Worldwide race for renewable energy

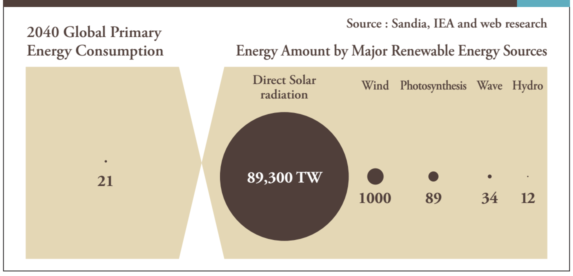
The shift to renewable energy is accelerating in Germany, China and India.
What will be the next generation power supply model?
In renewable era, what should the developed countries aim for?

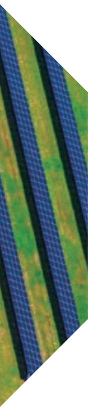
The reasons why renewable energy can cover all, global demand for electricity

Why renewable energy?

In 2016, world primary energy consumption was around 15.5TW (Terawatts). Due to strong demand in developing countries like China, India, South East Asia and Africa, the primary energy consumption will increase to 21TW by 2040. Currently more than 80% of the primary energy demand is satisfied by fossil fuels releasing around 33 billion tons of CO_2. It will be a major environment disaster if the fossil fuels share of primary energy consumption is not decreased. Therefore, to reduce CO_2 emissions, it is necessary to consider alternate sources of energy like renewables.

Renewable energy sources Chart 1
TW(terawatts)





Solar has big potential as next-gen source of energy

Solar rays are a major renewable energy source for earth. All the other renewable energy sources like wind, photosynthesis, wave, hydro etc are a byproduct of solar energy. At any given time, earth gets around 89,300TW of direct radiation which is 5,761 times of current primary energy consumption per year. Converting just 0.024% of the total solar energy into electricity is more than enough to satisfy the 2040 demand single handedly.

Advantages of solar

Solar has following advantages compared to other renewable energy sources;

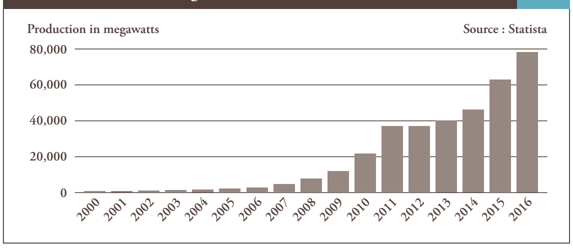
①Abundance: Solar is 89 times more than its nearest major renewable energy source wind energy.

②Predictability: Solar is easier to predict the productivity than wind energy.

③Accessibility: Wind blows well over oceans, remote deserts and inaccessible mountains compared to other places. Harvesting huge energy from such places will be complex and costly. Whereas solar energy can be generated quite near to consumption like rooftops

④Falling panel costs: Due to steeper experience curve of solar panels, the cost of solar panels is decreasing at a faster pace than wind turbines.

Annual solar module production globally Chart 2
from 2000 to 2016 (in megawatts)



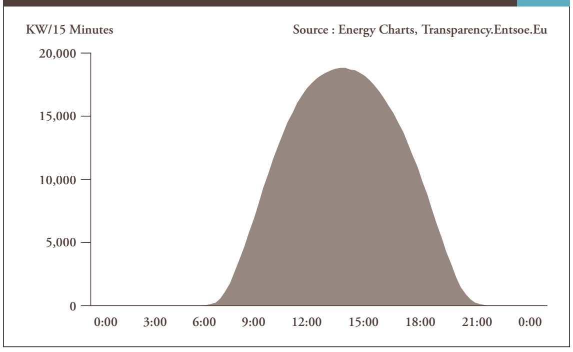
⑤Low maintenance: Due to lack of rotating parts, Solar panels require low maintenance compared to wind turbines. In addition wind turbines cannot be placed nearer to household due to noise.

What are challenges?

The only problem with solar energy is sun doesn't shine always.

