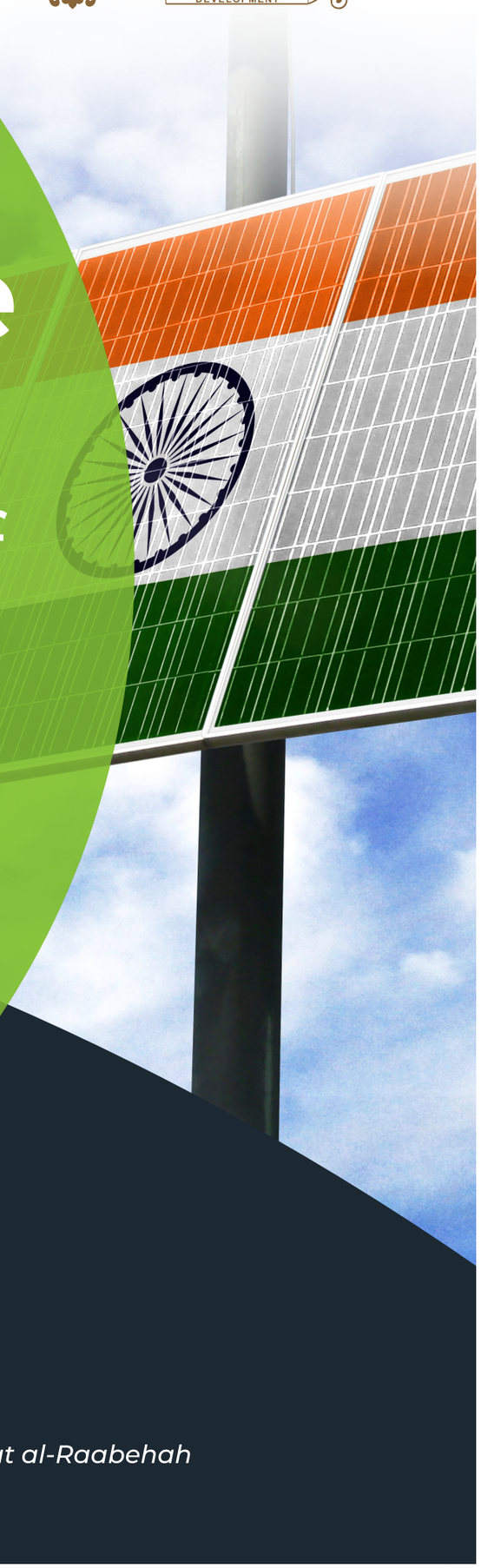

Renewable Energy

Dynamics of Demand in the Indian Market

The Power to Succeed...

Zilqadal Haram 1444
May 2023

Objective of the Research

The aim of this presentation is to understand the size of the opportunity in the renewable energy sector in India and reveal the drivers, restraints and unique trends in the market. This report is intended to form a base on which each of the individual business opportunities could be explored, in detail, later.

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Glossary of Terms

Abbreviation	Definition
AC	Alternating Current
ACS	Average Cost of Supply
ADIA	Abu Dhabi Investment Authority
ARR	Average Revenue Realized
AS	Additional Surcharge
AT&C	Aggregate Technical & commercial (AT&C) losses
Avg	Average
BESS	Battery Energy Storage Systems
BJP	Bharatiya Janata Party
C&I	Commercial & Industrial
CAD	Current Account Deficit
CAGR	Compound Annual Growth Rate
CAPEX	capital expenditure
ckm	Circuit Kilometers
CSS	Cross Subsidy Surcharge
CUF	Capacity Utilisation factor
DC	Direct Current
DISCOM	Distribution Companies
EAC-PM	Economic Advisory Council to the Prime Minister
EVA	ethylene vinyl acetate
FY	Financial Year
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GoI	Government of India
GoTN	Government of Tamil Nadu
GW	GigaWatt
HJT	Heterojunction Technology
ICE	Internal Combustion Engine
INR	Indian Rupee
Insts	Intra State Transmission System
kWh	Kilowatt Hour
LCOE	Levelised Cost of Energy

Abbreviation	Definition
MG Silicon	Metallurgical Grade Silicon
MNRE	Ministry of New and Renewable Energy
MVA	Mega Volt Ampere
MW	MegaWatt = 1000 kW
NDMC	New Delhi Municipal Council
O&M	Operation & Maintenance
PFC	Power Finance Corporation
PLI	Production Linked Incentive
PPP	Purchasing Power parity
RBI	Reserve Bank of India
RE	Renewable Energy
RPO	Renewable Purchase Obligations
SLF	System Load Factor
T&D	Transmission & Distribution
TANGEDCO	Tamil Nadu Generation and Distribution Corporation Limited
TOPCon	tunnel oxide passivated contact
UDAY	Ujwal DISCOM Assurance Yojana
UNFCCC	UN Framework Convention on Climate Change
VALCOE	value-adjusted LCOE
TWh	TerraWatt Hour. 1 TWh = 1000 GWh
GWh	GigaWatt Hour. 1 GWh = 1000 MWh
MWh	MegaWatt Hour. 1 MWh = 1000 kWh
kWh	Kilowatt Hour. 1 kWh = 1000 Wh

Executive Summary

The Vision of Aqa Moula (TUS)

The vision of Aqa Moula (TUS) is that mumineen set high ambitions in business and prosper in industry and manufacturing.

The Words of Guidance of Syedna Mohammed Burhanuddin R.A.

Syedna Mohammed Burhanuddin RA exhorted us to strive hard in earning a livelihood. He said ***"Allah, the Almighty, has bestowed great barakat in business; there are no limits to its potential. Ply your trade and business according to the demands of this day and age. Gain excellence in business by acquiring business acumen through education, but more importantly, through the experience and knowledge possessed by your elders. Be energetic and enthusiastic in your business."***

The Purpose of This Research

The renewable energy sector in India offers tremendous opportunities to anyone who intends to dream big, be innovative and bring technologically advanced products or services to the market.

This report aims to inspire mumineen with ideas so that they can explore and exploit the opportunities available in this sector and succeed in setting up market leading companies of the future.

The Structure of The Report

Today we live in an era of globalisation. Therefore, it is imperative that we first examine the global trends impacting this sector. The first part of the report deals with the dynamics of the renewable energy sector at the global scale.

We then move on to part two of the research which captures the size of the opportunity in India and reveals the drivers, restraints and unique market trends observed at a pan-India level.

Together the two parts of the research are intended to form a foundation of knowledge on which detailed exploration of opportunities can be carried out in the future.

Multiple business opportunities can be explored and pursued at several levels: at the individual entrepreneur level, at the level of business houses and at a collective community level as well.

Transitioning to Renewable Energy is Not a Choice; It is a Matter of Survival

While fossil fuels are unlikely to run out as new fossil fuel reserves will probably be found, and new technologies will be developed to exploit reserves that were uneconomical to tap until then, it is important to note that if we are to limit global warming to the 'relatively' safe level of 2C by 2050, 80% of coal, 50% of gas and 30% of oil reserves should not be “burned”. Adoption of renewable energy is therefore, one of the most important transitions that we must make to reach Net-Zero Carbon Emissions by 2050.

However, The Good News Is...

Renewable Energy is Free-For-All, Abundant and Inexhaustible

It is Non-Polluting

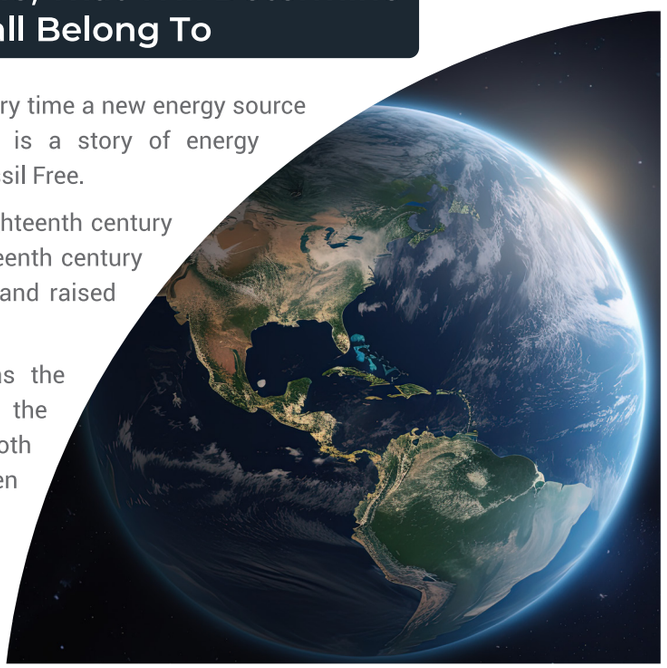
And with technological advances, today renewable power costs less than power generated from fossil fuels.

This Is Leading To A Scramble Among Nations to Transition Quickly Towards Renewable Energy:

To reduce the cost of energy for their business and industries

To reduce dependence on imported energy, the cost of which, is incumbent upon the vagaries of global geopolitical forces

This Is A Historic Moment In Time, That Will Determine To Whom The Next Century Shall Belong To



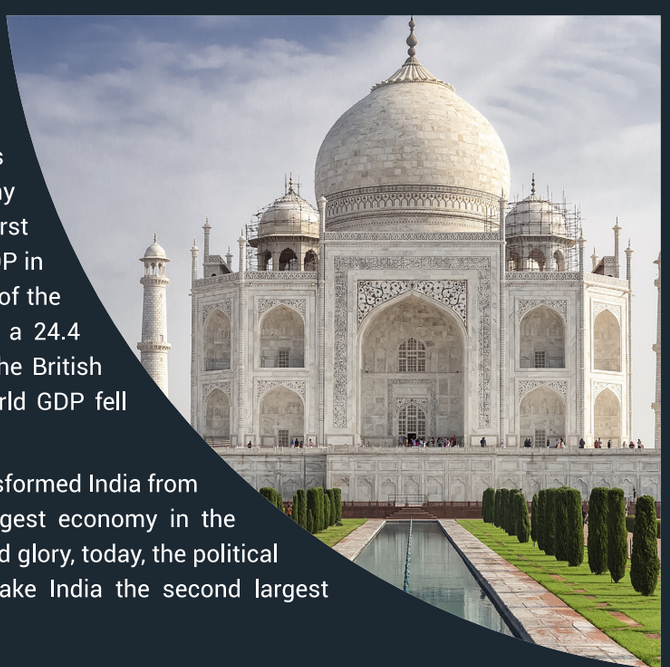
"Society has undergone a profound change every time a new energy source takes CenterStage. Indeed, human progress is a story of energy transitions", says Sumant Sinha in his book Fossil Free.

The rapid adoption of coal by Britain in the eighteenth century and that of petroleum by America in the nineteenth century took these nations to unprecedented heights and raised industrial output at a pace never seen before.

New modes of motorized transport, such as the automobile, the liquid-fuel powered ships, the airplanes and the military tanks, provided both mobility and power that had never been seen before in history.

Energy transitions are the cause of shifts in global political power. Today, we are in the midst of a new Great Energy Transition, which will determine to whom the next century belongs to.

And India is at the Cusp of Glory.



According to economic historian Angus Maddison, India was the world's largest economy with a 32.9 percent share of global GDP in the first century AD and 28.9 percent share of global GDP in the eleventh century. In the 1700s, when most of the country was ruled by the Mughals, India had a 24.4 percent share of world GDP. However, under the British rule, India lost its wealth and its share of world GDP fell below four percent by 1952.

The economic reforms that began in 1991, transformed India from a poor, slow-growing nation into the third-largest economy in the world. Having set foot on the path of growth and glory, today, the political leadership of the country has a vision to make India the second largest economy of the world, displacing the US.

Renewable Energy Will Play A Key Role In India's Vision For The Future

Access to low-cost energy resources will be critical in achieving this transition. India is poor in energy resources such as crude oil and natural gas and relies heavily on costly imports for its needs.

Cheaper sources of energy would reduce costs of production and help the nation become more competitive in manufacturing at a global level.

Recognizing these realities, the nation's leadership has embarked upon a mission to make India self-reliant in electricity generation by leveraging the potential of renewable energy.

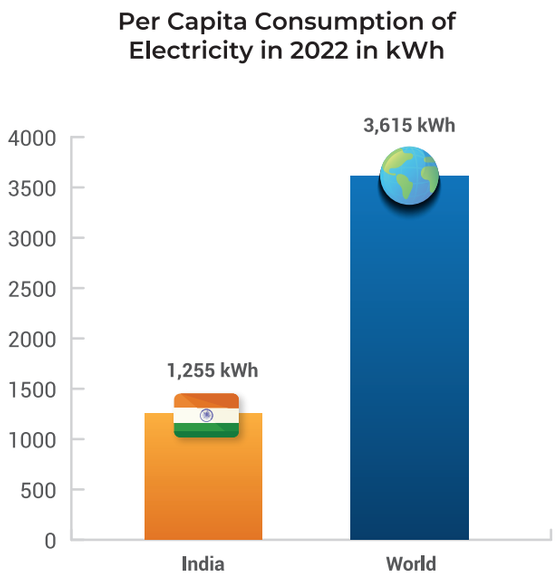
And The Nation's Leadership Is Willing To Offer A Lot Of Policy Support To This Sector

In his address at the 76th Independence Day, the Honorable Prime Minister Shri Narendra Modi said, "We should be self-reliant in the fields of solar energy, wind energy, various other renewable energy sources, Hydrogen, bio-fuels and electric vehicles".

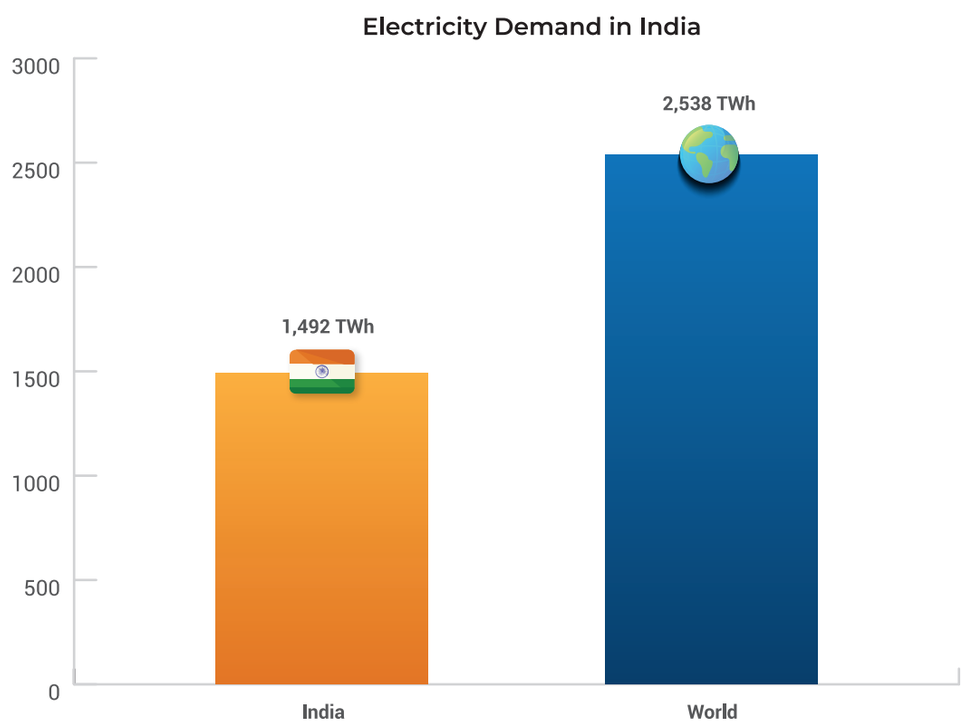
Being industries with massive growth potential, they offer Indian entrepreneurs a road to unprecedented success.

We Are Starting From A Low Base

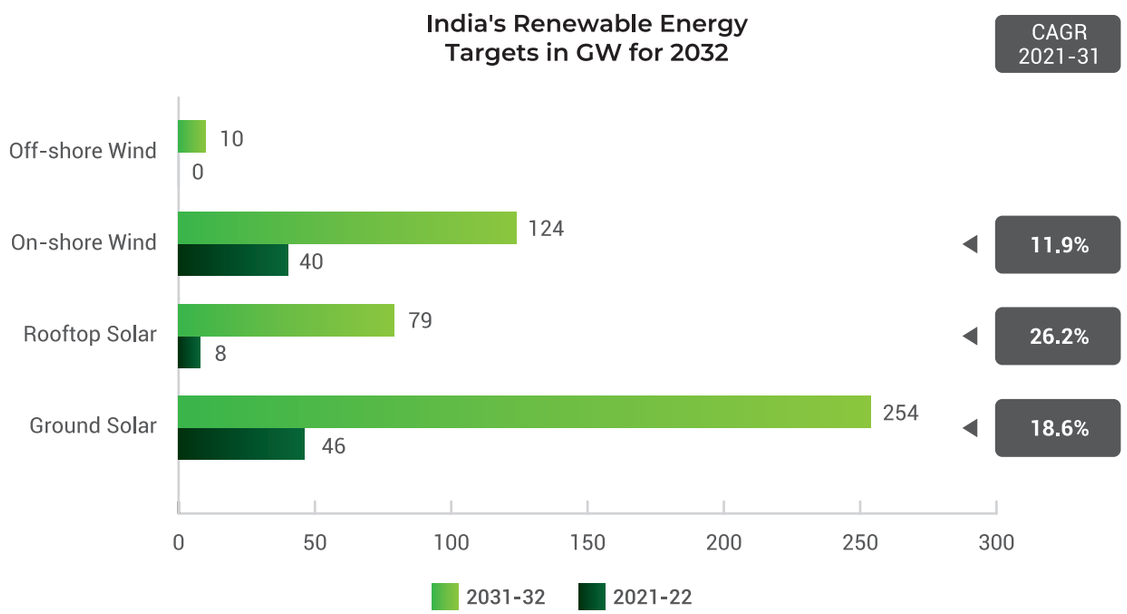
- India's per capita consumption of electricity at 1,255 kWh in 2022 is very low as compared to the world average at 3,615 kWh.
- However, rising incomes will lead to growing energy consumption at homes. Air conditioning being one of the fastest-growing end use application.
- At the same time, increasing electric vehicle sales will lead to increasing consumption of electricity in the road transport sector.
- The per capita consumption of electricity in India is therefore expected to grow strongly in the coming years.



But Electricity Demand is Projected to Rise Strongly in the Medium Term



Our Medium-Term Targets Are Tall...



And These Will Continue To Rise Higher Under The "2040 Peak Emissions - 2070 Net-Zero" Scenario

India's Renewable Energy Targets in GW for 2032	2031	2031
Solar	333	540
Wind	134	211

Source: CEEW-CEF analysis

The Corresponding Investments in US$ Billion Needed for Power Will Also Be Very High

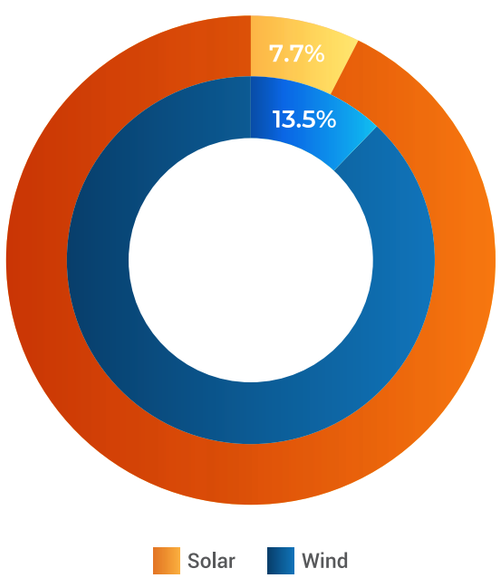
2040 Peak – 2070 Net-Zero	2020-30	2030-40
Power		
Generation	380	560
Integration	8	25
T&D	132	223
Power Total	**520**	**808**

Source: CEEW-CEF analysis

But The Long-Term Potential for Adoption of Solar & Wind Energy in India is Significant And Largely Unexploited

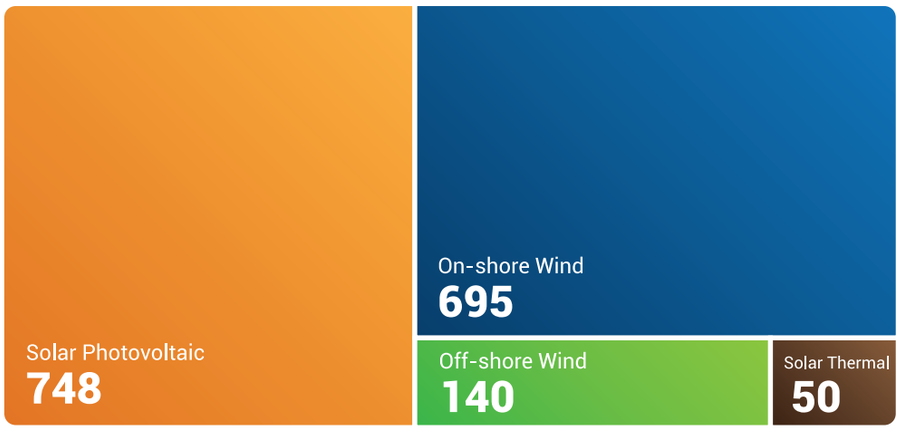
- The country's solar potential utilizing just 3% of the land area is about 748 GW. About 7.7% of solar energy potential has been currently utilized.
- Wind potential stands at about 302.25 GW at a hub height of 100m and 695.5 GW at a hub height of 120m. About 13.5% of wind energy potential (at a hub height of 100m) has been currently utilized.

Solar & Wind Energy Currently Deployed Vs Total Potential



While Each Technology Has Its Strengths... Each Has A Unique Role To Play As Well

Renewable Energy Potential in GW by Source



Solar Photovoltaic

Today, solar Photovoltaic is the cheapest source of electricity and is therefore the fastest growing. It boasts very high level of opportunities for businesses across the value-chain.

Wind Energy

That said, wind has a major advantage over solar, that it can be generated during the day or night. Also, wind is much less land intensive as compared to solar.

