installed Power Generation Capacity, 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**	10

https://en.wikipedia.org/wiki/Energy_policy_of_India

Total Installed Utility Power Generation Capacity

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

https://en.wikipedia.org/wiki/Energy_policy_of_India

Gross Electricity Generation – Mode Wise (GWh)

https://en.wikipedia.org/wiki/Energy_policy_of_India

Year	Fossil Fuel			Nuclear	Hydro	Sub total	RES						Utility and Captive Power			
	Coal	Oil	Gas				Mini hydro	Solar	Wind	Bio mass	Other	Sub total	Utility	Captive	Misc	Total
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

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, 35.5% of the population still live without access to electricity. 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.

https://en.wikipedia.org/wiki/Energy_policy_of_India

Rural Electrification

- The key development objectives of the power sector is supply of electricity to all areas including rural areas as mandated in section 6 of the Electricity Act. Both the central government and state governments would jointly endeavour to achieve this objective at the earliest. Consumers, particularly those who are ready to pay a tariff which reflects efficient costs have the right to get uninterrupted twenty four hours supply of quality power.
- About 56% of rural households have not yet been electrified even though many of these households are willing to pay for electricity. Determined efforts should be made to ensure that the task of rural electrification for securing electricity access to all households and also ensuring that electricity reaches poor and marginal sections of the society at reasonable rates is completed within the next five years. India is using renewables to electrify villages.

https://en.wikipedia.org/wiki/Energy_policy_of_India

Reliable Rural Electrification System

- Rural Electrification Distribution Backbone with at least one 33/11 kV substation in every block and more if required as per load, networked and connected appropriately to the state transmission system.
- Emanating from REDB would be supply feeders and one distribution transformer at least in every village settlement.
- Household Electrification from distribution transformer to connect every household on demand.
- Wherever above is not feasible (it is neither cost effective nor the optimal solution to provide grid connectivity) decentralized distributed generation facilities together with local distribution network would be provided so that every household gets access to electricity. This would be done either through conventional or non-conventional methods of electricity generation whichever is more suitable and economical.

https://en.wikipedia.org/wiki/Energy_policy_of_India