Non-availability of solar during night time

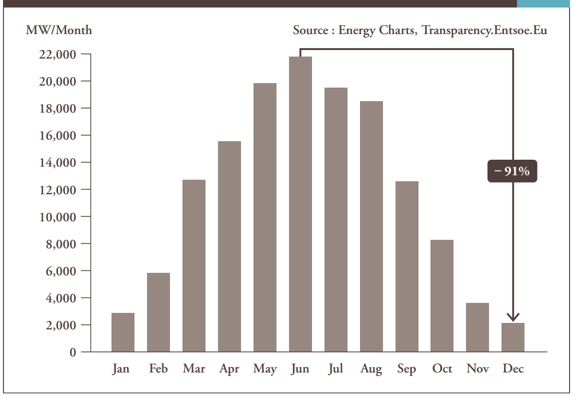
Solar Energy Production in Germany Chart 3
on 21-August-2017



For example, even on a sunny day in Germany, solar is generated only between 6am and 8pm. However, energy is consumed throughout the day. To cover the whole day production by only solar, at least 15 times more solar panels is required. In addition to setting panels the challenge is how to store the surplus solar energy and use it when sun is not shining.

Non-Availability of Solar during Winter Seasons

Annual Solar Energy Production in Germany Chart 4
in 2017



Solar energy production is very low in winter season because sun is not shining most of the days. For countries far from equator the sun is available only for few hours during winter seasons. But at the same period the consumption is very high due to winter heating requirements. It will be challenging to store the solar energy during non-winter seasons and use it during winter seasons. For example, in Germany to cover winter season consumption by only solar energy requires at least few thousand times of current solar panel installations. Setting up so many panels will is quite challenging due to land and investment requirements. Even though drastic reduction in solar panel costs and improvement in conversion efficiency can reduce the costs, but still it is necessary to think of alternate renewable energy sources like wind, biogas etc. as complementary sources.

Wind's potential

Centralized Versus Decentralized

Technology innovations are making many countries to move towards decentralized energy generation, storage and distribution with high involvement of consumers. Drawback of Centralized generation is construction requires huge investment and not efficient due to transmission losses. However decentralized which is installed near the consumption requires less investment and ignorable transmission losses as the generation is done near consumption. Even small players can enter decentralized generation business. For countries like Indonesia with many islands the centralized power generation is costly and complex. It makes sense to setup decentralized power generation stations.

Decentralized Wind Power can be promising area in future. Until now most companies concentrated on making big wind turbines which needs huge investment and cannot be installed in cities due to various reasons like huge space requirement, noise, bird protection, obstruction to view etc. However recently companies like Digisine Energytech, TEX Energy etc are coming up with small and portable wind turbines which can be installed even at homes. Digisine Energytech product Wind Turbine (DB-400) sold at USD399 can generate 400 Watts (wind speed 14m/hour). Height is 1.22 m and 7.6 kg. If there is good wind flow, compact products like this can be installed even at home with minor construction. However decentralized wind power effectiveness is dependent on location. Offshore is better than onshore due to good wind flow. For instance northern European countries with good wind at coastlines and good transmission infrastructure the wind power can be cheaper than other renewable energy sources. However Germany is spending a lot of money to bring the offshore wind power generated in the north to the national grid.

What are the different Storage Options?

Unlike fossil fuels which have both generation and storage functions together, renewable energy has to be captured and stored in some form. Lot of projects are going on worldwide to store renewable energy in some form. Some are in R&D stage and some are commercialized. Table on right page gives the list of some major storage solutions with Pros and Cons.

Currently there are only pumped hydro, SNG, hydrogen and CAES solutions which can support long term energy storage. Due to geography dependence, Pumped hydro and CAES can discharge only for few hours/days. Whereas hydrogen and SNG can be stored using the existing infrastructure. So, the stored hydrogen can be used to generate electricity or as it is. However, hydrogen and SNG are not yet economical due to various reasons like machinery, infrastructure costs, renewable energy costs etc. We will discuss further on this in later sections.