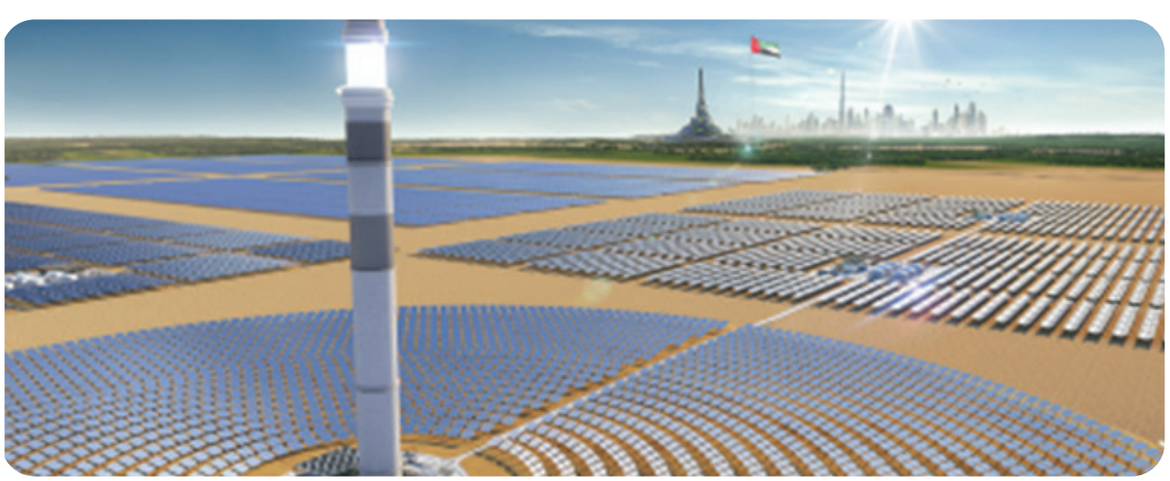
Adoption of wind in addition to solar contributes to diversifying the energy mix and brings down the cost of generation.

Apart from the mainstream horizontal axis wind turbines, there is significant potential for adoption of vertical axis wind turbines (VAWTs) in residential and urban areas, that can blend easily in any setting.

Solar Thermal

Solar thermal is a versatile solution for residential, commercial and industrial users. It can help reduce energy consumption from heating and cooling applications.

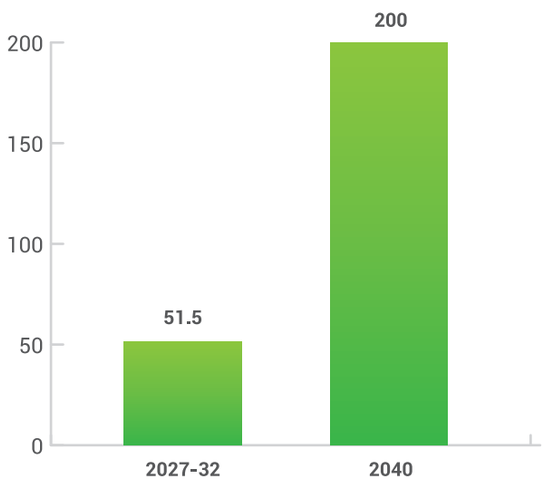
It is the perfect solution for heating water. It is more space efficient than solar PV. Solar thermal has many applications in industry ranging from water heating for industrial processes, space heating or space cooling, water distillation, water desalination, solar dryers, etc.



We Are Starting From A Low Base

- Solar and Wind energy generation is intermittent in nature due to the constantly changing solar irradiance or wind speeds as applicable.
- Demand, on the other hand, follows a different and independent trajectory, often with sudden surges or trips.
- Therefore, the importance of battery storage in the grid in a renewable energy era cannot be overemphasized.
- If India is to succeed in integrating high percentage of renewable energy in the grid, it will require 51.5 GW of battery storage capacity by 2032 and as much as 200 GW by 2040, the largest for any country in the world.

Battery Storage Capacity in GW Required in India



So, The Opportunities Range From...

1. Generation
2. Transmission
3. Distribution
4. Energy Storage
5. Manufacturing
6. Services

And There Are More...

Energy and Mobility

- Electric vehicles
- Green hydrogen
- Decentralised Solar such as Solar Pumps, etc

Other Sectors to Decarbonize

- **Agriculture**
- **Buildings**

And Hard To Abate Sectors - Industry, Shipping & Air Travel

- Non-carbon alternatives for the production of cement, steel, plastics and ammonia have to be developed to enable transition of these sectors from fossil fuels to renewable energy.
- Clean fuel alternatives need to be developed to power shipping and air travel before these sectors can move away from fossil-fuels.

And Energy Efficiency...

- Last, but not the least, energy efficiency is a big area of opportunity. According to the IEA, India could avoid electricity generation of up to 875 TWh per year by 2040 by improving energy efficiency.
- Energy efficiency includes energy audits, adopting super-efficient appliances including LED lighting, BLDC fans and efficient DC motors in industry, etc.

The Opportunities On The Path To Net-zero Are Worth Trillions Of Dollars

- Energy transition will be the single largest economic opportunity, accounting for nearly $8.4 trillion in investment by 2070. Energy transition includes building new solar and wind capacities, augmentation of transmission and distribution infrastructure, investments in energy storage, etc.
- Mobility transformation represents a $2-$4 trillion investment opportunity by 2070. Key drivers will include the shift in mode of transport from road to rail, and the electrification of the entire transport system, investing in the charging infrastructure, biofuels and gas-based fuels as well as infrastructure for a hydrogen-based heavy mobility ecosystem.
- Industry decarbonization could offer a $2-$3 trillion investment opportunity. The retooling and electrification of industrial processes and the build-out of a hydrogen-based infrastructure for industry will be the two key drivers of investments in this space.
- The Green Buildings, Infrastructure and Cities pillar could potentially offer a $2-$3 trillion investment opportunity for India.

AND THE TIME TO ACT IS NOW

1. Why should India transition to Renewable Energy?

Areas of focus in this Section

- What is the impact of high oil prices on the dollar-rupee exchange rate?
- What is the value of India's coal and petroleum imports?
- How do high oil prices impact India's GDP growth?

Mitigating the Impact of High Oil Prices on the Indian Economy

Impact on Dollar-Rupee Exchange Rate

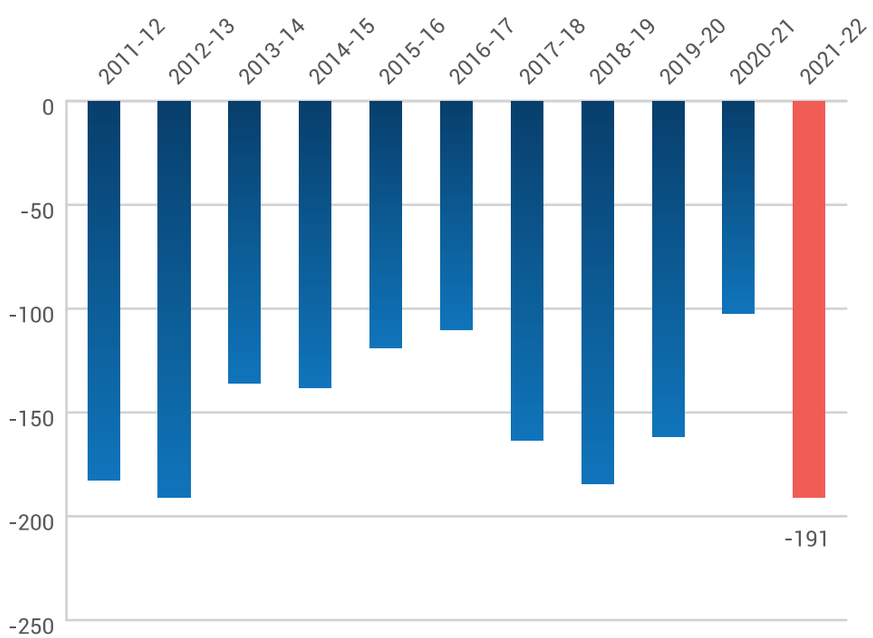
Crude oil accounts for nearly 17 per cent of India's total imports. Due to the inelastic nature of its demand, an increase in crude prices invariably leads to higher import bills for the country and worsens the current account deficit.

In essence, having a CAD or a deficit on the current account implies that, in monetary terms, India imports more goods and services than it exports. This, in turn, implies that the demand for the foreign currency (say the US dollar) is more than the demand for the Indian rupee.

That, in turn, implies that the rupee will depreciate. Whether or not it eventually does depreciate, however, depends on what is happening to the Capital Account of the Balance of Payment. (The capital account records the inflow and outflow of investments into the country).

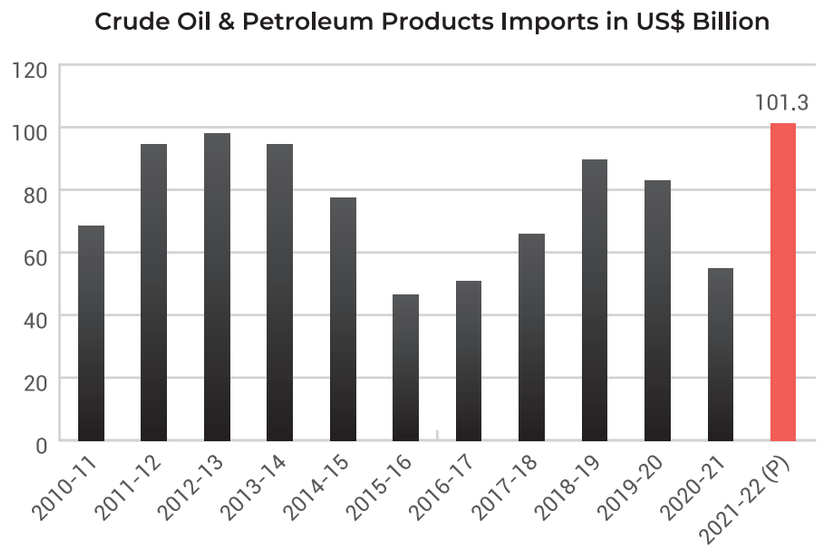
Mitigating the Impact of High Oil Prices on the Indian Economy

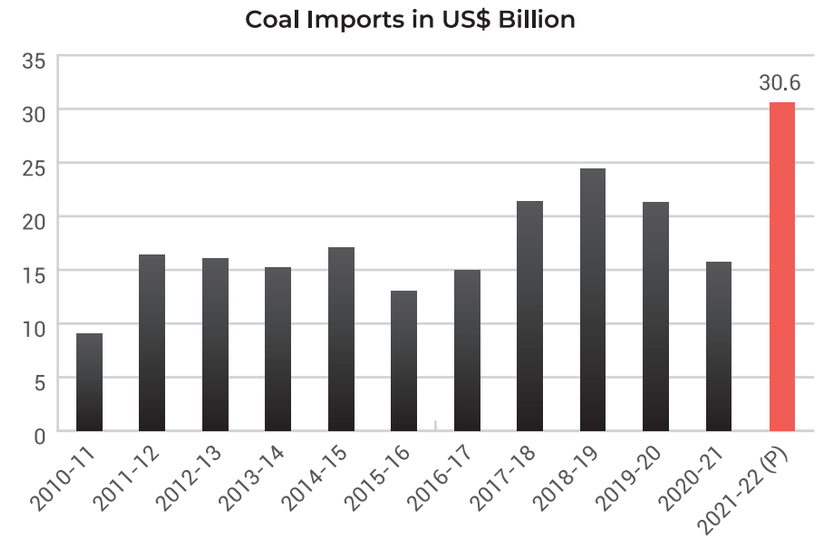
Year	Exports	Imports	Trade Balance
2011-12	306	489	-183
2012-13	300	491	-191
2013-14	314	450	-136
2014-15	310	448	-138
2015-16	262	381	-119
2016-17	275	384	-109
2017-18	303	466	-163
2018-19	330	514	-184
2019-20	313	475	-162
2020-21	292	394	-102
2021-22	422	613	-191



Source: Ministry of Commerce and Industry, GOI

Coal and Crude Oil and Petroleum Product Imports in US$ Billion





Source: Petroleum Planning and Analysis Cell, Ministry of Coal, GOI

Mitigating the Impact of High Oil Prices on the Indian Economy

Impact on GDP growth

Oil prices have always haunted the Indian economy. An adverse oil price shock tends to mess up many of India's macroeconomic variables. The most obvious impact of high oil prices in India is on domestic inflation. It also hurts India's GDP growth by making Indian manufacturing uncompetitive due to higher input energy costs.

Key Takeaways

- **High crude oil imports cause the rupee to depreciate.**

- **An adverse oil price shock to our economy is completely out of our control. It is solely dependent on international crude oil prices. If we could reduce our dependence on crude oil, we can use these additional resources for the development of our country.**

- **High oil prices also hurts India's GDP growth by making Indian manufacturing uncompetitive due to higher input energy costs.**

2. The Path to Net-Zero: Beyond Renewable Energy

Areas of focus in this Section

- **What are the other opportunities in a renewable energy future?**
- **What are the opportunities on the path to Net-Zero?**

Other Opportunities In A Renewable Energy Future

India's focus on renewable energy will lead to growth other technologies as well, such as manufacturing of electric vehicles, super-efficient appliances, green hydrogen, etc.

Energy efficiency is a big area of opportunity as well. By improving energy efficiency, India could avoid electricity generation of 875 TWh per year.

Low energy costs coupled with the "Make-in-India" initiative and other schemes that the government has launched will enhance India's manufacturing capabilities and exports.

The benefits of low-cost power can also be seen in the freight sector. The Indian Railways will phase out diesel engines and move towards 100% electric engines by 2023-24. Electrification will result into seamless (end to end) train operation. Electrification will also help in increasing average speed of freight trains and enable haulage of heavier freight. It will also allow the use of longer passenger trains running at higher speeds. The expected annual saving to the railways from this drive are estimated at 14,600 crore p.a.

https://www.iea.org/reports/india-2020

Opportunities on the Road to Net-Zero

India has committed to the UN Framework Convention on Climate Change (UNFCCC) that it will reach "Net-Zero" target by 2070.

The target of Net-Zero is significantly broader than just phasing out of fossil fuels or adopting renewable energy. In fact reaching Net-Zero will entail actions on many fronts. These projects will become mainstream in the years to come. Phasing out fossil fuels was just one low-hanging fruit on the path to Net-Zero. Regulatory action coupled with great economics for the alternative, will be key catalyst in achieving these shifts.

Net-Zero transition will open up further opportunities in sectors such as water, agriculture, forest, housing, waste management, circular economy, resource efficiency, etc.

Key Takeaways

- **India's renewable energy focus will lead to growth in renewable energy technologies as well as manufacturing of electric vehicles, super-efficient appliances, green hydrogen, etc.**

- **Energy efficiency is a big area of opportunity as well. By improving energy efficiency, India could avoid electricity generation of 875 TWh per year.**

- **Low energy costs will enhance India's manufacturing capabilities and exports.**
- **Low-cost power can also make the Indian rail freight sector more efficient and competitive and can bring savings of an estimated at 14,600 crore per annum.**

- **India has aimed to reach "Net-Zero" target by 2070. This transition will open up further opportunities in sectors such as water, agriculture, forest, housing, waste management, circular economy, resource efficiency, etc.**

3. Factors Driving the Growth of Renewable Energy Sector in India

Areas of focus in this Section

- What role would renewable energy play in India's vision for the future?
- How does India's business climate favor the transition to renewable energy future?
- How significant is the potential for adoption of renewable energy in India?

3.1 A Vision for the Future

Areas of focus in this sub-section

- Which were the Great Energy Transitions of the past two centuries? Are we in the midst of another great energy transition?
- What position did India hold in the global economy in the last two thousand years? Is India at the Cusp of Glory once again?
- How political intent is supporting India's development?

https://www.iea.org/reports/india-2020

The First Great Energy Transition

"Society has undergone a profound change every time a new energy source takes centerstage. Indeed, human progress is a story of energy transitions", says Sumant Sinha in his book Fossil Free, published in 2020.

He elaborates that the first great energy transition was from **wood to coal**, that happened in sixteenth century **England**. This coupled with the development of the **steam engine** in 1781, took British factories to unprecedented heights and raised industrial output at a pace never seen before. The coal-driven steam engine also paved way for the twentieth century's massive-scale generation of electricity.

The Second Great Energy Transition – Pre-World War II

The **US** was the origin of the second great energy transition. Driven by dwindling supplies of whale-oil, kerosene began to be used as fuel for lighting in the US, sometime around 1856. The development of the kerosene lamp led to the growth of the **oil exploration and refining** industry in the US.

In 1859, the first stable, **gasoline-powered internal combustion engine** (ICE) was invented. The ICE was smaller, more efficient, quicker to start, safer to use and easier to operate than the steam-engine. The ICE began to be used in automobiles when the latter were invented by Benz in Germany in 1886.

Initially automobiles remained a cottage industry in Europe. But in 1908, Ford Motor Company in the US, developed the Model T, which was one of the first mass produced cars. Cars rapidly replaced animal-drawn carriages in the US, though they remained a novel indulgence elsewhere in Europe. In 1900, there were 8,000 cars in the US, and by 1930, the number rose to 26.7 million.

The role of petroleum in global economy rose tremendously during the world wars. New modes of motorized transport, especially the tank and the airplane, and liquid-fuel powered ships provided both mobility and power that had never been seen before in history. The US oil industry supplied as much as 80 percent of fuel used by the Allies in the Second World War. The world wars demonstrated that **oil was an asset** whose continued supplies were of **strategic importance** to national security. The World Wars along with the achievements in the petroleum and the automobile industries t**ransformed the US into a global superpower**.

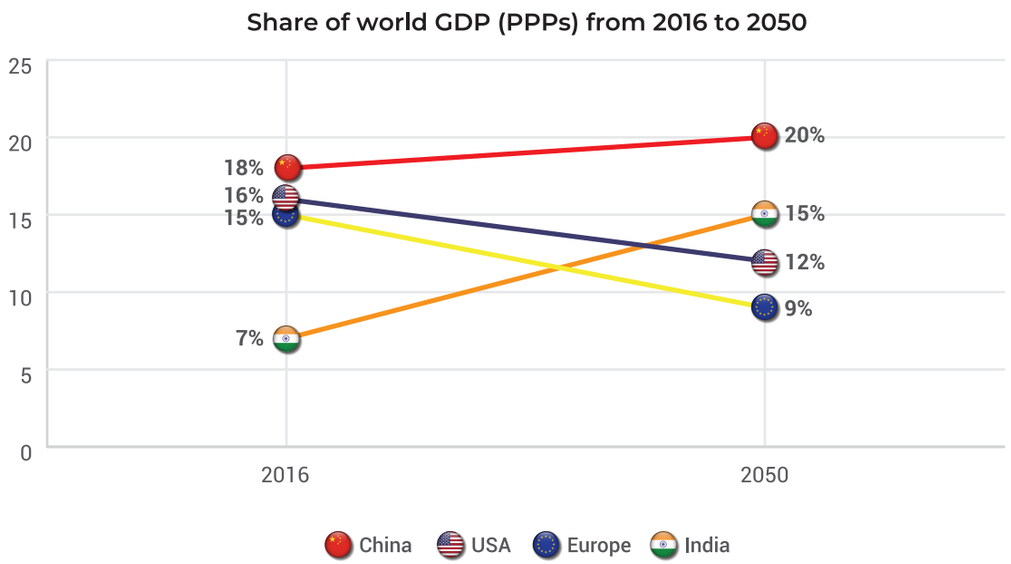
Source: Fossil Free by Sumant Sinha October 2020

Key Takeaways

"Energy transitions follow a path towards higher-performing fuels that are more affordable and available in plenty", says Sumant Sinha in his book Fossil Free and that they are the cause of shifts in global political power.

An Impending Shift in Balance of Power

A huge power shift is occurring in the world order. China and India are growing significantly faster in terms of GDP (PPP) than the United States and Europe. By 2050, the combined share of China and India in global GDP would be about 35% as compared to the combined share of United States and Europe at 21%. Consequently, China and India will acquire a significantly larger influence in global decision-making in relationship to the United States and Europe.



Access to energy resources will be critical in achieving this transition. India is poor in energy resources such as crude oil and natural gas and relies heavily on costly imports for its needs.

Cheaper sources of energy would reduce costs of production and help the nation become more competitive in manufacturing at a global level. Recognizing these realities, the nation's leadership has embarked upon a mission to make India self-reliant in electricity generation by leveraging the potential of renewable energy.

https://www.pwc.com/gx/en/news-room/docs/the-long-view-how-will-the-global-economic-order-change-by-2050-summary.pdf

An Ambition for India

A Global Economic Power

According to economic historian Angus Maddison, India was the world's largest economy with a 32.9 percent share of global GDP in the first century AD and 28.9 percent in the eleventh century. In 1700, when most of the country was ruled by Mughals, India had a 24.4 percent share of world GDP. However, thereafter it started falling and slipped below four percent by 1952.

The economic reforms that began in 1991, transformed India from a poor, slow-growing nation into the third-largest economy in the world. Having set foot on the path of growth and glory, the political leadership has a vision to make India the second largest economy of the world, displacing the US.

A Developed Nation by 2047

India also wants to transform itself into a developed nation by 2047. As per the "Competitiveness Roadmap for India@100", a study commissioned by the Economic Advisory Council to the Prime Minister (EAC-PM), India can become an upper-middle-income country by 2047 if it manages to achieve a sustained real GDP growth rate of 7.0-7.5 per cent for the next 25 years. At this rate India's GDP will rise from USD$ 2.7 trillion to US$ 20 trillion by 2047. This will raise India's per capita income to about US$10,000 per annum, so that it can be classified as an upper-middle-income country.

A Legacy for Posterity

In his address at the 76th Independence Day, the Honorable Prime Minister Shri Narendra Modi spoke on the importance of becoming self-reliant in the energy sector.

He said, "We should be self-reliant in the fields of solar energy, wind energy, various other renewable energy sources, Hydrogen, bio-fuels and electric vehicles". These are therefore the foremost goals for the country in the energy sector.