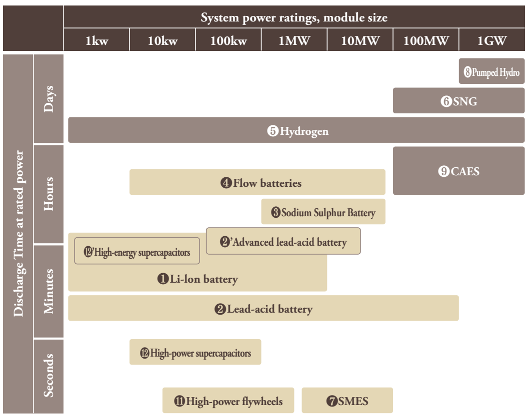
Energy storage options

Chart 5

		Electricity storage systems	Pros	Cons
Electro chemical	❶Li	Electricity is stored in the form of lithium ions	✓Fast discharge rate	×Not economical but will be in future due to experience curve
	❷Lead Acid	Electricity is stored in combination of lead, oxide and sulfur acid solution	✓Cheap	×Low energy density ×Short cycle time ×Heavy ×Slow charge ×Short life
	❸Sodium Sulphur	Energy is stored using molten sulfur and molten sodium	✓Low Cost ✓Round-trip efficiency around 75%	×Operate at high temperatures above 300degrees Celsius
	❹Flow	Energy is stored as electrolyte instead of storing in electrode as in conventional batteries	✓Almost instantly recharged by replacing the electrolyte liquid ✓Economical, low vulnerability means to store electrical energy at grid scale ✓Longer life than li	×Requires more space thank li battery to store same amount of energy ×Low efficiency than li around 75%
Chemical	❺Hydrogen	Electricity is used to generate hydrogen from electrolysis and retrieved from fuel cells	✓Long periods of energy storage	×Low efficiency around 40% ×complex, expensive transportation ×safety concerns
	❻Synthetic Natural gas (SNG)	Also called power to gas in which the excess electricity is converted into hydrogen and combined with the greenhouse gas CO2 to produce methane	✓Use existing infrastructure to store and transfer	×Low efficiency ×High costs
❼Thermal		Energy from the sun is stored in chemical bonds or by heating/cooling a liquid or solid storage material. Energy recovered in a chemically reverse reaction	✓Thermochemical method has high storage density, low heat losses, long storage, long distance transportation, compact storage	×Thermo chemical storage has high capital costs and technical complexity
Mechanical	❽Pumped hydro	Electricity is used to pump water to high areas like hills and generated by water flow from top to down when required	✓Developed and mature technology ✓Very high ramp up ✓Round-trip efficiency around 76% to 81.5%	×Depends on geography ×High project cost ×Environmental impacts
	❾Compressed air (CAES)	Electricity is used to compress air and stored in underground caverns or above-ground storage vessels (e.g., high-pressure pipes or tanks) and recovered when needed	✓High efficiency	×Above-ground storage is costly ×Dependent on geography for underground storage
	❿Liquid air	Liquid air energy storage (LAES) uses electricity to cool air until it liquefies, stores the liquid air in a tank, brings the liquid air back to a gaseous state (by exposure to ambient air or with waste heat from an industrial process) and uses that gas to turn a turbine and generate electricity	✓Long life	×Low efficiency ×Costly
	⓫Flywheels	Electricity is stored in heavy spinning rotors enclosed in vacuum with low friction	✓Environment friendly ✓Fast discharge ✓Round-trip efficiency around 70% to 80%	×Safety risks ×Not good for mobile applications
Electrical	⓬Super capacitors	A type of capacitor that can store a large amount of energy	✓Deliver high power ✓Fast discharge	×High cost

Energy storage system applications

Chart 6



Source : DOE/EPRI Electricity Storage Handbook

Future Energy Value Chain Options

Next table provides the different possible energy value chain options with implications. Although there may be other options but the below options are more feasible.