The nation's leadership is willing to offer a lot of policy support in this sector and being industries with massive growth potential, they offer entrepreneurs a road to unprecedented success.

https://www.pib.gov.in/PressReleseDetail.aspx?PRID=1851994

Key Takeaways

- The first great energy transition from wood to coal, transformed England into an industrial powerhouse.

- The World Wars along with the achievements of the US in the petroleum and the automobile industries transformed it into a global superpower.

Energy transitions therefore are the cause of shifts in global political power.

- By 2050, China and India will acquire a significantly larger influence in global decision-making in relationship to the United States and Europe due to their higher GDP (PPP).

- Access to energy resources will be critical in achieving this transition. Recognizing this, the nation's leadership has embarked upon a mission to make India self-reliant in electricity generation by leveraging its potential in renewable energy.
- India was the world's largest economy from the first century AD to 1700 AD, but lost this position during the British Raj. After the economic reforms in 1991, India has once again set foot on the path of growth and glory.
- The political leadership has a vision to make India the second largest economy of the world and a developed country by 2047. In it is an opportunity for the leadership to leave its legacy!

3.2 Favorable Business Climate

Areas of focus in this sub-section

- **How is India's current political scenario supporting decisive actions?**
- **How does India's federal structure with power distribution between Centre and States support or inhibit development?**

Strong Stable National Investment Climate

Since 2014, India enjoys a strong stable national government. This offers investors an ideal climate and more certainty in decision making. The strength of the administration can be seen from the following aspects:

- The 2014 victory of the BJP brought an end to the coalition era that had lasted for 25 years. An overwhelming voter's mandate is helping the current government push through relatively difficult decisions and reforms
- The country currently has the fourth largest forex reserves in the world at US$ 560 billion and therefore has a relatively stable currency
- It enjoys excellent relations with large trading partners such as the US, EU, Japan, China, GCC, etc
- It has a commanding stature in international forums and an ability to resist international pressure on treaties and agreements. Examples include the refusal to stop buying crude from Russia after the commencement of the Ukraine conflict under Western pressure
- National security has been strong, and destabilising elements have been mostly kept under check

Centre State Relations and Differing Priorities

The central and state governments share many common goals in energy policy. The standard concerns with affordable, abundant, and reliable energy supply do not differ across levels of government. Whenever a less expensive option is available, both central and state governments choose it.

However, while the centre has financial control, India's federal structure leaves state governments with considerable power over the success or failure in implementation of central policies, regulations, and programs.

https://www.belfercenter.org/sites/default/files/files/publication/harvard%20-project-india-subnational-climate-energy.pdf

Tamil Nadu's Priorities in Renewable Energy

Tamil Nadu has been one of the early adopters of renewable energy in India. It is currently one of the leading states in the renewable energy sector with a capacity of 15.6 GW.

In the case of Tamil Nadu, there is considerable alignment in terms of vision between the state government and the centre with regards to the renewable energy sector. Unlike the eastern states such as Jharkhand and Chhattisgarh, Tamil Nadu does not have coal mines. Coal is therefore not a revenue source or a large-scale employer for the state and therefore they have less resistance in moving towards renewable energy sources.

Key Takeaways

- **The 2014 victory of the BJP brought an end to the coalition era that had lasted for 25 years. An overwhelming voter's mandate is helping the current government push through relatively difficult decisions and reforms.**

- **Success in implementation of government programs is higher if relations between Centre and State are conducive, and there is a greater alignment on priorities.**

3.3 Significant Potential for Renewable Energy Adoption

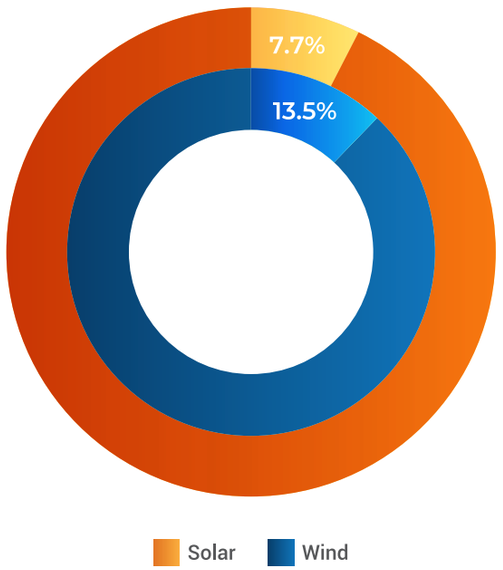
Areas of focus in this sub-section

- **How much is India's solar and wind power generation potential?**
- **How much of it is utilized and how much is unexploited?**

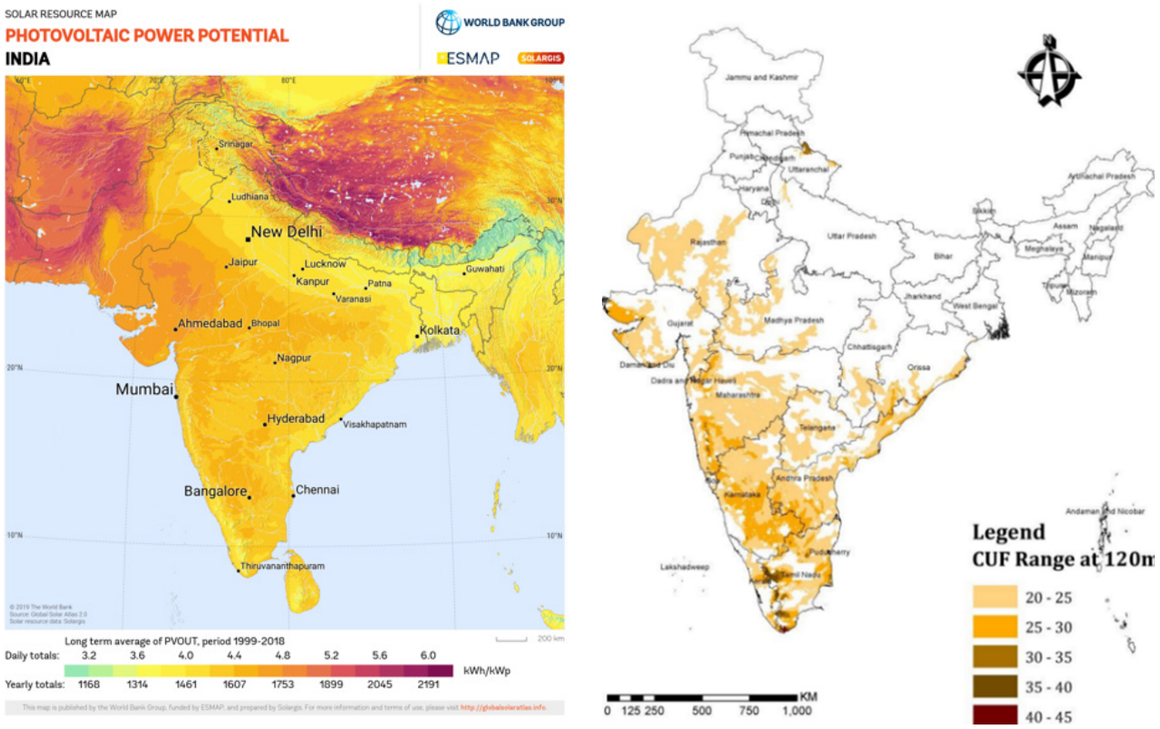
India's Solar & Wind Energy Potential

- India has abundant source of Solar irradiance due to its location in the solar belt. About 5 million TWh of energy is incident over India's land area per year with most parts receiving 4-7 kWh per sq. m per day. The country's solar potential utilizing 3% of the land area is about 748 GW. About 7% of solar energy potential has been currently utilized.
- Wind potential stands at about 302.25 GW at a hub height of 100m and 695.5 GW at a hub height of 120m. About 13% of wind energy potential (at a hub height of 100m) has been currently utilized.
- Actual potential for wind could be higher. This has been highlighted by a study by CSTEP in 2015, that estimates the country's wind potential to be 2,161 GW-2,759 GW at 100m and 2,540–2,959 GW at 120m.

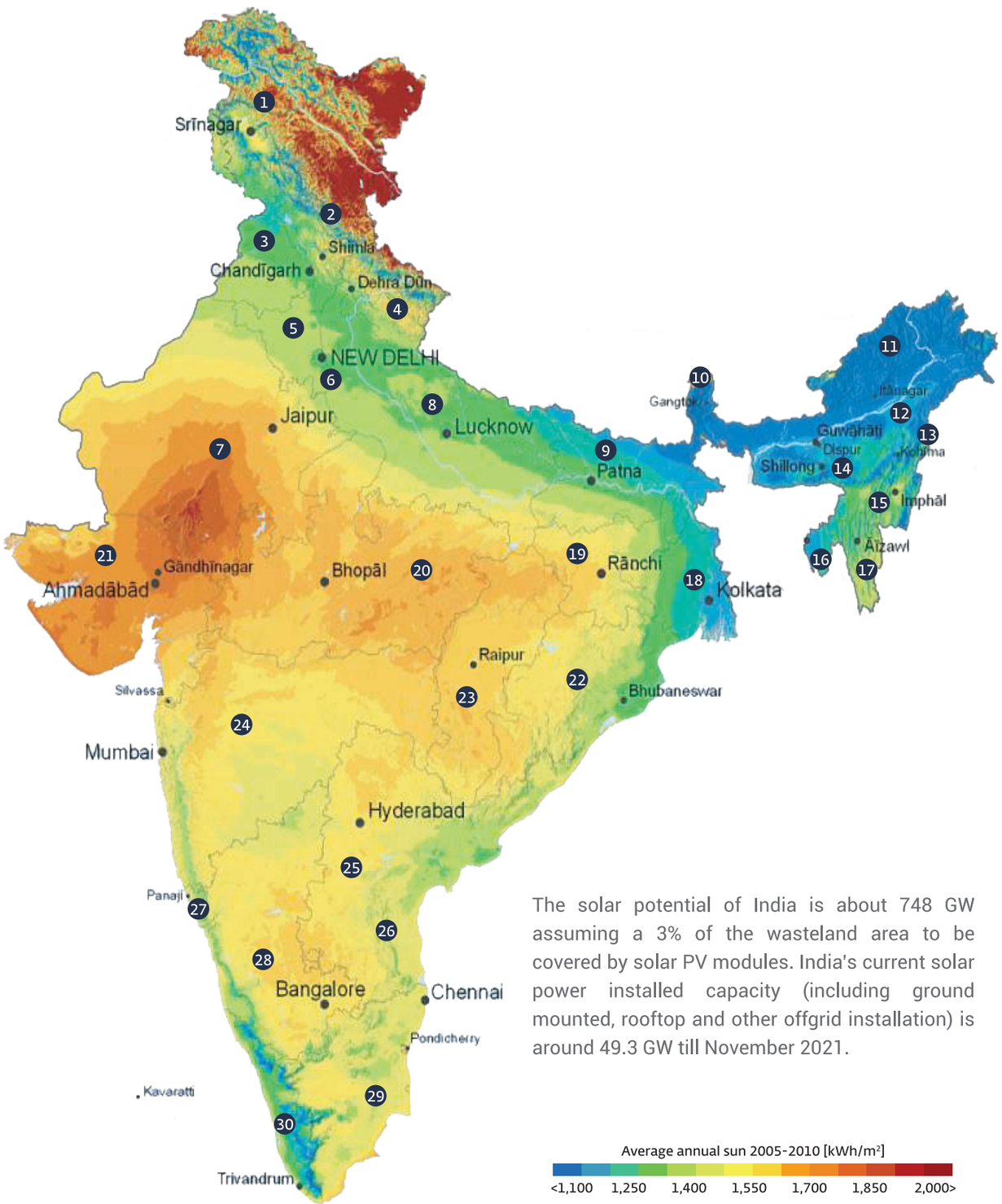
Solar & Wind Energy Currently Deployed Vs Total Potential



https://mnre.gov.in/solar/current-status/



© 2020 The World Bank, Source: Global Solar Atlas 2.0, Solar resource data: Solargis



The solar potential of India is about 748 GW assuming a 3% of the wasteland area to be covered by solar PV modules. India's current solar power installed capacity (including ground mounted, rooftop and other offgrid installation) is around 49.3 GW till November 2021.

Average annual sun 2005-2010 [kWh/m²]

<1,100 1,250 1,400 1,550 1,700 1,850 2,000>

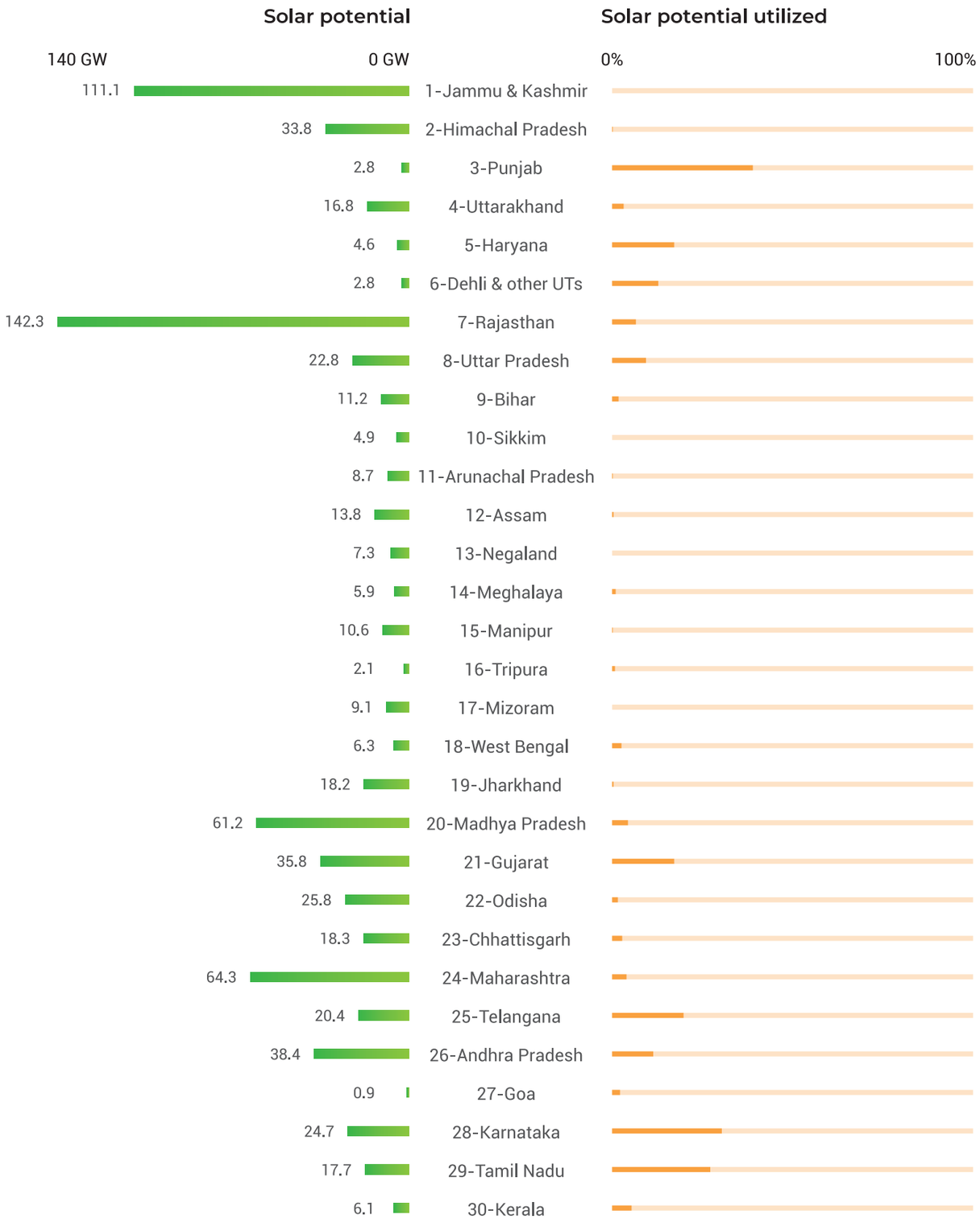
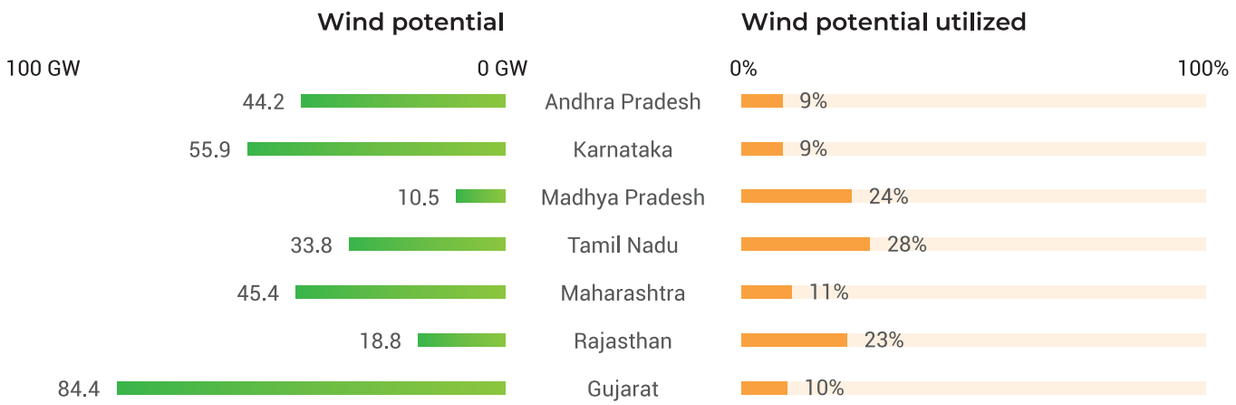


Fig. 1.1 left Indian solar irradiation map. Source: 2011 GeoModel Solar s.r.o.
Fig. 1.2 up Indian PV potential and utilised potential. Source:

Utilized Wind Potential, March 2021



Key Takeaways

- **Only a fraction of this has been utilized as yet.**
- **Conventional and unconventional solutions are needed to utilize this potential with minimal investment in land resources.**

4. India's Electricity Needs

Areas of focus in this Section

- **How much is the current electricity demand in India? What is the expected demand in 5-years and 10-years time?**
- **How does the government intend to meet this demand? What is the likely contribution of solar and wind energy in meeting India's energy demand?**
- **Why is actual electricity generation usually less than installed capacity?**

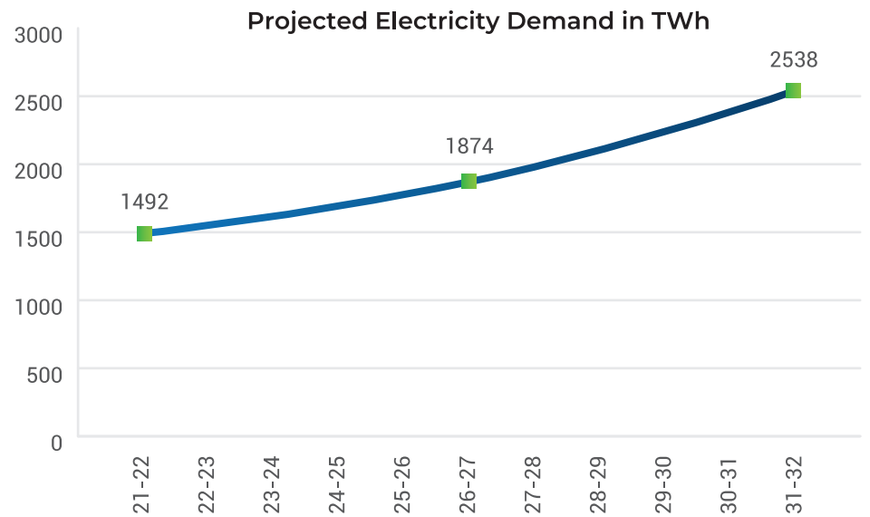
India's Electricity Needs

India's per capita consumption of electricity at 1,255 kWh in 2022 is very low as compared to the world average at 3,615 kWh. However, rising incomes will lead to growing energy consumption at homes. Air conditioning is likely to be one of the fastest-growing end use applications in the residential and commercial sector.

At the same time, increasing electric vehicle sales will lead to increasing consumption of electricity in the road transport sector. For a country that is poised to become the most populous nation in the world in a year's time, remaining acutely dependent on crude oil and petroleum imports will result in a big drain on the country's economic resources.

In the year ended March 2022, India's annual electricity demand stood at 1,492 TWh. As per forecasts by the Central Electricity Authority in September 2022, the projected electrical energy requirement is estimated as 1,874 TWh for the year 2026-27 and 2,538 TWh for the year 2031-32 respectively. This translates into an average annual growth rate of 5.5% until 2032.