Future options of energy value chains

	Storage Options	Pros	Cons	Implications
① Solar + Battery + Distribution with existing infra	During daytime the required amount of solar energy is captured. The captured amount should consider the daily and seasonal demand peaks. Solar energy is transmitted to grid with Surplus energy stored in battery. Battery should be able to store enough energy to cover the demand during night and winter seasons. Existing grid infra is used to transmit electricity to consumers. Consumers have own storage to store electricity during non-peak hours and use it during peak hours when the price is high. In addition, consumers can sell the unused electricity to grid.	✔ Store the surplus solar power when not used	✕ Huge amount of batteries required ✕ Huge amount of Land is required to place the solar panels and batteries ✕ Huge initial investment is required	• Good for few hours of supply. • Cannot supply for long hours due to low energy storage density in battery. **Short-term option**
② Wind + Battery + Distribution with existing infra	Decentralized Wind turbines convert wind energy to electricity. Wind energy is transmitted to grid with surplus stored in battery. Battery should be able to store enough energy to support non windy seasons. The subsequent transmission, distribution and consumption are the same as those in ①.	✔ Cheaper if wind energy is available throughout the year ✔ Higher capacity factor in abundant wind areas ✔ Low storage is required if stable wind energy is available	✕ Difficult to predict output ✕ Costly because good wind flow is available mostly in inaccessible areas like Oceans, Mountains, coastal areas etc. ✕ Cannot be placed near to populated areas due to Noise, obstruction of view etc. ✕ Due to moving parts wind turbines requires more maintenance than Solar Panels	• Unused electricity is sold to grid. • Due to non-predictability of wind energy, continuous supply is not guaranteed. **High dependency on geography**
③ Solar/Wind/Biomass + Battery + Battery Distribution	Solar, wind and biomass energy is converted to electricity in countries with abundance resources. The electricity is stored in Batteries. Charged batteries are exported to energy deficit countries. Charged Battery shipment is unloaded and used to supply electricity to grid. Used batteries are shipped back to origin country. The subsequent transmission, distribution and consumption are the same as those in ① and ②.	✔ Store the surplus solar power when not used ✔ Supply stability due to wind and biomass when sun is not shining	✕ Huge inventory of batteries required ✕ Large investment is required ✕ Not feasible in decentralized energy generation ✕ Due to low battery efficiency transportation costs are very high	• With current battery technologies it is not possible to store and ship energy via batteries due to huge volumes and weight. **Far future option**
④ Solar/Wind/Biomass to Gas/Liquid	Required amount of Solar(daytime) and biomass energy is captured. The captured amount should consider the daily and seasonal peak. In parallel wind energy is also captured as and when available. Electricity is transmitted to the grid with surplus electricity converted to gas/ liquid using CO2 and water. The generated gas is stored using existing gas infra. During night time & winter seasons gas is used to generate electricity. Electricity and gas are distributed using existing infra. Consumers have own storage to store electricity during non-peak hours and use it during peak hours when the price is high. The subsequent consumption processes are the same as those in ①, ② and ③.	✔ Long term energy storage with high density ✔ Wind/Biomass can be used as complimentary when Sun is not shining ✔ Use the existing infrastructure to transport the gas	✕ Co2 extraction is costly	• Good for long term energy storage • Can compete with fossil fuels but only if the CO2 capture costs becomes cheaper and carbon tax is implemented **Mid-/long-term option**

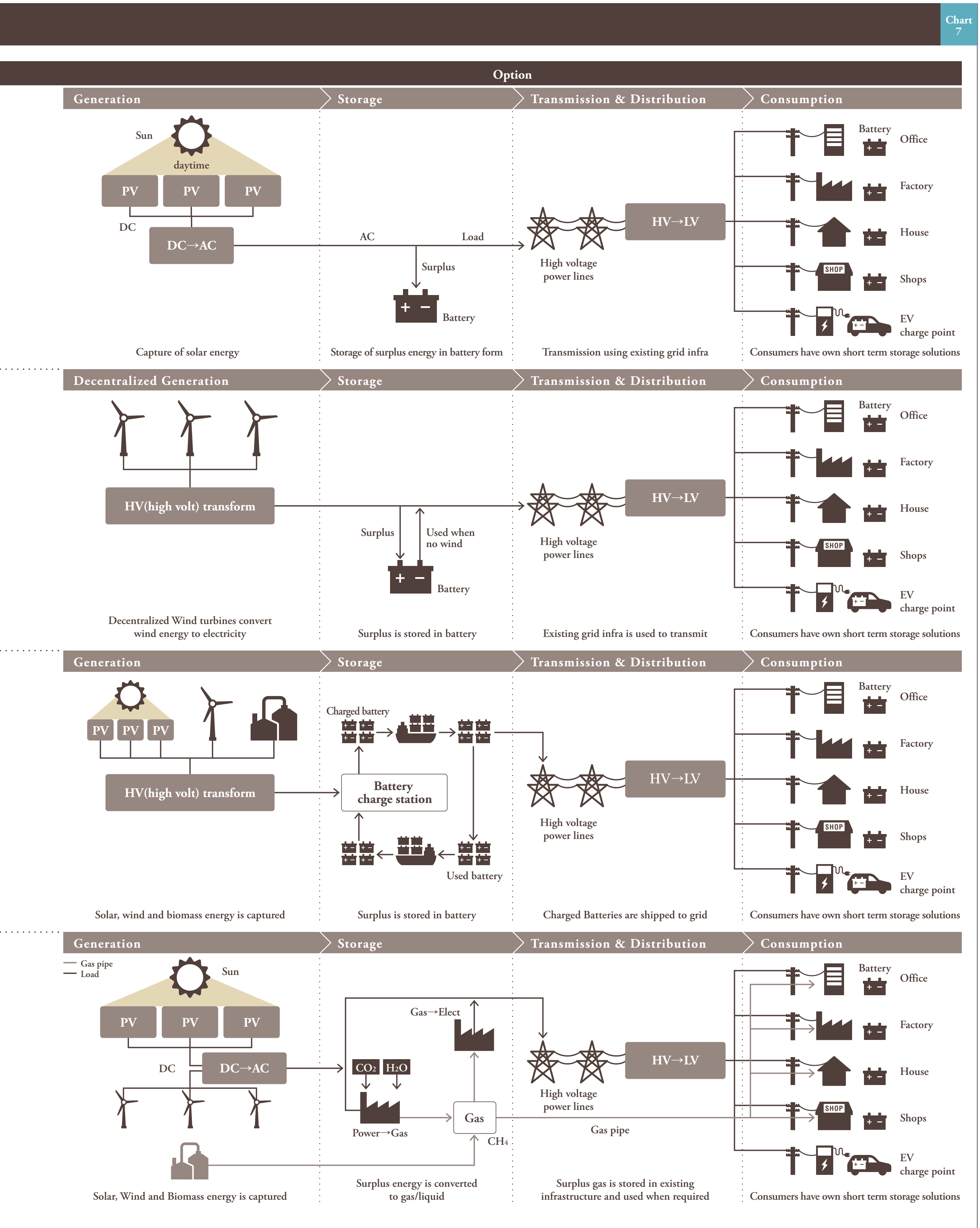


Chart 7
Option
Generation
Storage
Transmission & Distribution
Consumption
Sun
daytime
PV
PV
PV
DC
DC→AC
AC
Load
Surplus
Battery
High voltage power lines
HV→LV
Battery
Office
Factory
House
SHOP
Shops
EV charge point
Capture of solar energy
Storage of surplus energy in battery form
Transmission using existing grid infra
Consumers have own short term storage solutions
Decentralized Generation
Storage
Transmission & Distribution
Consumption
HV(high volt) transform
Surplus
Used when no wind
Battery
High voltage power lines
HV→LV
Battery
Office
Factory
House
SHOP
Shops
EV charge point
Decentralized Wind turbines convert wind energy to electricity
Surplus is stored in battery
Existing grid infra is used to transmit
Consumers have own short term storage solutions
Generation
Storage
Transmission & Distribution
Consumption
PV
PV
PV
HV(high volt) transform
Charged battery
Battery charge station
Used battery
High voltage power lines
HV→LV
Battery
Office
Factory
House
SHOP
Shops
EV charge point
Solar, wind and biomass energy is captured
Surplus is stored in battery
Charged Batteries are shipped to grid
Consumers have own short term storage solutions
Generation
Storage
Transmission & Distribution
Consumption
Gas pipe
Load
Sun
PV
PV
PV
DC
DC→AC
Gas→Elect
CO_2
H_2O
Power→Gas
Gas
CH_4
High voltage power lines
HV→LV
Gas pipe
Battery
Office
Factory
House
SHOP
Shops
EV charge point
Solar, Wind and Biomass energy is captured
Surplus energy is converted to gas/liquid
Surplus gas is stored in existing infrastructure and used when required
Consumers have own short term storage solutions

Who is doing what?