Central Electricity Authority - Executive Summary on Power Sector July 2022

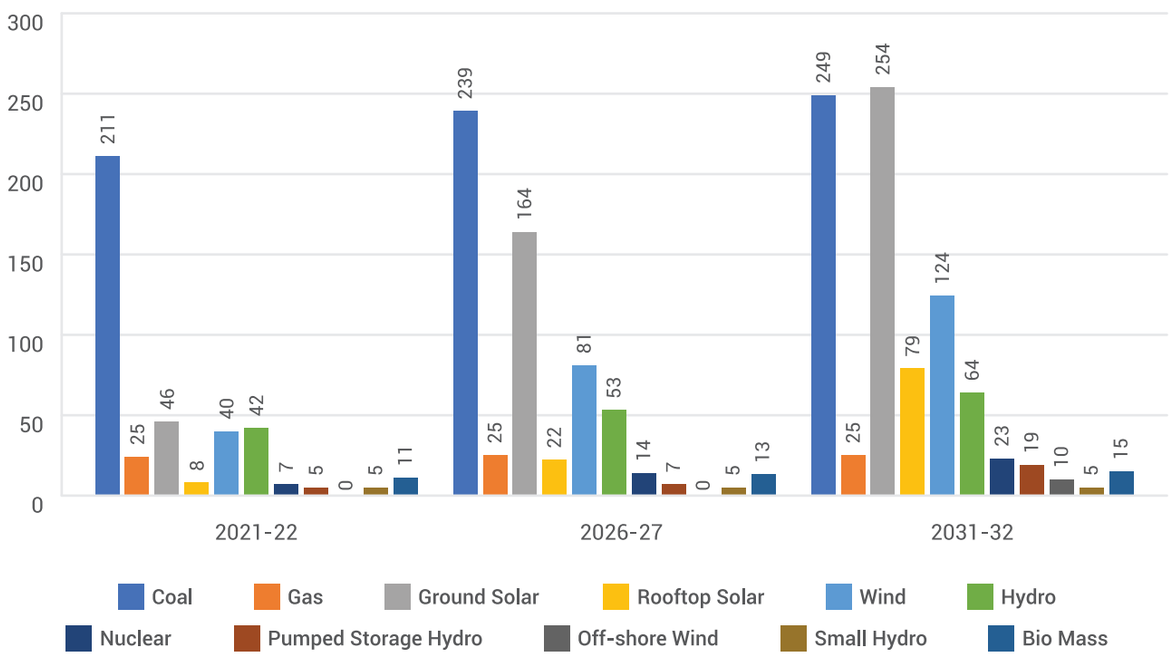


Generation Capacity Required to Meet 2032 Consumption Needs

India's currently installed power generation capacity is 400 GW, of which renewable energy capacity is 163 GW (including Nuclear).

As per projections of the Central Electricity Authority, India will require 623 GW of total power generation capacity by 2027 and 866 GW by 2032.

The share of renewable sources is expected to rise from 41% in 2022 to 58% in 2027 and 68% in 2032.



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Difference Between Installed Capacity & Electricity Generation

Installed Capacity

Capacity is the maximum output of electricity that a generator can produce under ideal conditions. Capacity levels are normally determined as a result of performance tests and allow utilities to project the maximum electricity load that a generator can support. Capacity is generally measured in gigawatts, megawatts or kilowatts.

Electricity Capacity

Electricity generation, on the other hand, refers to the amount of electricity that is produced over a specific period of time. This is usually measured in kilowatt-hours, megawatt-hours, or terawatt-hours (1 terawatt equals 1 million megawatts). An energy system that is running at 80% System Load Factor (SLF) implies that it is producing 80% of its maximum output. Electricity demand varies by time of day as well as season. Power plants are designed in such a way that they can ramp up generation to meet “Peak Demand”. At other times, the plant would be running at lower SLF.

Key Takeaways

- India's per capita consumption of electricity is very low as compared to the world average.

- However, rising incomes will lead to growing energy consumption at homes.

- Air conditioning is likely to be one of the fastest-growing end use application.

- At the same time, increasing electric vehicle sales will lead to increasing consumption of electricity.

- India's currently installed power generation capacity is 400 GW. As per projections of the Central Electricity Authority, India will require 866 GW of total power generation capacity by 2032.

- The sharpest growth is expected in ground solar from 46 GW in 2022 to 254 GW in 2032.

- In the same period, wind energy generation capacity is expected to go up from 40 GW to 124 GW.

- Rooftop solar is expected to grow from 8 GW to 79 GW in the same period.

5. Challenges to the Growth of the Renewable Energy Sector

Big Challenges Ahead for India's RE Targets

The capacity increases required in Ground Solar, Rooftop Solar and Wind, as seen in adjacent table, are large and will require overcoming the following challenges:

1. Large Investments
2. Integration of variable RE supply in the Grid
3. The Importance of Mix in reducing the cost of Energy
4. Overcoming dependence on imported solar PV panels
5. Challenges faced by Indian Wind Energy Sector
6. DISCOM Dues and Financial Health
7. Upgradation of Transmission Grid Infrastructure
8. Research and development to stay ahead of the renewable energy technology curve
9. Challenges to the adoption of rooftop solar

Sector	Capacity (GW) 2021-22	Capacity (GW) 2031-32	Additional (GW)	CAGR 2022-32
Coal	211	249	38	2%
Gas	25	25	0	0%
Ground Solar	46	254	208	19%
Rooftop Solar	8	79	71	26%
Wind	40	134	94	13%
Nuclear	7	23	16	13%
Large Hydro	42	64	22	4%
Pumped Storage Hydro	5	19	14	15%
Small Hydro	5	5	0	0%
Biomass	11	15	4	3%
Total Renewable	163	592	428	14%

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5.1 Large Investments

Areas of focus in this sub-section

- How much investment has been made in the solar and wind energy sector in the last 8 years?
- What is the capital expenditure required in installation of a solar or wind power plant? How much is the operational and maintenance cost for such a plant?
- What is the time required for construction of such a plant? What is the life of such a plant?
- What is the trend in tariff for solar and wind energy production?
- How much investment is required in the next 5-years and 10-years in the power generation sector to meet the generation capacity targets set by the government?

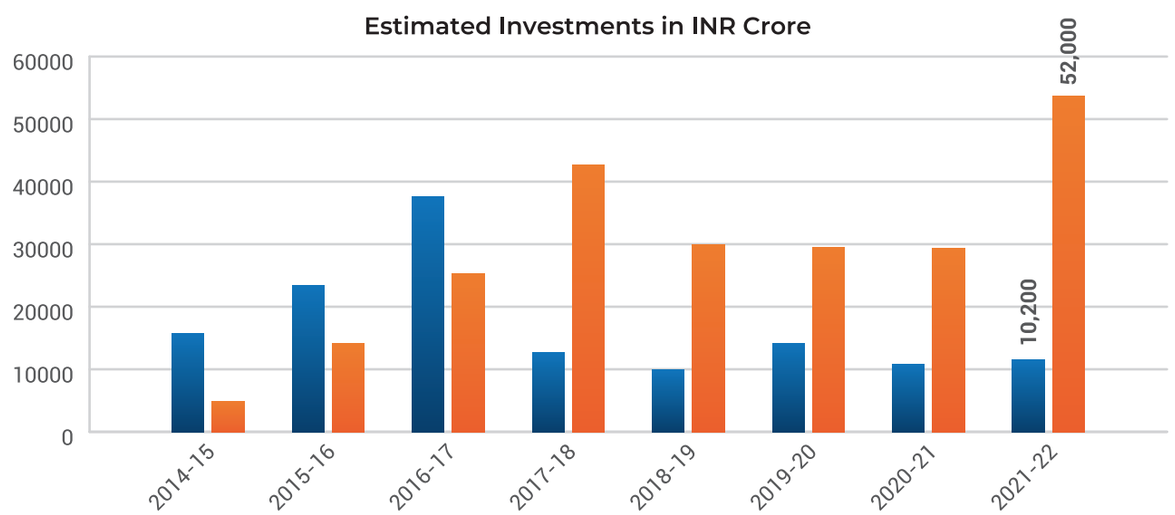
Existing Investments

Cumulative estimated investments in Solar and Wind Energy between 2014 to 2022 are as follows:

Wind – Rs 119,500 crore

Solar – Rs 205,840 crore

Total Investment: Rs 325,340 crore between 2014-22



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Reference Costs

- * Capex figures are on 2021-22 basis; inflation is not considered while calculating capex
- ! Solar Cost is assumed to reduce from Rs 4.5 Cr in 2021-22 to Rs 4.1 Cr in 2029-32
- $Off-shore wind has been considered as investment option from 2027-28 onwards with cost trajectory reducing from 16.59 Cr/MW in 2027-28 to 13.69 Cr/MW in 2031-32
- @Battery Energy Storage System Cost (5-hour storage) is assumed to reduce from Rs 9.3 Cr/MW in 2021-22 to Rs 6.99 Cr/MW in 2024-25 and then to Rs 5.24 Cr/MW in 2029-32. Customs duty of 22% on the Battery pack cost and GST of 18% on the total Battery system cost has been considered

	Capex*(in ₹ Crore /MW)	O&M Fixed Cost (in ₹ Crore /MW)	Construction Time (in years)	Amortization Life time (in years)
Coal	8.34	19.54 lakh/ MW	4	25
Nuclear	12	20	6	30
Hydro	6 to 20	2.5% of Capex	5 to 8	40
Solar !	4.5 to 4.1	1% of Capex	0.5	25
Wind (Onshore)	6	1% of Capex	1.5	25
Wind (Offshore) $	16.6 to 13.7	1% of Capex	1.5	25
Biomass	9	2% of Capex	3	20
Pumped Storage	3 to 8	5% of Capex	7	40
Battery Energy Storage @	9.3 to 5.24	1% of Capex	0.5	14
Transmission Line Cost	10,163/ MW/ km		1	25

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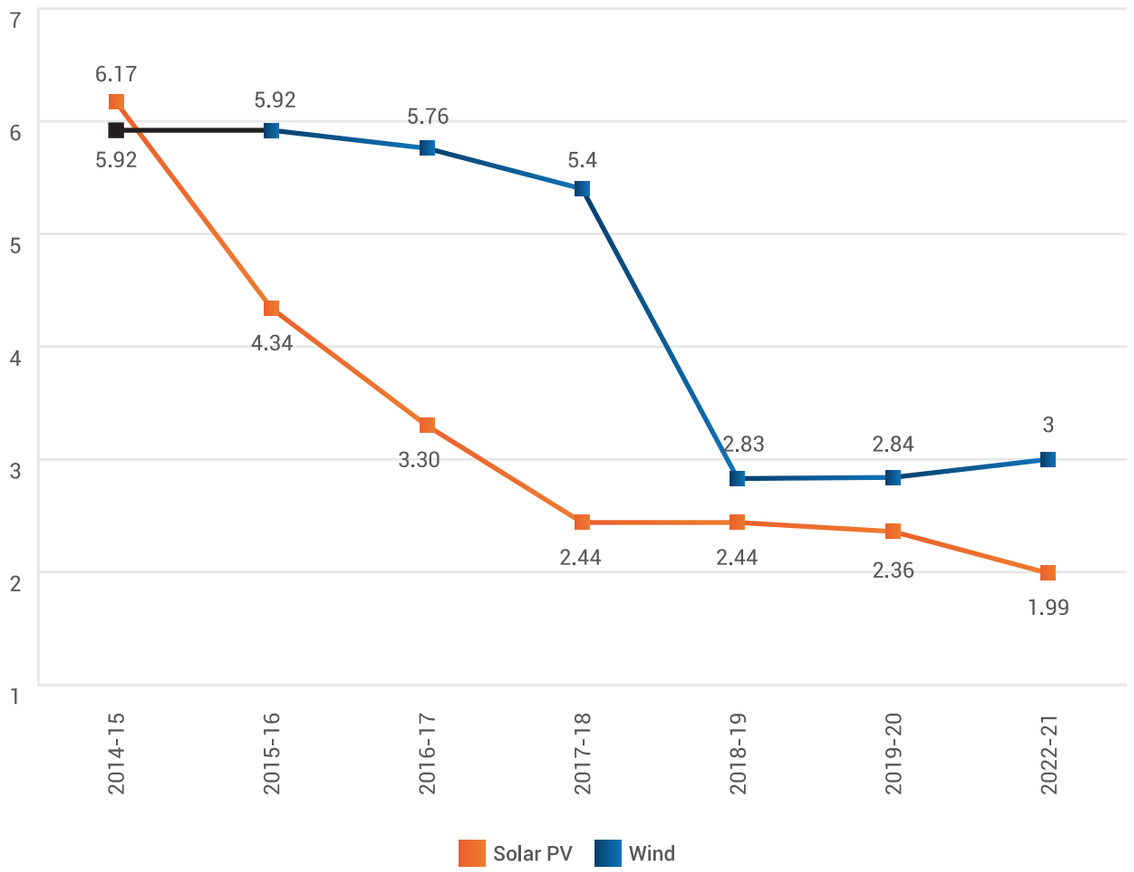
Trend in Tariffs for Solar PV & Wind Energy

With technological improvements, economies of scale and reduction in component prices, solar and wind tariffs in India have declined significantly as seen in adjacent chart.



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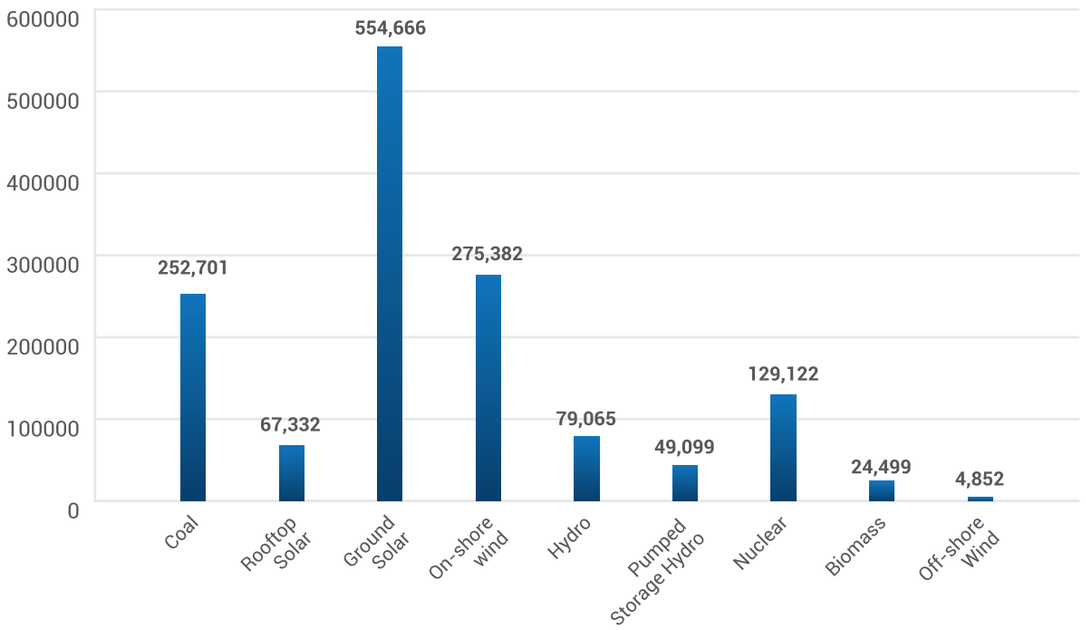
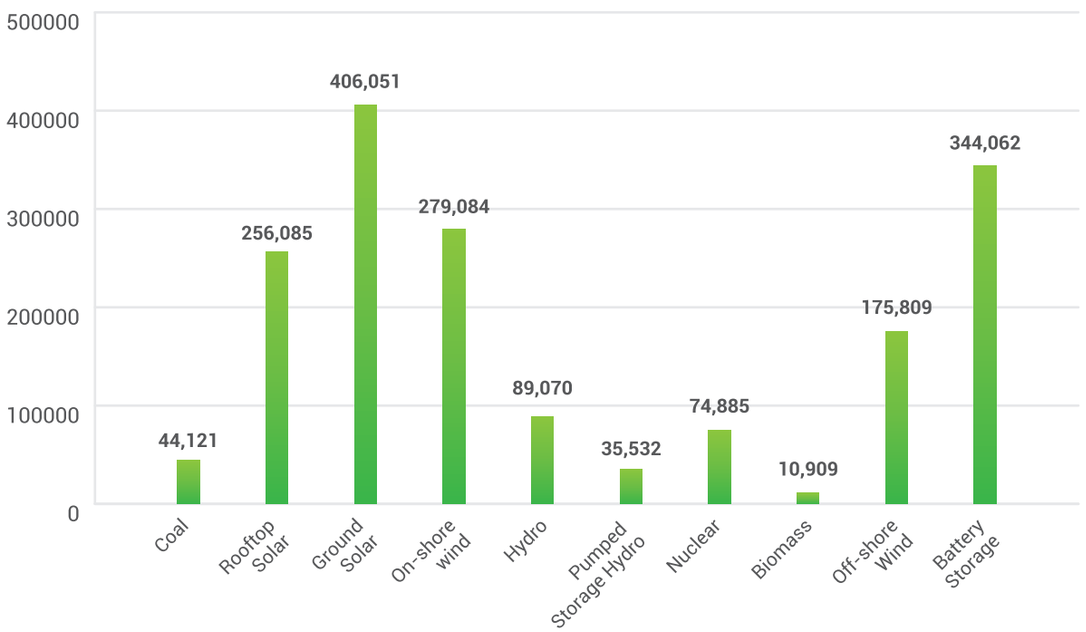
Trend in Tariffs for Solar PV & Wind Energy

2022-27: ₹ 1,430,718 Crore



2027-32: ₹ 1,715,608 Crore



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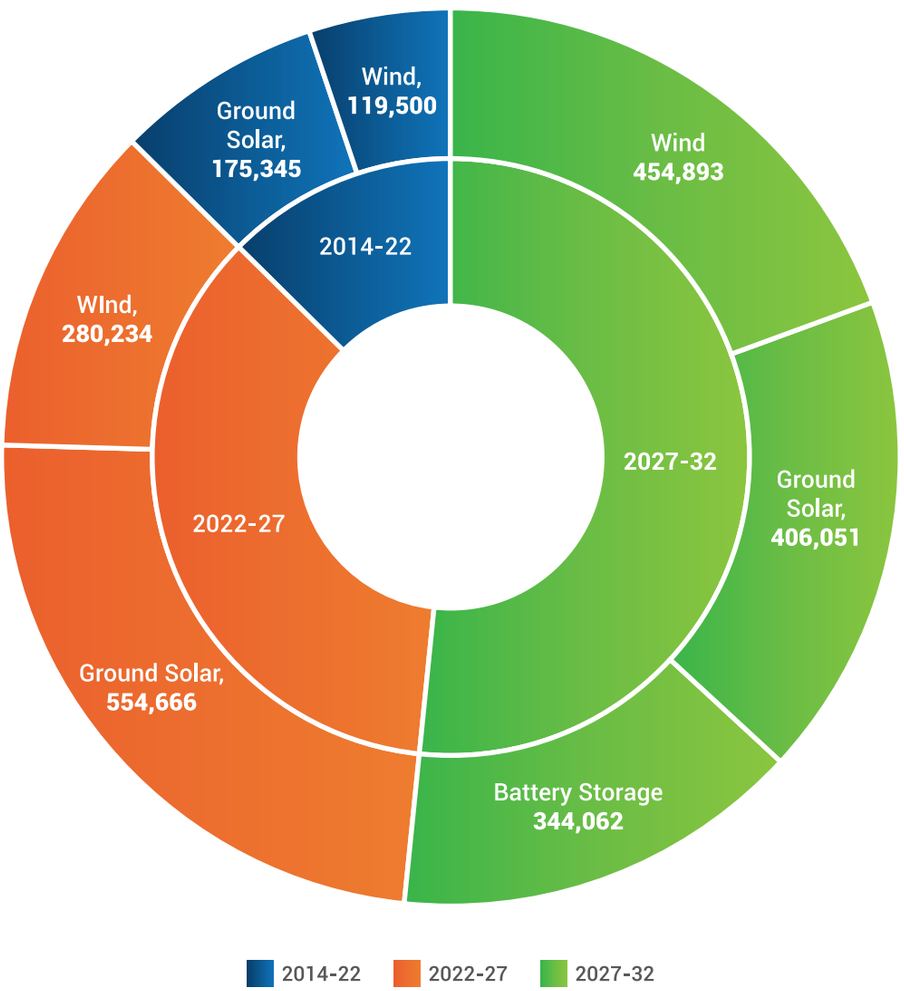
Comparative Investments Made & Required in Ground Solar, Wind & Battery Storage

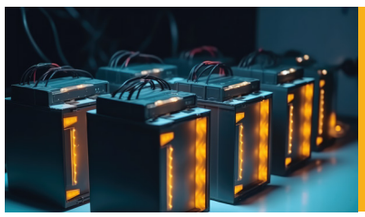
The investment required between 2022 to 2032 in these three areas is nearly 7 times the investment made between 2014 and 2022. Figures in adjacent chart are in Rs Crore.



Key Takeaways

- **In the last 8 years, the total investment in solar amounted to INR 206,000 crores and the total investment in wind was nearly INR 120,000 crores.**
- **However, an investment of INR 1,300,000 crores required for solar until 2032. The corresponding figure for wind is INR 735,000 crores. And that for battery storage is INR 344,000 crores.**
- **This shows that there is massive opportunity for investment in renewable energy projects in the next 10 years.**

- **Renewable energy projects can be done at various investment levels depending on the capacity of the investor. On an average, the capital expenditure required for a 1MW solar project is about INR 4.5 crores. The annual cost of operation and maintenance is about 1% of CAPEX. It would take about 6 months to build and has a life of 25 years. The corresponding figure for wind energy projects is about INR 6 crore per MW and would require about 1.5 years to build.**



- **As per the existing trends in tariff, power generators can obtain INR 2.50 to 3.50 per kWh for power generation.**

5.2 Integration of Variable Solar & Wind Energy in the Grid

Areas of focus in this sub-section

- **What are the causes of variability and unpredictability of renewable energy generation? How can these be overcome?**
- **What are the advantages of battery storage?**
- **What is the cost of battery storage?**
- **How much is the average levelized cost of energy across various renewable energy sources with and without battery storage costs?**
- **What role can conventional power generating units play in a renewable future?**

Causes of Variability and Unpredictability of Renewable Energy and the Ways to Mitigate their Impact

For both solar and wind energy plants, power output varies with time-of-the-day as well as season-of-the-year. These daily and annual variations can be studied and measures can be taken to mitigate the impact of their variability.

In addition, sudden weather changes can also cause sharp variation in power output. These variations, however, cannot be forecasted with high accuracy and would require backup from alternative sources.

Demand too follows a curve that varies by time-of-the-day as well as season-of-the-year. However, the supply and demand curves are completely uncorrelated with each other and there are invariably periods of high demand and low supply.

In such a scenario, renewable energy power plants must be backed up with either energy storage systems or generation from other conventional sources so that the shortfall in generation can be easily met.

Solar-Wind Hybrid Plants cannot completely mitigate this issue, but can help in reducing the extent of variability.

The Importance of Energy Storage in a RE Generation System

Solar and wind energy share in the grid can be increased by using energy storage solutions. Energy storage does away with curtailment of production when supply is higher than demand.