Germany

As per experts, to support night time and seasonal storage Germany is actively engaged in 5 major solutions;

1. Pumped Hydro for long term: Germany is exporting the abundant renewable energy available during non-winter seasons to countries like Norway and Sweden where there are lot of mountainous areas where water can be stored. Using the abundant renewable energy exported from Germany, the water from low lying areas is pumped to high areas. During winter season the water at high lying areas in those countries is used to generate hydel power and send the electricity back to Germany. As per experts this is commercially viable due to the usage of existing infrastructure.
2. PV with battery storage for short term: Germany is actively promoting setting up of battery storage systems with PV. However, this solution cannot provide huge energy for long hours.
3. Thermal: Solar power is used to heat water in boilers and store the hot water for many months. This can be achieved using innovations in insulation technology. By doing so households in Germany are achieving 70% thermal autonomy.
4. Hydrogen and Synthetic natural gas: Many Hydrogen and power-to-gas plants are being setup across Germany. However there are challenges like costs, safety especially for hydrogen gas storage due to corrosion effect on the existing pipelines etc.
5. Old EV batteries: Use of the old EV batteries to store energy and supply to the grid. However, the number of EV cars in Germany is small - one-twelfth that of China, half that of Japan.

Germany is working proactively on various research and development of the renewable energy in advanced technology and its application. Germany, which steered from nuclear power generation to renewable energy earlier after Fukushima, is inferior to China and India on the scale, but it can be said that technology is one step ahead in renewable-related technology.

China

Large scale push by China into renewable energy is driving the world renewable energy market. With a target to achieve 15% of its energy from renewables by 2020, China has spent around USD127 billion in 2017 on renewable energy projects which is 45% of the global total. The spending by other developing countries like India and Brazil is picking up but not even near to china. China is rolling out more renewable energy than any other country. China has installed 618GW (Gigawatts) in 2017, whereas its nearest competitor USA has installed only 225GW.

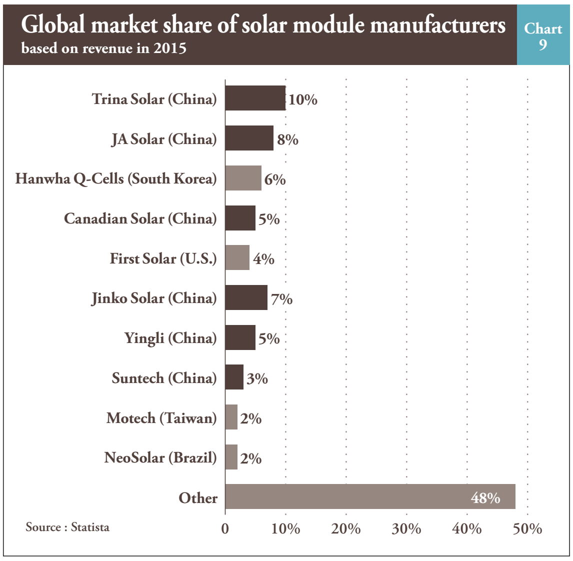
Renewable Energy Investment
In China, India And Brazil By Sector, 2016,
Chart 8

	China	India	Brazil
Solar	86.5	6.7	2.1
Wind	36.1	4.0	3.6
Biofuesis	0.1	0.0	0.2
Geoyhermal	0.0		
Biomass & w.t.e	1.5	0.1	0.0
Small hydro	2.4	0.1	0.1
Marine			
Total	126.6	10.9	6.0

Source : UN Environment , Bloomberg New Energy Finance

The major reasons for such a fast growth are government subsidies and cheaper capital. Due to rising pollution, the Chinese government is replacing coal powered plants by renewable energy farms.

Chinese companies control almost 38% of the worldwide solar module market. Due to their huge volumes it has been possible to bring the PV costs further down. Experts say the costs will further go down. In terms of R&D spending, Europe and USA have spent USD2.7 billion and USD2.1 billion compared to china's USD2 billion. One of the reason maybe the cost of research is china is cheaper than Europe and USA.