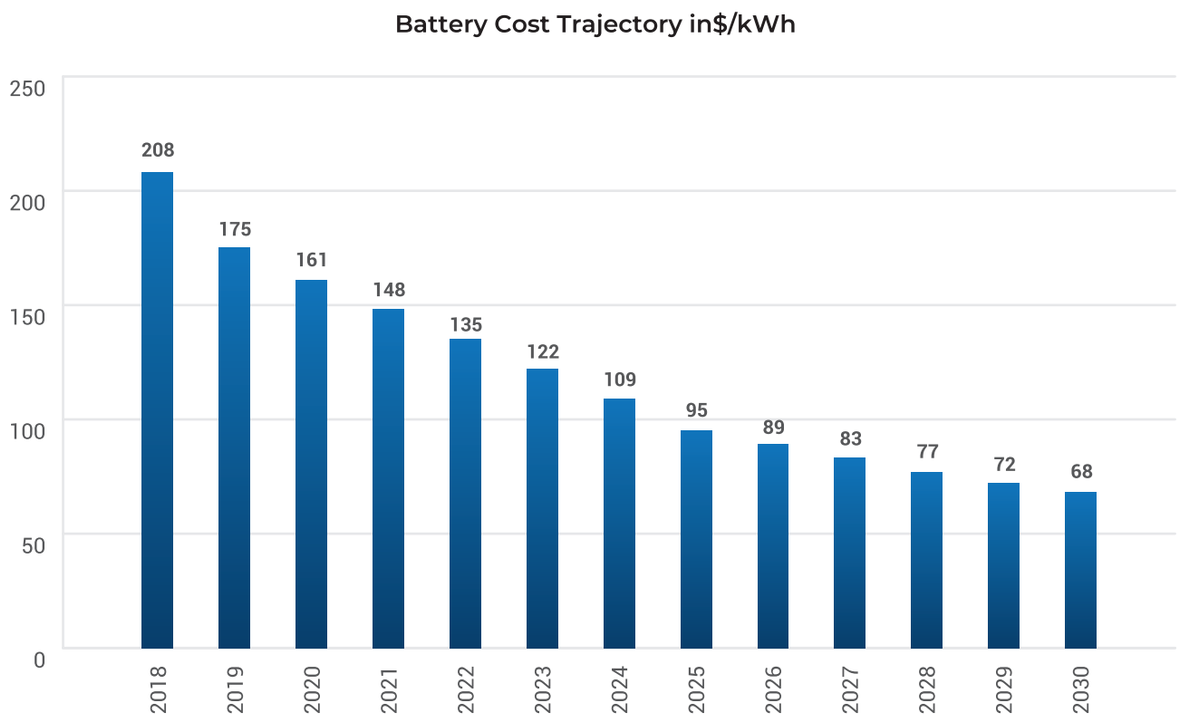
Energy storage systems have various other advantages as well, such as balancing the grid against load fluctuations, taking care of intermittency in generation, energy time-shifting and ramping services.

Battery Energy Storage Systems (BESS) using Lithium-ion batteries currently dominate the energy storage industry globally. Due to technological innovations and improved manufacturing capacity, lithium-ion chemistries have experienced a steep price decline since inception. Significant effort is underway to further improve their capacity, power, size, reliability and safety for applications involving both electrical vehicles and power generation.

Current & Forecasted Costs of Battery Storage

The cost trajectory of Battery Energy Storage system in future years is projected to decline as per Bloomberg NEF projections shown in the adjacent chart.

Crucially, India is planning to invest in BESS only after 2027. The Central Electricity Authority estimates BESS requirement of 51.6 GW to 84 GW during the period 2027 to 2032. The higher value corresponds to the scenario where planned Hydro, Nuclear, Solar and Wind energy plants do not come onstream as scheduled.



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Value Adjusted Levelized Cost of Energy

Low renewable energy generation costs do not guarantee accelerated deployment, as they are only part the story.

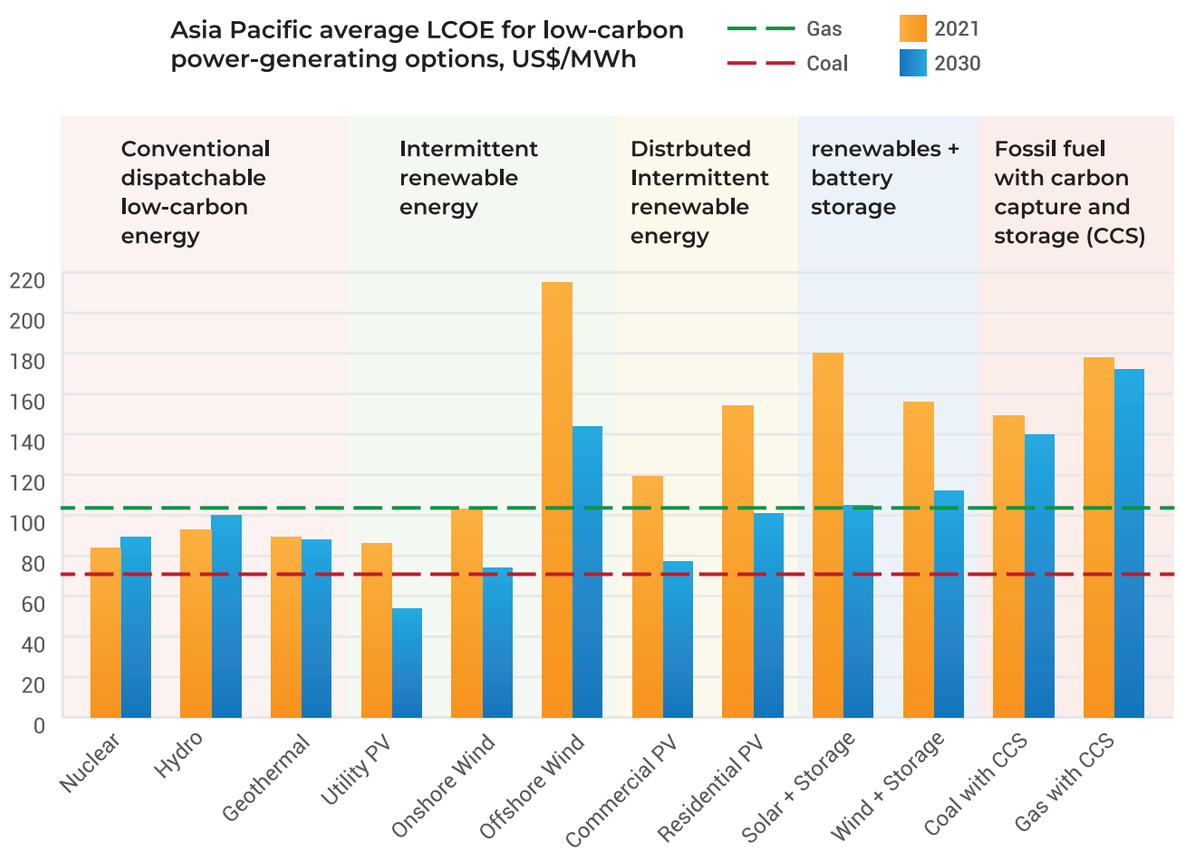
To better assess the relative competitiveness of technologies, a new metric of competitiveness has been developed over several years, called value-adjusted LCOE (or VALCOE).

VALCOE builds on the foundation of LCOE (Levelized Cost of Energy) that incorporates all cost elements, but also adds three categories of value in power systems: energy, flexibility and capacity. Combining these elements provides a stronger basis for comparisons between renewables.

While it is true that the LCOE for renewable energy will reduce even further, true cost can only be ascertained if storage costs are taken into consideration.

The next slide shows the average LCOE for various renewable energy technologies with and without storage.

Average LCOE for Various Renewable Sources



https://www.woodmac.com/press-releases/renewable-power-in-asia-pacific-gains-competitiveness-amidst-cost-inflation/

Flexibility From Conventional Generating Units

To accommodate the cyclical variability and uncertainty of generation from renewable energy sources, conventional energy generating plants can also provide flexibility. The flexibility of a generating station refers to:

- The maximum and minimum output the plant can generate
- To turn on and off in a shorter lead time (cycling)
- To vary level of generation as required (ramping)

In terms of flexibility, hydro plants, pumped storage plants, gas turbines, etc. are very suitable. In many countries, thermal stations (coal) are also used for cycling as well as ramping purposes.

"Exponential Growth of Renewable Energy is Possible Only if Affordable Energy Storage Solutions Are Available"

In India for example, the LCOE of new solar PV is projected to drop below that of coal-fired power plants by 2025. But the story is different using VALCOE.

As the share of solar PV surpasses 10%, the value of daytime production drops and the value of flexibility increases. After 2030, even with further cost reductions, solar PV is likely to becomes less competitive. Therefore, it is important to recognise that market will shift to other sources such as Hybrid Solar Wind, On-shore Wind, Off-shore Wind, Large Hydro, Nuclear, and so on.

At the same time, coal will continue to play an important role until battery storage or other forms of storage such as Hydrogen takes over.

Currently storage is mainly in the form of Li-ion batteries or pumped hydro storage. In future it could be some other battery technology or Hydrogen.

Hydrogen is likely to be a game changer in the energy industry and will be the next big investment opportunity.

Key Takeaways

- For both solar and wind energy plants, power generation varies with time-of-the-day as well as season-of-the-year. In addition, sudden weather changes can also cause sharp variation in power output.
- Demand too follows a curve that varies by time-of-the-day as well as season-of-the-year.

- Renewable energy power plants must therefore be backed up with either energy storage systems or generation from other sources so that the shortfall in generation can be easily met.
- Energy storage does away with curtailment of production when supply is higher than demand as well as balances the grid against load fluctuations, takes care of intermittency in generation, provides energy time-shifting and ramping services.

- The Central Electricity Authority estimates BESS requirement of 51.6 GW to 84 GW during the period 2027 to 2032.
- Conventional energy generating plants such as hydro plants, pumped storage plants and gas turbines are also very suitable for providing flexibility.

5.3 The Importance of Mix in Reducing the Cost of Energy

Areas of focus in this sub-section

- What is the average capacity utilization factor for a solar and wind energy plant?
- How can hybrid solar and wind energy plants improve overall capacity utilization factor?

Flexibility From Conventional Generating Units

$$\text{CUF} = \frac{\text{Output (kWh)}}{\text{Capacity (kW) x 8760h}}$$

To accommodate the cyclical variability and uncertainty of generation from renewable energy sources, conventional energy generating plants can also provide flexibility. The flexibility of a generating station refers to:

The maximum and minimum output the plant can generate

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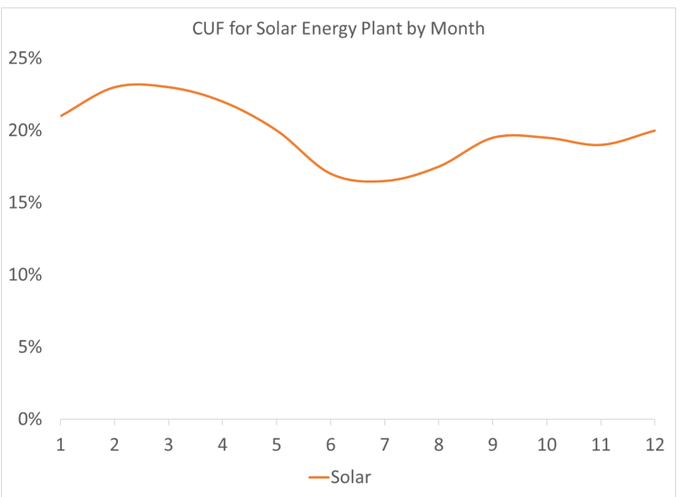

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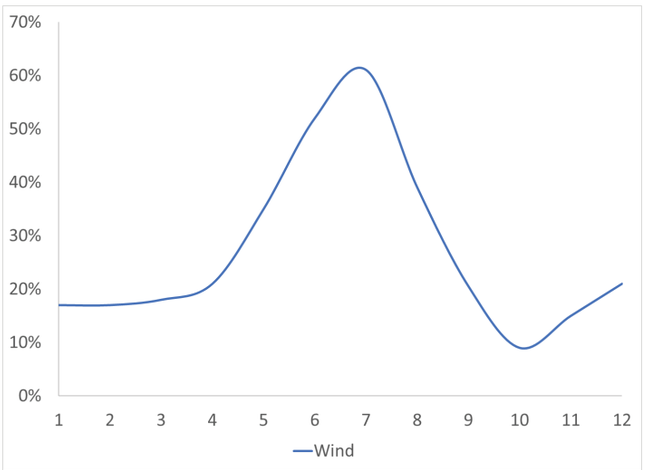
Capacity Utilization Factor for Wind Energy

CUF for wind power plants is the ratio of the wind turbine's actual power output to its nominal or maximum power output. The average Capacity Utilization Factor (CUF) for wind energy plants is 25.2%.

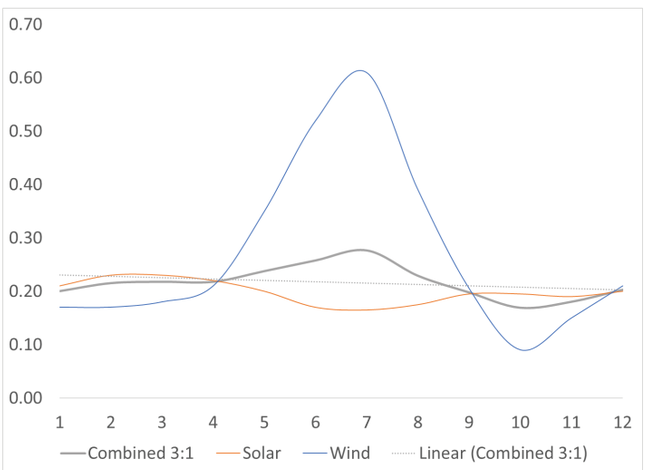
Wind does not always blow at the same speed for 24 hours a day, 365 days a year. Sometimes, the wind resources at a location changes seasonally. Sometimes, unexpected weather activities within the day decides how much wind is available. Because of this, a wind turbine might not always be operating at its nominal standard. There might be times when the wind turbine does not rotate at all due to the lack of wind. Also at slower wind speeds, the power production decreases dramatically. When the wind speed drops by half, power production decreases eight times.



Hybrid of Solar and Wind Energy

An increasingly popular solution to address the challenges of integration of renewable energy with the grid is a simple balancing approach in which the production of intermittent renewables such as wind and solar are monitored and intermixed to utilize the available energy from both sources at a given time. The approach allows the maximum possible power to be delivered by combining dominating and non-dominating resources of the time – and mitigates the intermittency of individual resources.

The CSTEP study estimates that nearly 10 GW of wind hybrid (with solar) potential is available. As of July 2022, only 1.38GW of Solar Wind Hybrid has been installed in Rajasthan.



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Key Takeaways

- **Power generation for solar PV plants is lowest in June and July. It is maximum in mid-Feb when skies are clear, and temperatures are not too high. As temperatures rise in summer, CUF falls. May being one of the hotter months has low CUF. CUF again starts increasing in Sept onwards. The average Capacity Utilization Factor (CUF) for solar plants is 22.2%. It is low because solar PV systems do not work at night. Power generation is higher when the sun is higher in the sky.**

- **For wind energy projects, generation is highest from May to August. Unlike solar, wind turbines can generate electricity at night. The average Capacity Utilization Factor (CUF) for wind energy plants is 25.2%. At slower wind speeds, the power production from wind turbines decreases dramatically. When the wind speed drops by half, power production decreases eight times.**

- **Output from solar and wind can be intermixed to reduce the variation in total power generated from the hybrid plant. About 10 GW of wind hybrid (with solar) potential is available across the country.**

5.4 Overcoming Dependence on Imported Solar PV Panels

Areas of focus in this sub-section

- **What is the extent of domination of China in the global solar panel manufacturing value chain?**
- **What are the disadvantages faced by Indian manufacturers vis-à-vis their Chinese counterparts?**
- **How does the PLI scheme aim to address this disadvantage issue?**
- **What other measures have the government implemented to protect Indian manufacturers against dumping by Chinese manufacturers?**

Global Monopoly of Chinese Companies in Solar PV Manufacturing

According to a IEA report published in August 2022, China's share in the entire solar panel manufacturing value chain (polysilicon, ingots, wafers, cells and modules) exceeds 80% globally.

Based on the current expansion plans, China will be responsible for 95% of the entire manufacturing process by 2025.

Last year, Chinese solar panel manufacturers increased solar panel prices by about 20% on the back of higher commodity prices and supply chain bottlenecks. Buyers across the globe were impacted by these price increases. However, India being the largest solar PV panel buyer, was impacted the most.

Given the geo-political tensions between India and China, the Indian government is rightly concerned about the situation.

https://www.downtoearth.org.in/news/energy/china-to-dominate-95-of-solar-panel-supply-chain-83651.

Factors that Impede Solar PV Panel Manufacturing in India

Chinese solar manufacturers enjoy the lowest costs in the world. The best Indian PV manufacturers report an overall 10 percent higher cost than Chinese producers. Large variations in energy, labour, investment and overhead costs account for these differences. For example, electricity used in PV manufacturing in China is priced at 30 percent below the global industrial average price of electricity. Also, Chinese PV producers obtain loans at extremely low interest rates of about 4 to 5 percent as compared to 11 to12 percent in India.

Therefore, factors that impede production of solar PV panels in India can be summarised as follows:

- Inferior terms of debt capital
- Higher electricity prices
- Lower scale of operations
- Lack of vertical integration
- The changing technological landscape

https://www.iea.org/reports/solar-pv-global-supply-chains/executive-summary

PLI for Manufacturing of Solar PV Modules in India

The PLI scheme would facilitate 29 GW capacity of fully integrated solar PV manufacturing plants, 18 GW plants integrated from wafers to modules, and 18 GW integrated over cells and modules plants. That comes to a total capacity build of 65 GW of modules.

Based on India's target of 280-300 GW solar energy capacity by 2030, for the remaining years up to 2030, domestic requirement will be 30-35 GW of modules, while the additional commissioned capacity will meet any higher domestic requirements as well help in acquiring share of export markets.

The PLI scheme will also help to create domestic manufacturing capacity for balance of materials like solar glass, backsheet, EVA (ethylene vinyl acetate), etc and give impetus to R&D to achieve higher efficiencies in solar PV modules.

https://www.india-briefing.com/news/manufacturing-high-efficiency-solar-pv-modules-india-investment-considerations-pli-scheme-25958.html/

Other Measures to Boost Manufacturing of Solar PV Modules in India

The other measures introduced by the government included an introduction of 25 percent import duty on solar cells and 40 percent import duty on photovoltaic modules, effective April 2, to encourage domestic manufacturing.

There are four stages in module making, namely, polysilicon, wafers, cells, and modules.

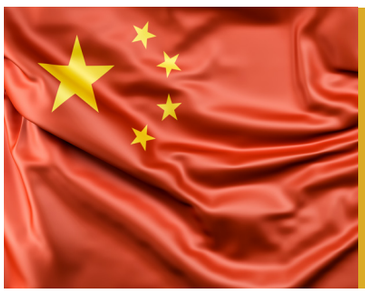
As a consequence of the PLI scheme and other measures, there has been a doubling of India's module manufacturing capacity – from 10 GW to 20 GW – and cell manufacturing capacity from 3 GW to 4.5 GW.

There are no polysilicon ingot or wafer production facilities currently in India.

Crucially, the PLI scheme and the above measures will result in import substitution of approximately ₹137,000-crore.

https://www.india-briefing.com/news/manufacturing-high-efficiency-solar-pv-modules-india-investment-considerations-pli-scheme-25958.html/

Key Takeaways



- China's share in the solar panel manufacturing value chain exceeds 80% globally. Based on the current expansion plans, China will be responsible for 95% of the entire manufacturing process by 2025.

- Inferior terms of debt capital, higher electricity prices, lower scale of operations and lack of vertical integration are some of the factors that raise the cost of production of solar PV panels in India. The best Indian PV manufacturers report an overall 10 percent higher cost than Chinese producers.

- The PLI scheme would facilitate 29 GW of fully integrated solar PV manufacturing plants, 18 GW plants integrated from wafers to modules, and 18 GW integrated over cells and modules plants, summing up to 65 GW.

- This would meet India's annual domestic requirement of 30-35 GW of modules, while the additional commissioned capacity will cater to export markets. The PLI scheme will also create domestic manufacturing capacity for solar glass, backsheet, EVA etc.

- The above measures will result in import substitution of approximately ₹137,000-crore.

5.5 Challenges faced by Indian Wind Energy Manufacturers

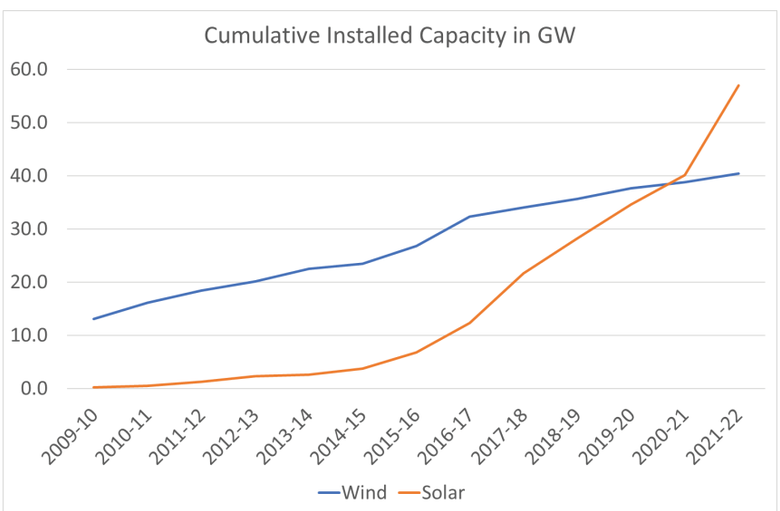
Areas of focus in this sub-section

- **How has wind energy fared in terms of installations as compared to solar energy in the last 13 years in India and why?**
- **How strong is India in terms of manufacturing of wind energy components?**
- **What has been the impact of reduction in solar power generation tariffs on the wind energy sector?**
- **At low tariffs, wind energy generation is only feasible at good wind energy sites. However, some of these have already been taken and are running outdated wind turbine models thus underexploiting the potential for these sites. Can repowering old turbines help in resolving this issue and support the wind energy manufacturing sector?**

Trend in Tariffs for Solar PV & Wind Energy

The adjacent figure shows that while wind energy had an early start in the 1990s, solar has grown aggressively since 2014-15 and has displaced wind as the leading source of RE in India.

Competition from solar energy is also pushing wind sector tariffs lower. The lowest wind tariff bid in 2021 was ₹2.84 per kWh. On the other hand, declining module prices have allowed solar power producers to bring down bids to as low as ₹2.14 per kWh.



https://www.irena.org/Data/View-data-by-topic/Capacity-and-Generation/Statistics-Time-Series

State of the Wind Energy Manufacturing Sector in India

- Wind energy in India has grown from 41 MW in 1992 to 40,000 MW in 2022 in terms of installed capacity.
- Around 70-80% indigenisation has been achieved in the manufacturing of wind energy systems. Several major global manufacturers have their presence in the country. As many as 17 companies produce upwards of 44 wind turbine models in India supported by almost 4,000 vendors.
- The unit size of machines has gone up to 3MW to 4MW and the current annual production capacity of domestic wind turbines is about 10GW to 12GW.
- But the local market has shrunk to about 1.0GW to 1.5GW per annum as the pace of capacity addition by wind power developers has reduced due to unfeasibility of projects at low tariffs.
- Most wind energy component manufacturers are struggling and many are using their plants for exports.

Low Tariffs Are Impacting Capacity Addition And Adversely Affecting Local Component Manufacturers

- The competitive bidding route was introduced by the central government in 2017 for awarding renewable energy projects. As a result of this system, bids reached historical lows for wind as well as solar projects.
- Such low bid prices have squeezed margins across the value chain to unsustainable levels. They allow no room for project cost escalations, which could occur due to various reasons such as delays in land acquisition, or changes in component prices, etc.
- Curtailment of power purchase by DISCOMs as well as delays in receiving payments from them are other factors that impact projects and developers have no room to deal with such issues.
- As a result of this, the commissioning and deployment of renewable power projects has got adversely affected and some projects have become financially unfeasible. In some cases, MNRE had to revise bids upwards to rescue developers.
- In order to support rapid capacity addition as well as nurture local component manufacturing industry, the MNRE is considering changes in the bidding structure. They are planning to introduce feed-in-tariffs for some projects. This system is likely to come into effect from April 2023.

Scarcity of Good Wind Energy Sites at Existing Tariff Rates With Current Technology and Costs

- Solar energy can be tapped from any site. However, this is not the case with wind. Sustained good wind speeds are available only at some places across the country.
- The top windy states in India are Gujarat and Tamil Nadu. Apart from these, other windy states include Andhra Pradesh, Karnataka, Maharashtra, Rajasthan and Madhya Pradesh. These 7 states account for more than 95% of wind energy potential in India.
- At current low tariffs, developers are only willing to deploy projects in two wind rich states of Gujarat and Tamil Nadu.

- However, advances in wind turbine technology promise to overcome this hurdle. Wind turbines with larger rotor diameters sweep more area, capture more wind, and produce more electricity—even in areas with relatively less wind. Being able to harvest more wind at lower wind speeds can increase the number of areas available for wind development nationwide.

The Need to Repower Old Wind Turbines

- Roughly 10.5 GW of India's installed wind capacity was commissioned with wind turbine of sizes under 1 MW. Most of these older and smaller turbines occupy the top wind sites, underleveraging the country's wind energy resource.
- Wind turbine technology has advanced in the last decade with improved rotor diameters, turbine sizes and hub heights. For example, the Siemens Gamesa SG3.6 145 is the largest wind turbine manufactured in India. It has a rotor diameter of 145m , a turbine capacity of 3.6MW and stands at a hub height of 127.5m.
- The government has in October 2022 announced the policy for Repowering of Older Wind Turbines of less than 2 MW capacity with modern turbines could massively boost India's wind power generation, adding up to 25GW of new capacity.
- This policy is likely to give a major boost to the wind energy manufacturing sector in India.

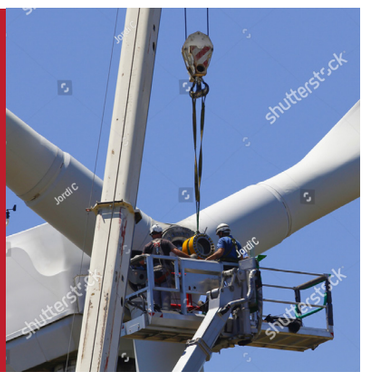
Why is Repowering of Old Wind Turbines not taking off?

- The lack of financial incentives is one of the reasons for failure to repower wind sector until now. In the early years of wind power deployment, many people pooled resources to own wind farms. Such multiple ownership of wind farms and lands poses a challenge as not every owner is willing to reinvest as they continue to get revenue from the old turbines.
- DISCOMs too had imposed limits on capacity addition as they do not have adequate electricity infrastructure to carry the extra power and are unwilling to upgrade capacity unless financial incentives are offered.
- The government has tried to address these challenges in its policy and has offered solutions and alternatives that could help in successful implementation of the policy.

Key Takeaways

- **Solar has grown aggressively since 2014-15. Competition from solar energy is also pushing wind sector tariffs lower.**

- **Around 70-80% indigenisation has been achieved in the manufacturing of wind energy systems in India. As many as 17 companies including several major global manufacturers produce upwards of 44 wind turbine models in India supported by almost 4,000 vendors.**



- **The current annual production capacity of domestic wind turbines is about 10GW to 12GW. But the local market has shrunk to about 1.0GW to 1.5GW per annum as the pace of capacity addition by wind power developers has reduced due to unfeasibility of projects at low tariffs.**

- **Repowering of Older Wind Turbines could open up a major opportunity for wind farm owners and wind turbine manufacturers by adding nearly 25GW of new wind power capacity at high wind power potential sites.**

5.6 Distribution Company Dues and Financial Health

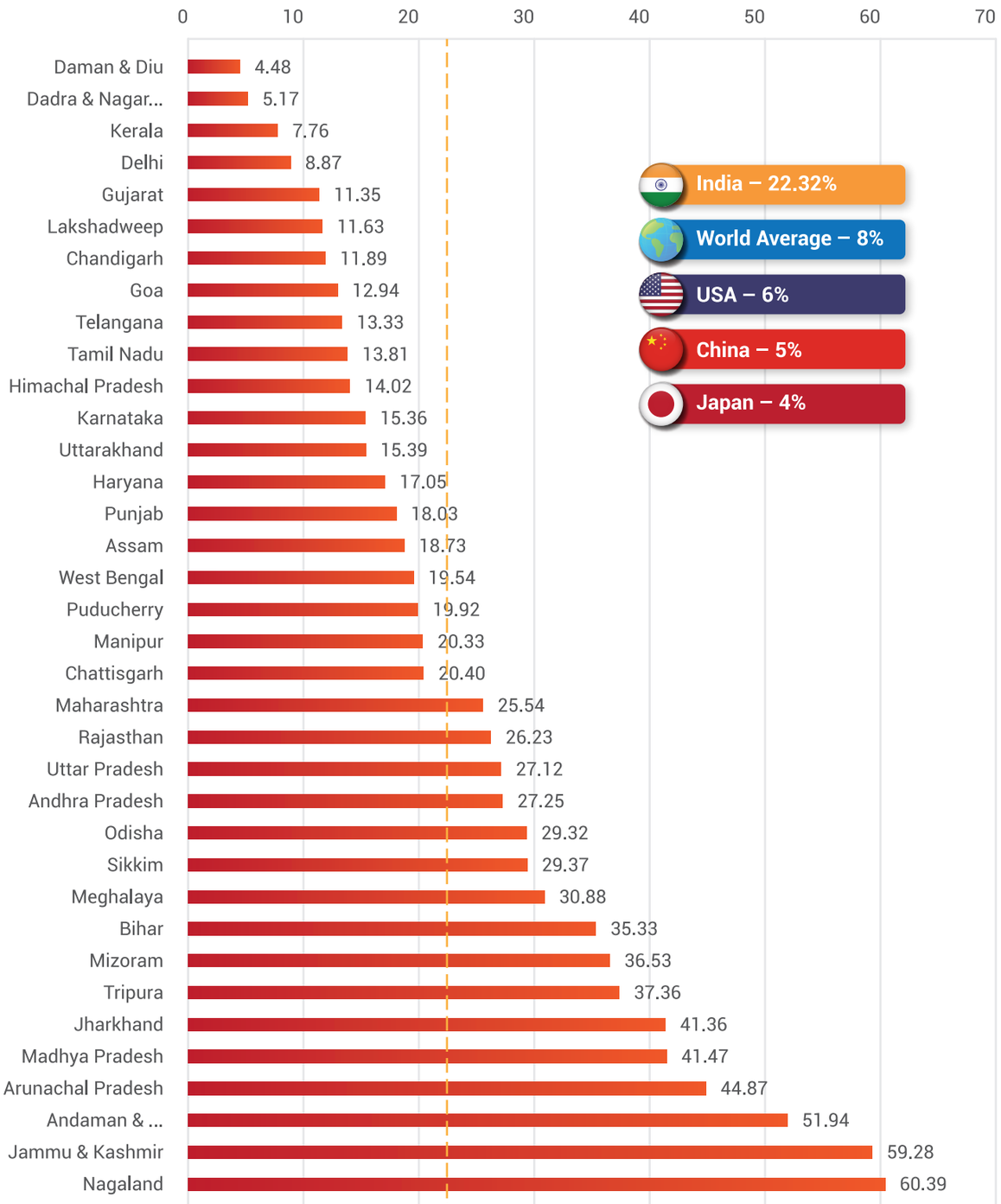
Areas of focus in this sub-section

- **What is the debt burden on the state power distribution sector? How did these entities reach such a state?**
- **Which states are incurring high aggregate technical & commercial (AT&C) losses? How does it compare with other countries in the world?**
- **What is the average cost of supply (ACS) per unit of power? What is the average revenue realized (ARR)?**
- **How does the Centre intend to reform the power distribution sector?**
- **What drastic steps are being taken in case of DISCOMs that have not yielded to reason?**

Dues owed by Distribution Companies to Power Generation Companies

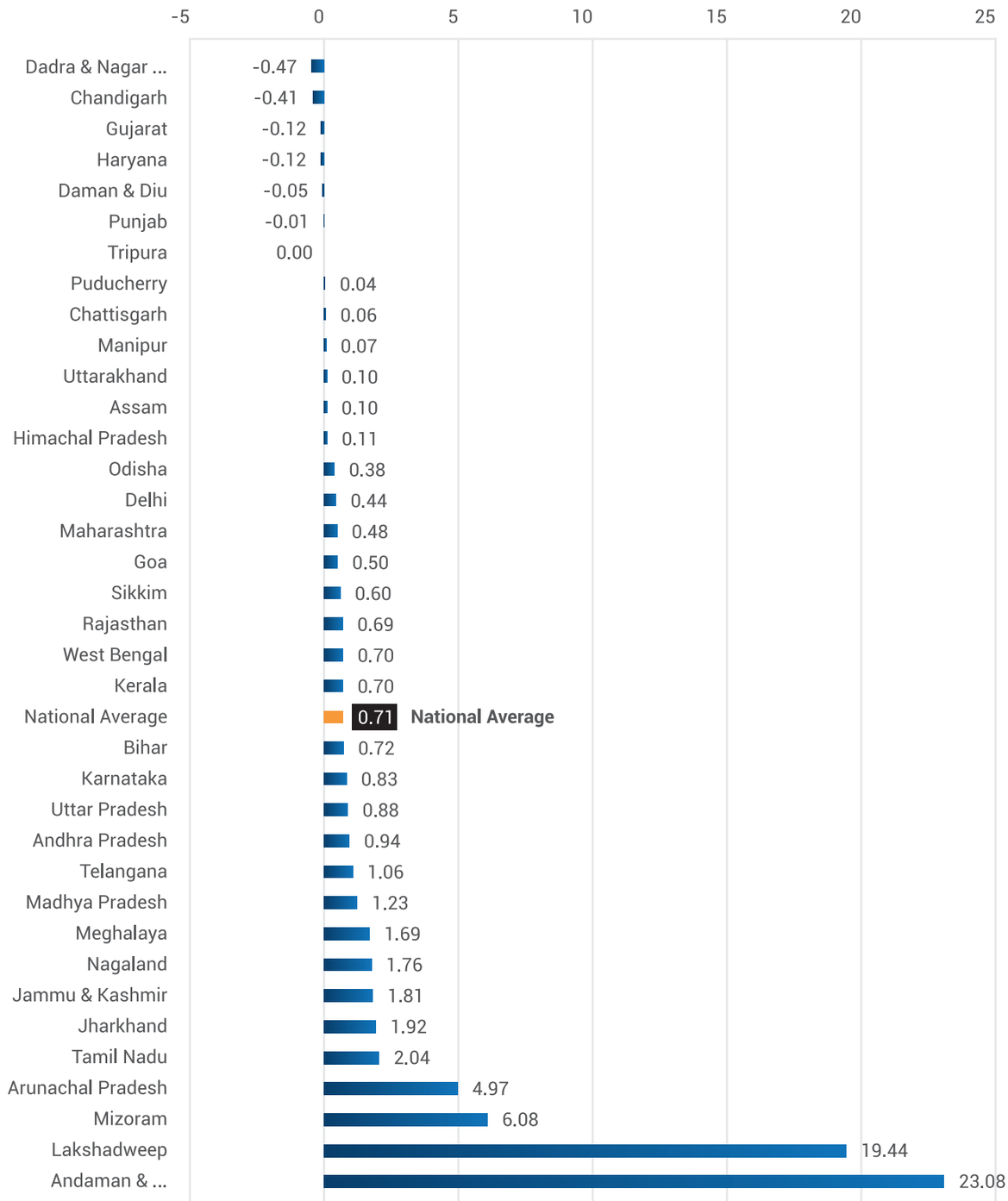
- Power Distribution remains the most critical link in the power sector value chain. It generates cash that feeds to the entire value chain right up to power generation and fuel supply. The impact of any inefficiency or financial mismanagement within power distribution flows to all upstream players in the value chain which adversely affects their operations and financial viability.
- State political parties often use the promise of free/ subsidized electricity to win votes, knowing well that such a step is unfeasible financially. This results in DISCOMs not being able to realize revenues for the power supplied.
- One of the important issues facing the power sector is the mounting dues owed by Distribution Companies (DISCOMs) to Generation Companies. It stands at an alarming level of Rs. 113,000 crores as on Aug 2022.

Aggregate Technical and Commercial (AT&C) losses 2020-21



https://pfcindia.com/Home/VS/29

ACS–ARR gap for 2020–21



https://pfcindia.com/Home/VS/29

Electricity (Amendment) Bill 2022

- In a bid to reform the power sector, the central government has introduced the Electricity (Amendment) Bill, 2022. The main provision of the bill is to provide consumers with options to choose between multiple service providers in an area and create competition in the power distribution sector.
- The Electricity (Amendment) Bill, 2022 was tabled in the Lok Sabha on August 8, 2022. However, due to reservations from Opposition parties, it was referred to the Parliamentary Standing Committee on Energy for scrutiny.
- The Bill also has a strong clean energy component with clear penalties (₹0.25 paise to ₹0.50 paise per kilowatt) for non-compliance of Renewable Purchase Obligations (RPOs).

Measures Taken by Government of India to Reform Distribution Companies – TANGEDCO's Example

- A agreement was signed between GoI, GoTN (Government of Tamil Nadu) and TANGEDCO in January 2017 under the Ujwal DISCOM Assurance Yojana (UDAY) Scheme for the financial turnaround of TANGEDCO.
- However, due to refusal of GoTN to honour its obligations, and the increase in borrowings for generation projects and working capital, TANGEDCO's outstanding debts increased from ₹81,000 crore (September 2015) to 145,000 crore by August 2022.
- At this point the Reserve Bank of India asked Rural Electrification Corporation (REC) and Power Finance Corporation (PFC) not to provide any further loans to Tangedco.
- Following the RBI decision, thermal projects at Uppur and Udangudi were stalled. With Tamil Nadu having only 4,314 MW of thermal capacity, meeting future power demands will be difficult unless additional thermal capacity is added.
- Due to non-payment of dues, Tangedco was also among 13 state electricity distribution agencies that were barred from purchasing power from the Electricity Exchange.
- With no way out, the GoTN in September 2022 finally gave approval to revise tariffs (last revised in December 2014) by 6% or based on inflation rate whichever is higher, every year till 2026-27.
- However, it retained the existing scheme of providing 100 units free to domestic, multi-tenements, old age homes, and handlooms consumers.
- Domestic consumers will now pay a minimum of ₹4.50 per unit consumed up to 400 units, as against ₹3 per unit up to 500 units earlier, going up to ₹11 per unit for consumption above 1,000 units.
- Tariff for the high-tension consumers has been hiked from ₹6.50 per unit to ₹12 per unit power.
- Currently the gap between the Average Cost of Supply (ACS) and Average Revenue Realised (ARR) is currently ₹1.04 per unit, however, it is likely to be brought down by revision of tariffs.

Key Takeaways

- Power Distribution remains the most critical link in the power sector value chain. It generates the cash that feeds the entire value chain. Inefficiency or financial mismanagement within power distribution sector flows to all upstream players in the value chain which adversely affects their operations and financial viability.

- DISCOMs across the country owe an alarming Rs. 113,000 crores to Generation Companies.

- In a bid to reform the power sector, the central government has introduced the Electricity (Amendment) Bill, 2022. The main provision of the bill is to provide consumers with options to choose between multiple service providers in an area and create competition in the power distribution sector.
- The Electricity (Amendment) Bill, 2022 has been referred to the Parliamentary Standing Committee on Energy for scrutiny.

- The Bill also has a strong clean energy component with clear penalties (₹0.25 paise to ₹0.50 paise per kilowatt) for non-compliance of Renewable Purchase Obligations (RPOs).

5.7 Upgradation of Transmission Grid Infrastructure

Areas of focus in this sub-section

- **Why is transmission infrastructure critical to the growth of the renewable energy sector in India?**
- **What measures have been taken to improve the Intra State Transmission System?**

Upgradation of Transmission Grid Infrastructure

- The country's weak transmission grid remains a serious hurdle for renewable energy projects, which are forced to halt in the advanced planning phases due to transmission line upgrade delays and associated costs.
- Since renewable energy projects are typically located in distant places far from major cities, transmission is critical.
- Recently a project to build huge solar plants in Leh was cancelled due to a lack of transmission infrastructure.

Green Energy Corridor Phase-1

- The Green Energy Corridor Project aims at synchronizing electricity produced from renewable sources, such as solar and wind, with conventional power stations in the grid.
- The Intra State Transmission System (InSTS) project is being implemented by 8 renewable-rich states of Tamil Nadu, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh, and Madhya Pradesh.
- The purpose is to evacuate over 20GW of large-scale renewable power and improvement of the grid in the implementing states.
- The total project cost is Rs. 10141 crores.
- Status of implementation of the project as on 31 Oct 2021 is shown in adjacent table.

State	Lines Target (ckm)	Line constructed (ckm)	Substations Target (MVA)	Substations Changed (MVA)
Tamil Nadu	1,068	1,058	2,250	1,850
Rajasthan	1,054	984	1,915	1,915
Andhra Pradesh	1,073	696	2,157	635
Himachal Pradesh	502	456	937	353
Gujarat	1,908	1,320	7,980	3,660
Karnataka	618	565	2,702	2,490
Madhya Pradesh	2,773	2,714	4,748	4,365
Maharashtra	771	612	--	--
Total	**9767**	**8,405**	**22,689**	**15,268**

https://mnre.gov.in/green-energy-corridor/

Green Energy Corridor□Phase-2

- It will facilitate grid integration and power evacuation of approximately 20 GW of Renewable Energy (RE) power projects in 7 States namely, Gujarat, Himachal Pradesh, Karnataka, Kerala, Rajasthan, Tamil Nadu and Uttar Pradesh.
- The transmission systems will be created over a period of five year from Financial Year 2021-22 to 2025-26.
- It is targeted to be set up with a total estimated cost of Rs. 12,031 crores
- The scheme is for addition of 10,753 circuit kilometres (ckm) of transmission lines and 27,546 Mega Volt-Amperes (MVA) capacity of substations
- Breakup of targets by state is shown in adjacent table.