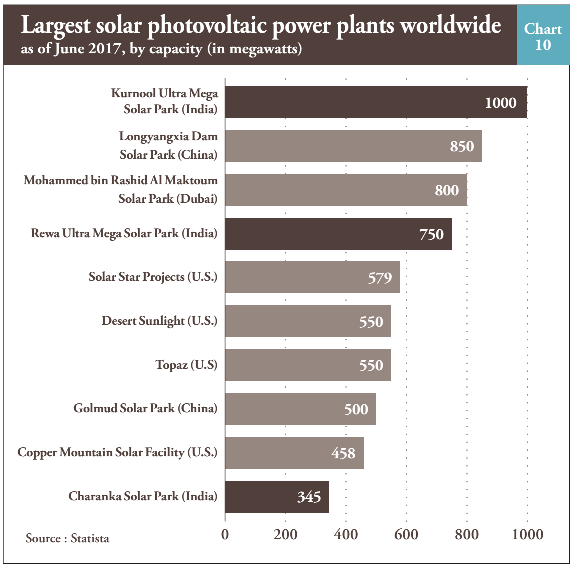
There are not many people who have an image of China as an environmentally friendly country. However, due to that belief, such people will lose a huge market opportunity by misjudging China's strategy. The statistical data will tell us that China is definitely building its advantage in economies of scale.

India

India is a late comer in renewable energy. India has vast potential in Solar due to good availability of sunshine throughout the year; In addition to sunlight India has lot of land to setup solar PV systems. The government of India has set an ambitious target of setting up 175GW of renewable power capacity by end 2022. This includes 100GW from solar, 60GW from wind, 10GW from biomass and 5GW from small hydro. The government of India is committed to increased use of clean energy sources and is already undertaking various large-scale sustainable power projects and promoting green energy heavily. In addition, renewable energy has the potential to create many employment opportunities at all levels, especially in rural areas. India will need investments of around USD125 billion to reach this target. It is expected that by the year 2040, around 49% of the total electricity will be generated by the renewable energy, as more efficient batteries will be used to store electricity which will further cut the solar energy cost by 66% as compared to the current cost. As per the government, use of renewables in place of coal will save India Rs 54,000 crore (USD8.43 billion) annually. As per United National development program expert, Commercial solar power generation has picked up very well due to;

1. On time payment by power off takers.
2. RPO (Renewable purchase obligation) on distribution companies.
3. Payment security to investor/developer by central/state government.
4. Drastic improvement in power infrastructure... such as high voltage transmission lines.
5. Improvement in statutory approvals process. This has reduced the project commissioning period substantially which leads to reduction in cost overrun and reduction in working capital requirement.
6. Transparency and clarity in regulatory and policy framework.

India has world biggest solar farm with a 1000MW capacity. In addition to commercial generation, residential solar power generation is picking up slowly which has to be fastened to achieve the 2022 target.



India is a country with a lot of blackouts due to the fact that the vastness of the country was a barrier to social infrastructure. However, in the era of solar energy, India can be said to be one of the most loved by the sun. In other words, India will have a very competitive advantage as a power generation station.

Future scenarios

In next 50 years we can expect lot of changes in energy industry. Although SNG using solar is not economical currently but invention of new cheaper technologies to extract CO2 from atmosphere can make it economical. Some companies like Electochaea, Carbon Engineering etc. are doing research in these areas. Carbon engineering has recently been successful in capturing CO2 for under USD100 a ton. It is converting the CO2 to zero emissions methane fuel by combining with hydrogen extracted from water using the surplus renewable energy. By increasing the volumes it is trying to decrease the costs further. Once the carbon taxes charged for green house emission become costlier, companies will be forced to collect the CO2 instead of emissions. In such a case there will be demand for companies like carbon engineering. CEO of Carbon Engineering Mr. Steve Oldham says "Initially our costs will be about 20% higher than wholesale fuel. However, our fuel is carbon neutral so in jurisdictions that have a carbon pricing policy, carbon credits / taxes more than offset that 20%. Over time, we expect to reduce our costs as the technology becomes mature and is fielded widely. Also - our technology just uses water, air and electricity to produce diesel, gasoline and jet fuel. That allows liquid energy independence for nations without oil".

Domestic demand → International demand

Once the cost CO2 extraction becomes cheaper, countries with abundant solar energy will start generating the SNG at huge amounts and export to energy hungry countries at a competitive price compared to fossil fuels. Although it is difficult to achieve at this point but in near future it is possible. Drastic reduction in renewable energy and storage prices may make countries far from equator to rethink before buying non-renewable energy. Time may come when current OPEC countries will stop exporting fossil fuels and import or generate cheaper renewable energy.

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