State	State Length of transmission lines (ckm)	Capacity of substations (MVA)
Gujarat	1,068	1,058
Himachal Pradesh	1,054	984
Karnataka	1,073	696
Kerala	502	456
Rajasthan	1,908	1,320
Tamil Nadu	618	565
Uttar Pradesh	2,773	2,714
Total	**9767**	**8,405**

https://powermin.gov.in/en/content/green-energy-corridor

Key Takeaways

- **Since renewable energy projects are typically located in distant places far from major cities, transmission is critical.**

- **The Green Energy Corridor Project is aimed at synchronizing electricity produced from renewable sources, with conventional power stations in the grid. This project involves laying transmission lines and sub-stations. It is being implemented by renewable-rich states.**

- **Phase 1 of this project is near completion and phase 2 has been started.**

5.8 Research to Stay Ahead of the Renewable Energy Technology Curve

Areas of focus in this sub-section

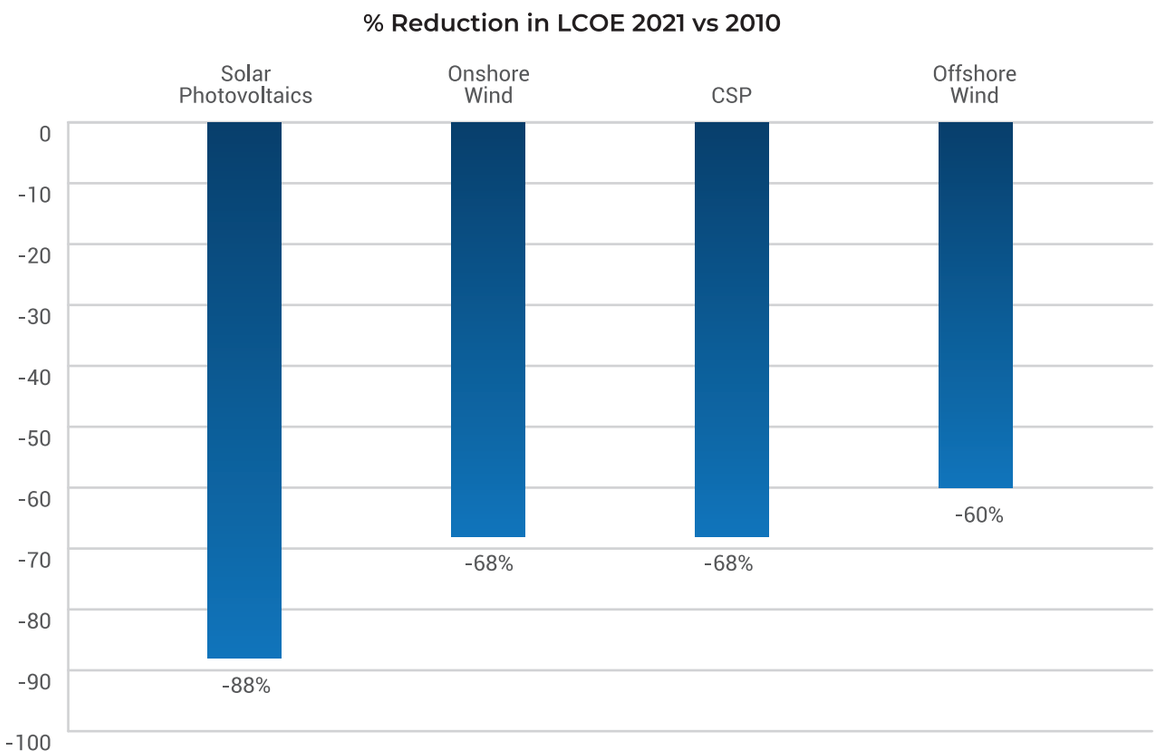
- What are the critical areas of research in the renewable energy sector?
- How have advances in R&D helped bring down the cost of generation for renewable energy?
- How can nations gain competitive advantage over others?
- How is India performing on the Global Innovation Index?

Technological Advances in Renewable Energy

Critical areas of research in the renewable energy sector include:

1. New technologies of energy conversion, storage and utilization have been brought to the fore to achieve environmental sustainability.
2. The cost of electricity generation has been brought down considerably. Advances have been made in reducing the cost of electricity storage, though more is needed.
3. New production methods are being employed to solve technological limitations of existing production methods.
4. Materials with better properties are being discovered and employed to increase the efficiency of energy conversion and storage.
5. Digitization tools are expected to be employed in managing the grid, decentralising supply and demand, and in trading of energy. Decentralisation will help in reducing energy transmission losses.
6. AI and Machine Learning are expected to help in predicting changes in supply and demand.

The Impact of Advances in Renewable Energy Technology



https://www.irena.org/Data/View-data-by-topic/Costs/Global-Trends

Gaining Competitive Advantage

Michael Porter in "Competitive Advantage of Nations" notes that

"A nation's competitiveness depends on the capacity of its industry to innovate and upgrade. Companies gain advantage against the world's best competitors because of pressure and challenge. They benefit from having strong domestic rivals, aggressive home-based suppliers, and demanding local customers."

India is a large market with nearly one-sixth of humanity living here. There is little scarcity of demand for any product or service, which in a way reduces the pressure to innovate. It also reduces the incentive to seek and compete in export markets.

Recently, however, India has made significant strides in improving its rank on the Global Innovation Index. The 2022 edition released in September 2022 positions India at 40 globally among 132 nations.

Government support can help industry only to a certain extent. Manufacturing has been India's weakness and this is especially true for high-tech products. In a highly globalised economy, gaining competitive advantage will only be possible if companies innovate and lead. Companies must invest in R&D and bring the most advanced products to market. Doing this will help them lead nationally as well as gain substantial footprint in export markets.

https://hbr.org/archive-toc/3902
https://www.wipo.int/global_innovation_index/en/2022/

Key Takeaways

- **New technologies of energy conversion, storage and utilization have been brought to the fore to achieve environmental sustainability.**

- **The cost of electricity generation has been brought down considerably. Advances have been made in reducing the cost of electricity storage, though more is needed.**

- **The levelized cost of electricity for all renewable energy technologies has decreased significantly in 2021 as compared to 2010.**

- **In order to stay competitive in this high-tech industry, companies must invest in R&D and bring the most advanced products to market.**

5.9 Challenges to the Adoption Of Rooftop Solar

Areas of focus in this sub-section

- **How much electricity can be generated in India through large-scale adoption of rooftop solar?**
- **What are the obstacles in its path?**
- **Which customer segments lead in the adoption of rooftop solar systems?**
- **Which states are most supportive to the adoption of rooftop solar systems? And how do various states compare in terms of installed capacity?**
- **What steps is the Centre taking to ensure rooftop solar targets for states are met?**
- **What is Open Access market for renewable energy? How would Open Access accelerate the adoption of renewable energy?**

The Promise of Rooftop Solar

- High resolution global spatiotemporal assessment of rooftop solar photovoltaics potential for renewable electricity generation indicates that 27,000 TWh of electricity can be generated worldwide per year through 100% adoption of rooftop solar for costs between US$ 40–280 per MWh.
- The cost of attaining the potential is lowest in India (US$ 66 per MWh) and China (US$ 68 per MWh).
- USA (US$ 238 per MWh) and UK (US$ 251 per MWh) represent some of the costliest countries to attain this potential.
- Electricity generation potential is highest in China at 4,300 TWh per year, followed by the USA at 4,200 TWh per year, and India at 1,700 TWh per year.
- Findings from this study indicate that if 100% rooftop solar potential is tapped in India, it could easily meet India's 2021 annual electricity needs of 1,492 TWh.

Challenges to the Adoption of Rooftop Solar Systems

- Rooftop solar faces the following challenges:
- Most DISCOMs in India make adoption of rooftop solar by its consumers an uphill task. However, differences exist due to circumstances of individual states.
- For example, Kerala is actively supporting the rooftop solar programme as the state does not have enough land for utility solar and it imports 70% of its electricity needs from other states or from the national grid.

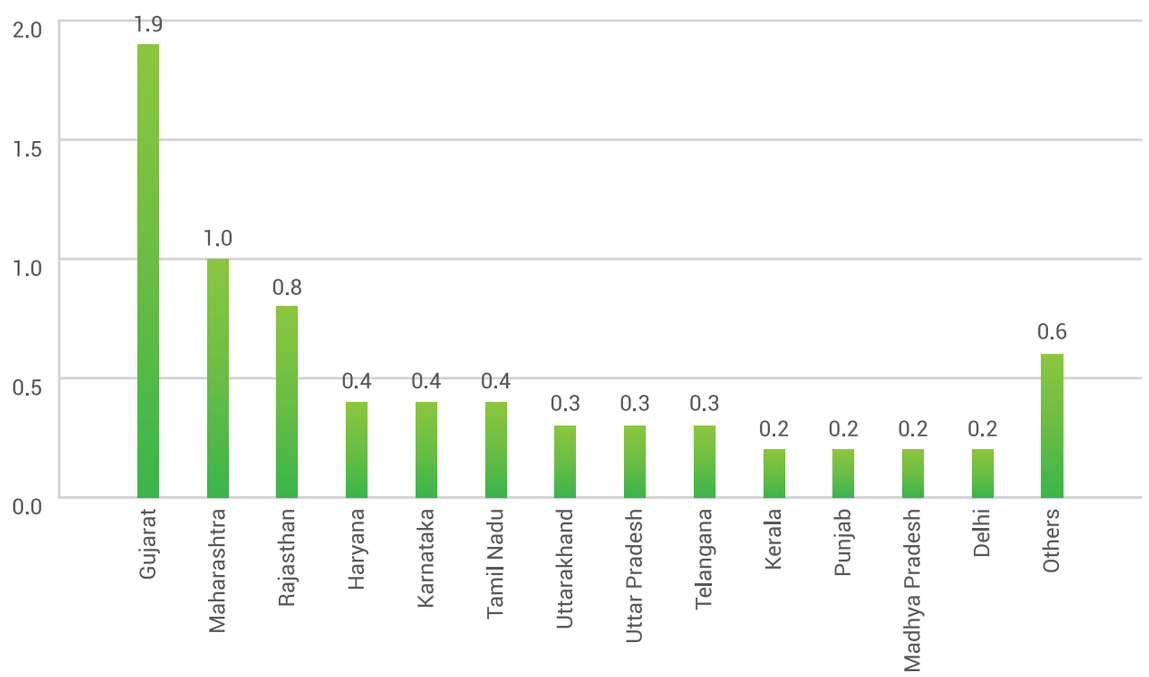
https://www.nature.com/articles/s41467-021-25720-2

- Similarly New Delhi Municipal Council (NDMC) intends to provide 100% renewable energy by 2025. It will support deployment of grid connected solar systems of 1kWp or more capacity with net metering on all government buildings, hospitals, educational institutes, embassies, stadiums, bridges, public toilets, bus stops, and kiosks.
- Other challenges include time and effort required to obtain approvals, high upfront cost of installations, obstacles in obtaining government subsidies and frequent changes in policies by DISCOMs.

Trends in Adoption of Rooftop Solar by Customer Segment

- Currently more than 50% of rooftop capacity installations has happened in the industrial segment, 29% in commercial segment and 21% in residential segment.
- It is comparatively easier for commercial and industrial (C&I) clients to get rooftop solar systems installed than residential clients because they can deploy time, manpower, funds and influence to expedite the process.
- Another factor that facilitates faster adoption of rooftop solar by C&I clients is the tariff rate charged to C&I customers. C&I customers often subsidise electricity used by residential consumers and pay a significantly higher tariff to DISCOMs. So it makes a lot of economic sense for them to adopt rooftop solar and reduce their operating costs.
- Besides, moving to renewable energy is a source of pride for corporate consumers and helps them achieve net-zero targets.

Adoption of Rooftop Solar by State (7.1 GW by July 2022)



Key Takeaways

- The annual rooftop solar electricity generation potential in India is about 1,700 TWh, which is more than India's 2021 annual electricity needs at 1,492 TWh.

- Most DISCOMs in India make adoption of rooftop solar by its consumers an uphill task. However, differences exist due to circumstances of individual states.

- A key factor supporting the faster adoption of rooftop solar by C&I clients is the significantly higher tariff charged to C&I customers by DISCOMs. Shifting to rooftop solar helps them to reduce their energy costs.

- Adoption of rooftop solar has been highest in Gujarat, followed by Maharashtra, Rajasthan, Haryana, Karnataka and Tamil Nadu.

- The Electricity (Amendment) Bill, 2022 will make it mandatory for all states to ensure that a certain percentage of electricity demand in their state is met from renewable energy sources.

- The Ministry of Power has streamlined Open Access approval process. The rules also provide certainty on other open access charges to be levied on consumers.

6. Companies in Renewable Energy Generation

Generation Companies	Installed Capacity (GW)	2030 Target Capacity (GW)	Net Additions (GW)	Promoter/ Shareholders
Reliance New Energy	-	100	100	Reliance Industries
NTPC Limited	5.7	60	54	Government of India (GoI)
Adani Green Energy	5.8	45	39	Adani Group
Renew Power	7.6	25	17	Goldman Sachs, CPPIB
Tata Power	4.9	25	20	Tata Group
ACME Solar	2.9	25	22	Acme group
Greenko Group	7.2	22	15	ADIA
JSW Energy	4.7	20	15	JSW Group
SJVN	2	17	15	Government of India (GoI)

Source: IEEFA

Generation Companies	Installed Capacity (GW)	2030 Target Capacity (GW)	Net Additions (GW)	Promoter/ Shareholders
Ayana Renewables	4	10	6	NIIF
Sembcorp Green Infra	1.7	10	8	Sembcorp Industries Singapore
Azure Power	2.9	7.4	5	CDPQ Canada
NLC India	1	6	5	Government of Tamil Nadu
Amp Energy India	2	5	3	Amp Energy Canada, CIP
Hero Future Energies	1.6	5	3	Hero Group
Fourth Partner Energy	1.5	3	2	Norfund, TPG
Radiance Renewables	0.2	2	2	Eversource Capital, NIIF
Net Additions	**56**	**287**	**231**	

Source: IEEFA

7. Renewable Energy Manufacturing Landscape and Technical Knowhow by Stage and Component

7.1 Solar Module Manufacturing Companies

Generation Companies	Existing Capacity (GW)	Additional GW by 2026	Total Capacity (GW)
Waaree	9	3	12
Reliance		10	10
Shirdi Sai Electricals		10	10
Vikram Solar	3.5	3.8	7.3
Others	7		7
Goldi	2.5	3.5	6
Premier	1.6	3.4	5
ReNew		4.8	4.8

https://pfcindia.com/Home/VS/29

Generation Companies	Existing Capacity (GW)	Additional GW by 2026	Total Capacity (GW)
RenewSys	1.75	3	4.75
Adani (Mundra)	4		4
Grew Energy		4	4
Rayzon	1.5	2.5	4
Tata Power Solar		4	4
Solex	1.2	2.5	3.7
Navitas	0.5	3	3.5
First Solar		3.4	3.4
Emmvee	1.25	1.8	3.05
Avaada		3	3
Jakson	0.6	2.4	3
Saatvik	1.5	1	2.5
Bharat Vikas Group		2	2
Jupiter Solar		2	2
Websol		1.8	1.8
Gautam Solar	0.5	1	1.5
Pahal	0.9		0.9
Insolation	0.7		0.7
Total	**38**	**75.9**	**113.9**

While the existing nameplate module manufacturing capacity is 38 GW in 2023, the high wattage module capacity is only about 27 GW. Currently the actual production of high wattage modules is only about 13.5 GW. By 2026, the solar module manufacturing capacity is likely to reach 114GW. Typically, the capex of a mono PERC module manufacturing line is about Rs1 billion (~US$13 million) per GW.

https://pfcindia.com/Home/VS/29

Additional PV Module Manufacturing Capacity by 2026, by State

State	Additional Capacity Expected by 2026 GW
Gujarat	43.3
Telangana	5.3
Rajasthan	4.6
Andhra Pradesh	4.6
Tamil Nadu	4.6
Others	13.7
Total	**75.9**

7.2 Solar Cell Manufacturing Companies

- The operational cell manufacturing capacity in March 2023 is estimated to be 50% (or less) than the nameplate capacity of 6.575 GW.
- Nearly 52GW of additional cell manufacturing capacity is expected to come online in India by 2026. Five manufacturers — Reliance, Waaree, Goldi Solar, Shirdi Sai Electricals and Tata Power Solar are expected to account for 58% of this new capacity.
- Some other prominent players looking to set up new cell manufacturing lines include Vikram Solar, ReNew, Emmvee, Premier Energies and Solex. Grew Energy plans to build a 2GW cell manufacturing facility by 2026.
- Existing players, such as Jupiter and Websol, are also expanding their operational cell capacities.
- By 2026, the manufacturing capacity for solar cells is likely to reach 59 GW.
- A mono PERC cell manufacturing line typically costs Rs5 billion (~US$65 million) per GW. MonoPERC is the most popular cell technology currently in use. Mono PERC lines can typically be upgraded to TOPCon technology in future.

Generation Companies	2023 Capacity GW
Adani	4
Jupiter Solar	0.8
Premier	0.75
Tata Power Solar	0.53
Websol	0.25
RenewSys	0.13
BHEL	0.105
BEL	0.01
Total	**6.575**

Current Status of PV Manufacturing Facilities of Beneficiaries of PLI - 1

Company	Capacity	Technology	Land Procurement	Location
Shirdi Sai	4GW	Mono PERC + TOPCon	Completed (5147 acres)	Nellore Andhra Pradesh
Reliance New Solar Energy	10GW	HJT	Completed (~5,000 acres)	Jamnagar, Gujarat
Adani Infrastructure	10GW (4GW already operational)	Mono PERC + TOPCon	Completed	Mundra, Gujarat

Company	Equipment Procurement	Date of Commissioning	Proposed Expansion
Shirdi Sai	Under Progress	April 2024 10GW	10 GW
Reliance New Solar Energy	Done	2024	20GW, 2026 onwards
Adani Infrastructure	Under Progress	2024	

Source: JMK Research

7.3 Ingot/ Wafer Production

Ingot/ Wafer Production

- While there are more than 70 companies producing modules, this number drops to just 8 when it comes to manufacturing solar cells and to "zero" for ingot/ wafer production.
- However, Adani Solar plans to bring online 2GW of ingot/ wafer production capacity by the end of 2023, which it intends to scale up to 10GW by 2025. Adani will be India's first manufacturer of monocrystalline silicon ingots, capable of producing M10 (182mm) and M12 (210mm) size wafers. Adani Solar will exclusively use these ingots to produce its modules. Reliance is also likely to enter wafer production.
- Emmvee Photovoltaic also plans to set up 1.5GW of wafer-to-module capacity by the end of 2023.
- The manufacturing capacity for ingots/ wafers is likely to reach 56GW.

7.4 Polysilicon Production

Polysilicon Production

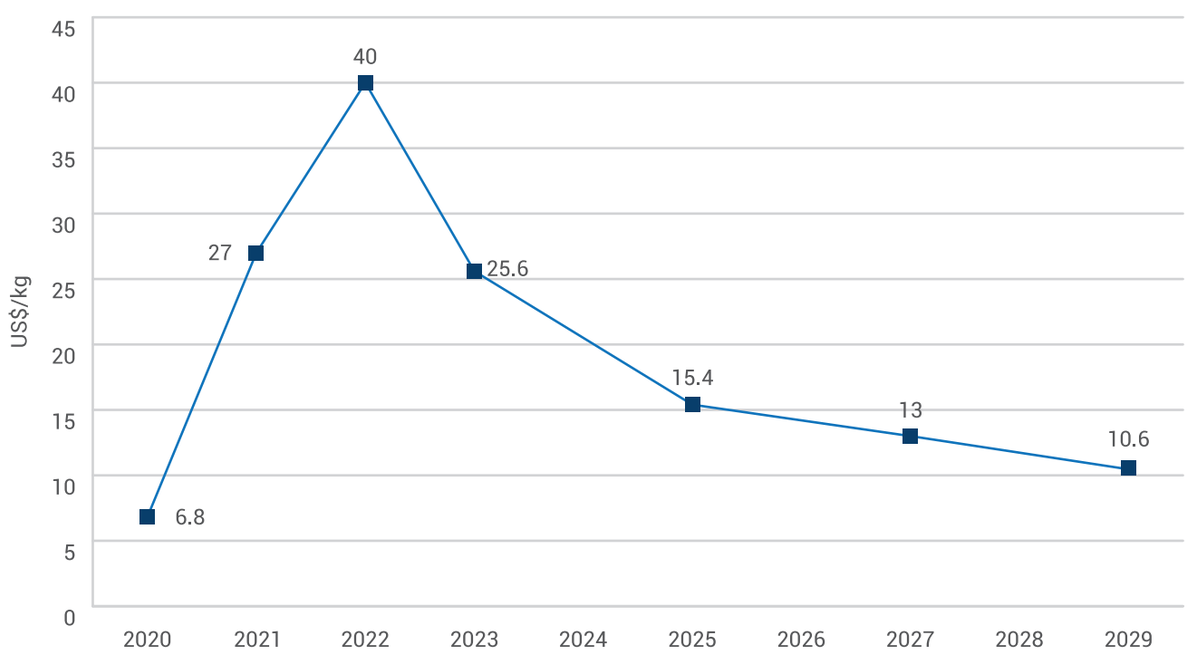
- Currently there is no polysilicon production in India. However, by 2026, manufacturing capacity for polysilicon is likely to reach 38GW.
- The capex requirement for Polysilicon production is very high. For example, setting up a polysilicon manufacturing facility to produce 1GW of solar modules can cost approximately US$100–150 million.
- Setting up a polysilicon factory takes at least two to four years. The considerable infrastructure investment makes any polysilicon facility of less than 3-4GW financially unviable.
- Due to the higher initial capex and higher industrial electricity prices, it is more expensive to build and operate a polysilicon factory in India vis-à-vis China (see next slide).
- Indian manufacturers are therefore apprehensive about entering polysilicon production.
- Those that have announced plans to enter the Polysilicon segment (such as Adani and Reliance) may use a large proportion of their polysilicon production mostly for their own plants.

Polysilicon Production Parameters (India vs China)

Parameter	India	China
Cost to develop (per GW)	US$130 million	US$60 million
Polysilicon nameplate capacity (2022)	0	340GW
Proposed polysilicon capacity (by 2026)	38GW	637GW
Industrial electricity prices	US$100/ MWh	US$60–80/MWh

Source: IEA, JMK Research

Polysilicon Price Forecast



Source: PwC analysis, PV Infolink

7.5 PV Machinery

Currently, there is high reliance on imports for PV machinery from China. Thus, in the event of breakdowns or process fine-tuning, etc., there is an understated overreliance on spare parts/assistance from the PV machinery supplier.

Supplier	Importer	Order Date	Country of Origin	Capacity (GW)	Type
SC-Solar	Reliance New Energy	Jan-23	China	5.2GW	Module (HJT)
Jinchen Machinery	All major tier-1 Indian Manufacturers	H1 2022	China	18GW	Module
Maxwell	Reliance New Energy	Apr-22	China	4.8GW	Cell (HJT)
Centrotherm	6 different Indian manufacturers	Dec-22	Germany	10GW	Cell (Mono PERC)

7.6 Ancillary Products Manufacturing

While there are some companies manufacturing ancillary products in India, however, in most cases there is a high reliance on imports.

List of Important Solar PV Ancillary Products

- Aluminium Frames
- Backsheet
- Battery
- Crucibles
- Cutting Wires
- DC and AC Cables
- EVA
- Graphite parts
- Inverters
- Junction Box
- Low Iron Glass
- MG Silicon
- Module Mounting Structure
- Monosilane gas
- Silicon Carbide
- Silver Paste
- Tabbing Wires
- Trackers
- Transformer (Grid/Distributed)
- Blocking diode, charge controller, circuit breaker, switch gear

7.7 Wind Turbine Manufacturers

Company	Base
PASL Windtech	Ahmedabad
Suzlon	Ahmedabad
Global Wind Power Limited	Mumbai
NuPower Technologies Private Limited	Mumbai
Senvion Wind Technology	Mumbai
Power Wind Limited	Gurgaon
RRB Energy	New Delhi
Inox Wind limited	Noida
Envision Wind Power Technologies	Bangalore
GE Wind Energy Limited	Bangalore
Nordex India Private Limited	Bangalore
Emergya Wind Turbine	Chennai
Indowind Energy Limited	Chennai
Leitwind Shriram	Chennai
Orient Green Power Limited	Chennai
Pioneer Wincon	Chennai
Regen Powertech	Chennai
Siemens Gamesa Renewable Power	Chennai
Southern Wind Farms	Chennai
Vestas India	Chennai
WinwinD Power	Chennai
Siva Wind Turbine India	Perundurai

Components of Wind Turbines That Are Mostly Imported

- Pitch Systems
- Electrical Control Systems
- Castings/ Pitch bearings
- Generators/ Generator frame
- Rotor Magnets
- Power Capacitors
- Yaw Systems
- Anemometer
- Converter Systems
- Tower Flanges

Key Takeaways

- **In this section, we briefly examined the landscape for manufacturing of solar and wind energy components including machinery. Each of these products represents an opportunity with high business potential and each of these must be researched individually in future publications.**

8. Conclusions

Innumerable Opportunities On The Path to Net-Zero

Energy and Mobility

- Energy Storage
- Electric vehicles
- Shipping and Air Travel
- Super-efficient appliances
- Energy efficiency
- Green hydrogen

Other Sectors to Decarbonize

- **Industry**
- **Agriculture**
- **Buildings**

Aggregate Generating Capacity Required in India in GW in the "2040 Peak - 2070 Net-Zero" Scenario

Aggregate Generating Capacity Required (GW)	2031	2040
Solar	333	540
Wind	134	211

Source: CEEW-CEF analysis

Total Investments in US$ Billion Needed for Power under the 2040 Peak – 2070 Net-zero

2040 Peak – 2070 Net-Zero	2020-30	2030-40
Power		
Generation	380	560
Integration	8	25
T&D	132	223
Power Total	**520**	**808**

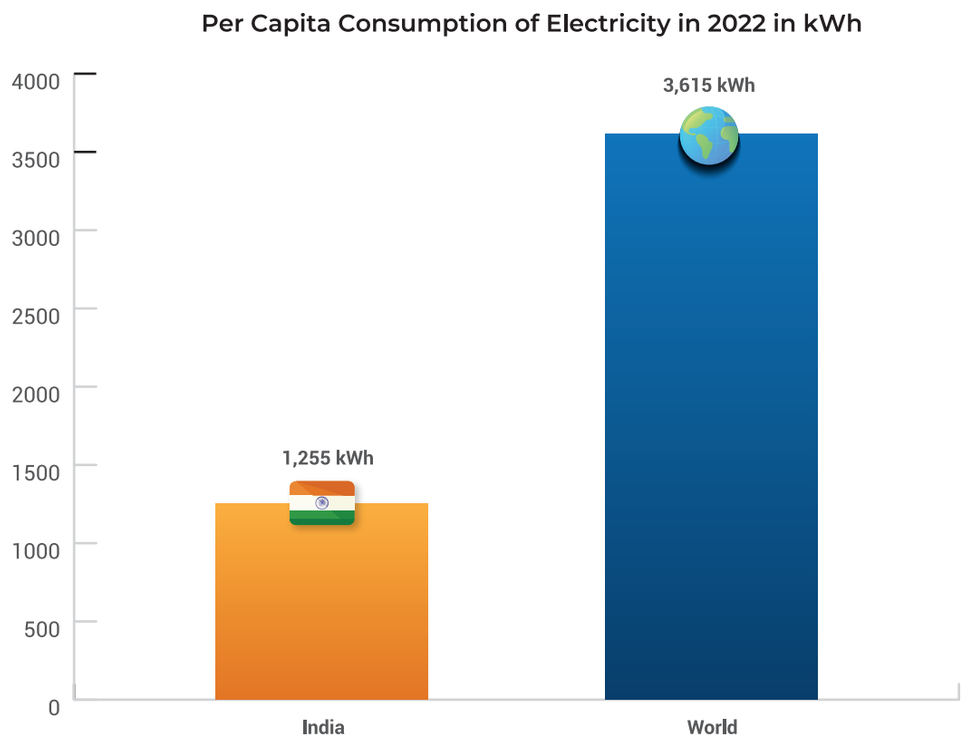
Source: CEEW-CEF analysis

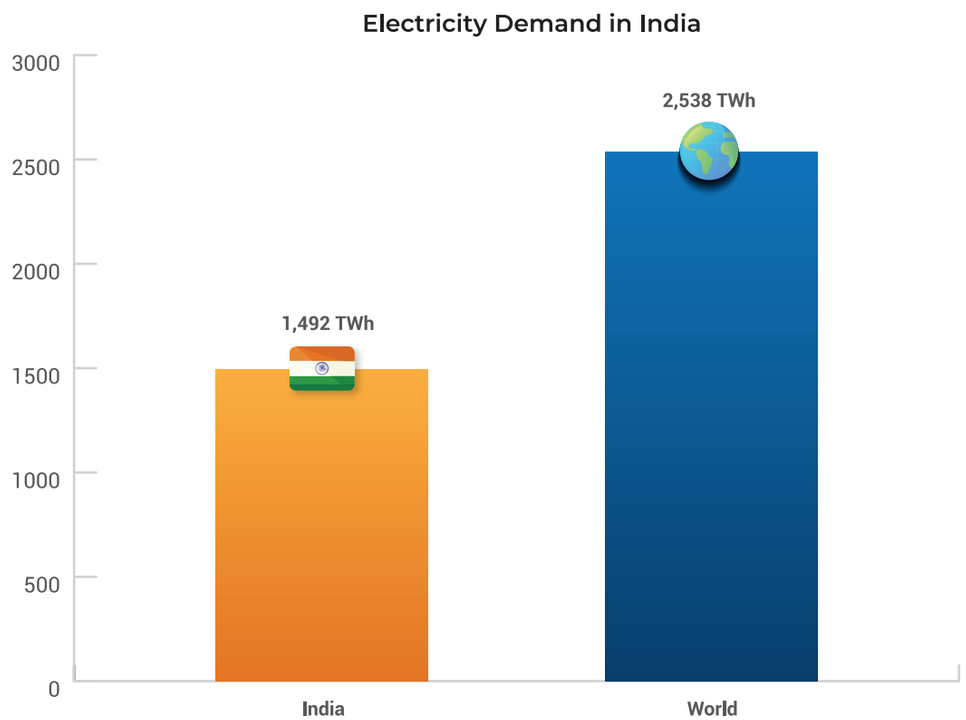
Investment Required in the Long Term to Attain Net Zero

- The transition to Net Zero will happen across five sectors, namely: Energy, Mobility, Industry, Green Buildings, and Agriculture.
- Energy transition will be the single largest economic opportunity, accounting for $8.4 trillion in investment by 2070. Energy transition includes building new solar and wind capacities, augmentation of transmission and distribution infrastructure, investments in energy storage, etc.
- Mobility transformation represents a $2-$4 trillion investment opportunity by 2070. Key drivers will include the shift in mode of transport from road to rail, and the electrification of the entire transport system. This transition will need more than $1-$1.5 trillion in investment for the charging and associated infrastructure. Additional investment opportunities in mobility will include biofuels and gas-based fuels as well as infrastructure for a hydrogen-based heavy mobility ecosystem.
- Industry decarbonization could offer a $2-$3 trillion investment opportunity. The retooling and electrification of industrial processes and the build-out of a hydrogen-based infrastructure for industry will be the two key drivers of investments in this space.
- The Green Buildings, Infrastructure and Cities pillar could potentially offer a $2-$3 trillion investment opportunity for India.

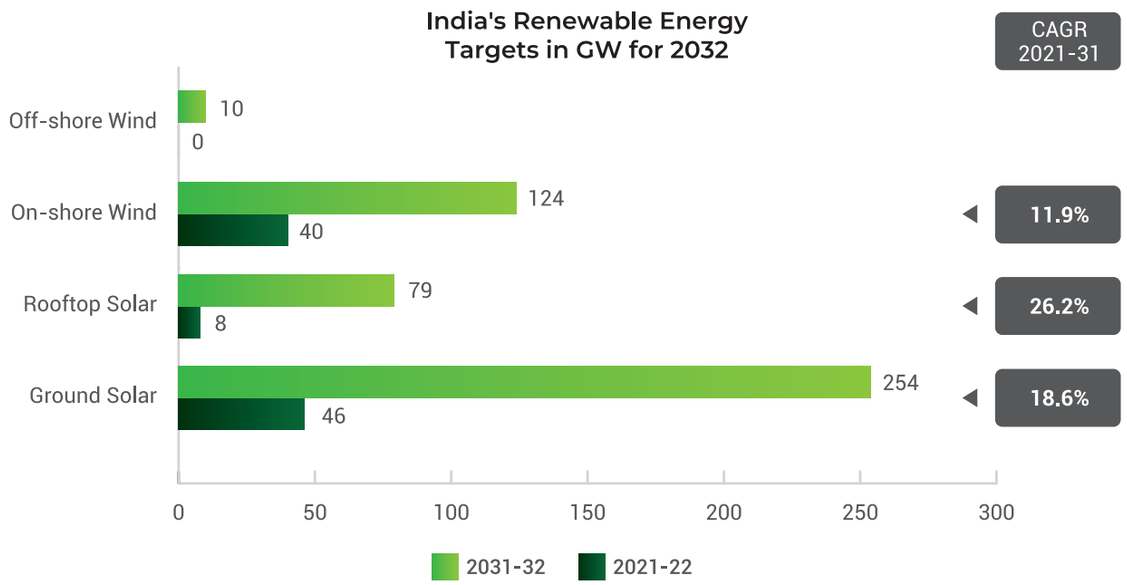
Source: CEEW-CEF analysis, World Economic Forum's "Mission 2070 – A Green New Deal for India

Electricity Demand is Projected to Rise Strongly



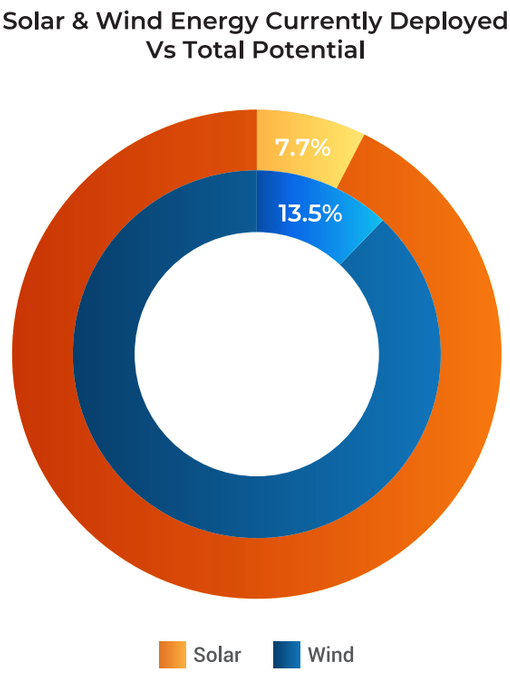


There is Huge Potential for Renewable Energy in the Medium Term...

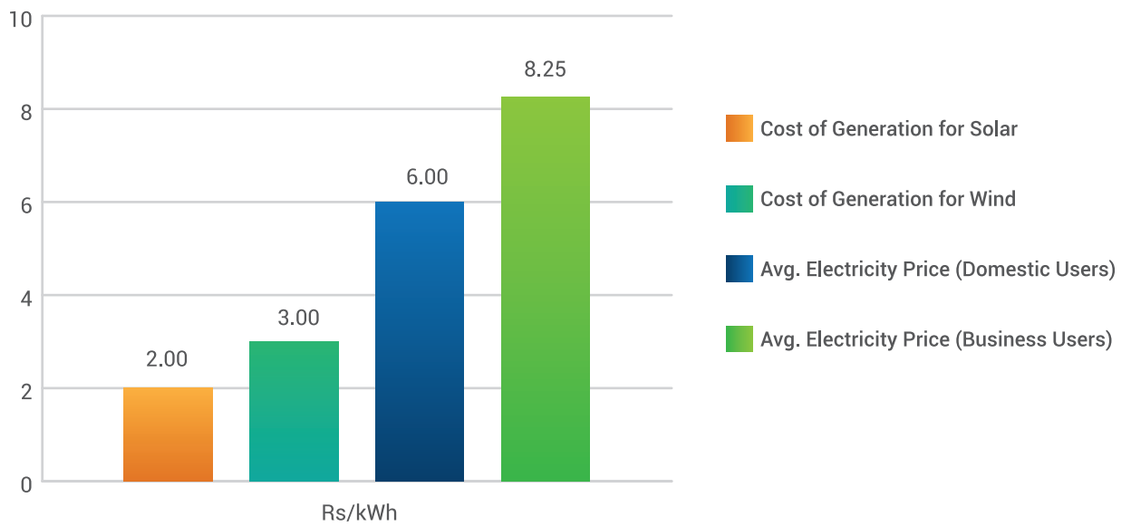


And Long Term as well...

- The country's solar potential utilizing 3% of the land area is about 748 GW.
- About 7.7% of solar energy potential has been currently utilized.
- Wind potential stands at about 302.25 GW at a hub height of 100m and 695.5 GW at a hub height of 120m.
- About 13.5% of wind energy potential (at a hub height of 100m) has been currently utilized.



Generation Economics Are Favorable



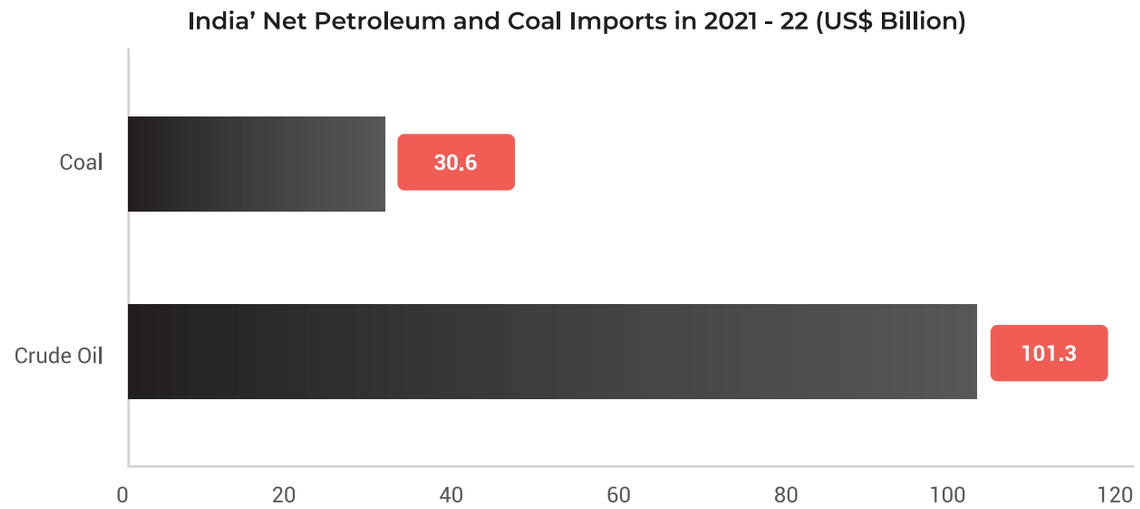
https://powermin.gov.in/en/content/national-electricity-plan-0

Investment Options Are Scalable

	Capex *(in ₹ crore/ MW)*	O&M Fixed Cost *(in ₹ Crore /MW)*	Construction Time *(in Years)*	Amortization Life Time *(in Years)*
Solar	4.50 to 4.10	1% of Capex	0.5	25
Wind (Onshore)	6.00	1% of Capex	1.5	25

Renewable Energy Will Have Huge Positive Impact on Indian Economy

- Electricity generation through renewable sources is already helping in reducing India's coal import bill.
- That said, once electric cars replace existing petrol and diesel vehicles, imports of crude oil will also reduce.
- This is helping save precious forex reserves that were once spent on fossil fuel imports.
- Besides, high price of imported energy also hurts India's GDP growth by making Indian manufacturing uncompetitive.



Renewable Energy Sector is Receiving Full Policy Support

- Energy transitions are the cause of shifts in global political power.
- Having set foot on the path of economic growth and glory, the political leadership, now has a vision to make India the second largest economy of the world. In it is also an opportunity for the leadership to leave its legacy!
- Access to cheaper sources of energy will be critical in achieving this ambition. Recognizing this reality, the nation's leadership has embarked upon a mission to make India self-reliant in solar energy, wind energy, bio-fuels, various other renewable energy sources, Hydrogen and electric vehicles.
- The nation's leadership is willing to offer a lot of policy support in this sector and being industries with massive growth potential, they offer entrepreneurs a road to unprecedented success.

Business Climate is Stable and There is Alignment on Priorities Between Centre and State

- Since 2014, India enjoys a strong stable national government. This offers investors an ideal climate and more certainty in decision making.
- The central and state governments share many common goals in energy policy. The standard concerns with affordable, abundant, and reliable energy supply do not differ. Whenever a less expensive option is available, both central and state governments choose it.
- Having said that, success in implementation of government programs is still dependent upon relations between Centre and State, and the alignment on priorities, between the two.

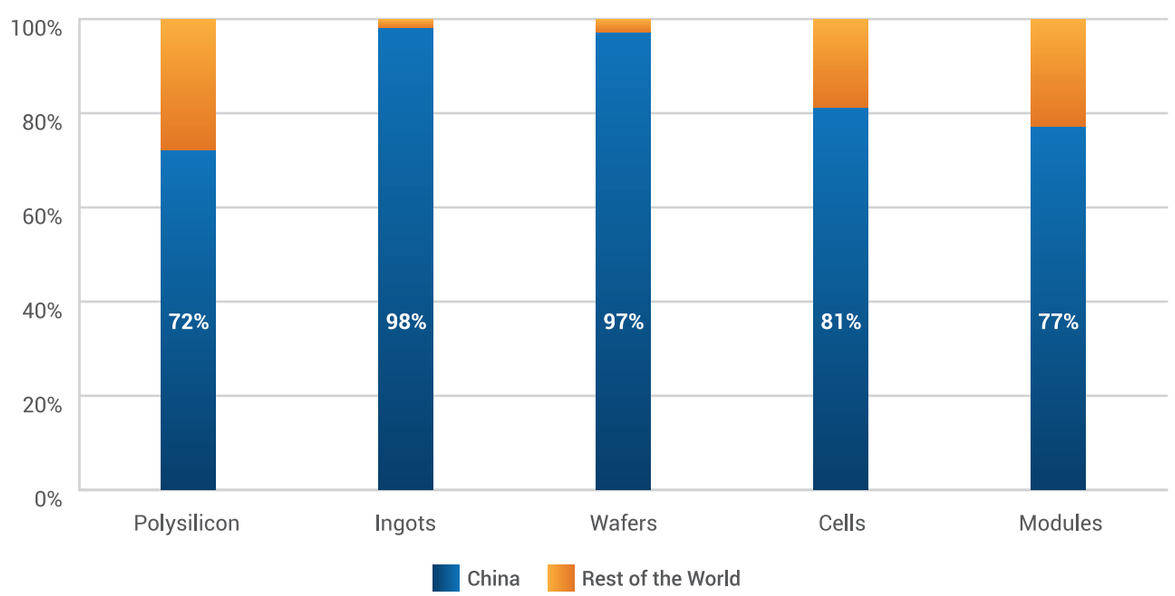
Electricity (Amendment) Bill 2022 Would Safeguard Renewable Energy Producers And Boost Rooftop Solar

- In a bid to reform the power sector, the central government has introduced the Electricity (Amendment) Bill, 2022. The main provision of the bill is to provide consumers with options to choose between multiple service providers in an area and create competition in the power distribution sector.
- The Bill also has a strong clean energy component with clear penalties (₹0.25 paise to ₹0.50 paise per kilowatt) for non-compliance of Renewable Purchase Obligations (RPOs).
- The bill will also make it mandatory for all states to ensure that a certain percentage of electricity demand in their state is met through generation from renewable energy sources. This will force them to either meet this requirement through utility scale projects or rooftop solar or import the deficit in renewable energy from other states. If enacted, it will be a game changer for rooftop solar.

Threshold for Availing Open Access Reduced and Rules Streamlined

- Green Open Access Rules 2022 has reduced the threshold for Open Access from 1 MW to 100 kW allowing more users to avail Open Access facility.
- The Ministry of Power has also streamlined Open Access approval process. The rules also provide certainty on other Open Access charges to be levied on consumers.

But Chinese Companies Have A Monopoly in Global Solar Manufacturing as of 2021



PLI Scheme Likely to Boost Solar Manufacturing in India

- Large-scale production of modules will also create domestic manufacturing capacity for solar glass, backsheet, EVA etc.

	Capacity after PLI in GW
Solar	0
Polysilicon	38
Wafer	56
Cell	59
Module	114

Policy of Repowering of Old Wind Turbines Could Be A Short-Term Savior for the Wind Energy Sector

- This policy could generate 25GW of new wind energy capacity.
- It will also open-up opportunities for selling old wind farms to new investors.

9. Next Research

Selection of Opportunities in the Renewable Energy Technologies Sector

1. Mapping of the Industry's Primary Value Chain
2. Determining the Value-Add for Each Block of the Value Chain
3. Assessment of Capabilities Required (Investments, Know-how, etc.)
4. Selecting a Set of High Value Opportunities with High Capability Alignment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