



Clean energy for sustainable development in India

Srikantaswamy Shivanna¹ · K. S. Rangappa¹

Accepted: 7 February 2024

© The Author(s), under exclusive licence to Institute for Social and Economic Change 2024

Abstract

Energy is essential and people with no sustainable access to it are deprived of the opportunity to become part of national and global progress. And yet, one billion people around the world live without access to energy. India is projected as a significant contributor to the rise in global energy demand. The main aim of encouraging the use of renewable energy in India is to advance economic development, improve energy security and mitigate climate change. Sustainable development goals can be achieved by the use of sustainable energy and by ensuring access to affordable, reliable, sustainable, and modern energy for citizens. With strong government support and increasing opportunity of using sustainable energy, India is among the top leaders in the world's most attractive renewable energy market. Lack of access to energy supplies and transformation systems is a constraint to human and economic development. Increased use of fossil fuels without steps to mitigate greenhouse gases will have global climate change implications. Energy efficiency and increased use of renewable resources contribute to climate change mitigation and disaster risk reduction. One of the greatest global challenges is to integrate environmental sustainability with economic growth and welfare by decoupling environmental degradation from economic growth.

Keywords Renewable energy · Solar energy · Wind energy · Bio-mass energy

Introduction

The Secretary-General of the United Nations, Ban Ki-moon, has said, “Energy is the golden thread that connects economic growth, social equity and environmental sustainability”.¹ With access to energy, people can study, go to university, get a job, start a business and reach their full potential.² There are tangible health benefits to having access to electricity

¹ See the speech of the Secretary General, the United Nations, at Global Development Center, on 20 April 2012. <https://press.un.org/en/2012/sgsm14242.doc.htm>, accessed on 25 December 2023.

² Potential here generally refers to one's ability to develop when valid opportunities are given. When energy is provided, one can use it in the form of electricity to get access to internet and the rest of the achievement depends on one's potential.

✉ K. S. Rangappa
rangappaks@yahoo.com
Srikantaswamy Shivanna
srikantas@hotmail.com

¹ Centre for Material Science and Technology, Institution of Excellence, University of Mysore, Vijayana Bhavana, Manasagangothri, Mysore 570006, India

and a demonstrable improvement in well-being of people. Energy access therefore constitutes a core component of the sustainable development agenda for energy. The production of useable energy can also be a source for climate change—accounting for around 60% of total global greenhouse gas emissions. An energy source is a necessary element of socioeconomic development. The increasing economic growth of developing nations in the last few decades has caused an accelerated increase in energy consumption. This trend is anticipated to grow more. Almost 80% of electricity is produced by burning fossil fuels such as coal, oil, and natural gas. In future, renewable energy sources can lead to the production of electricity in each part of the world. Likewise, an outlook to future power consumption helps to determine future investments in renewable energy. Energy supply and security have not only increased the essential issues for the development of human society but also for their global political and economic patterns.

Types of renewable energy

The most popular renewable energy sources currently are **Solar energy**, **Wind energy**, **Hydro energy**, **Tidal energy**, **Geothermal energy**, **Biomass energy**.

Renewable Energy



Photos clockwise (starting top left) – wind turbines, water tidal turbines, wave energy, geothermal energy, solar panels, biofuels

The Indian government has designed policies and programs to attract investments such as National Solar Mission 2015, National Offshore Wind Energy 2015, National Biofuel Policies, etc., to propel the country forward in the renewable energy market at a rapid rate. The Tariff Policy Amendment 2016 attracted investors across the world, which not just helped increase the nation's GDP but also improved livelihoods and the environment. It is anticipated that the renewable energy sector can create a large number of domestic jobs over the following years in India. The anticipation is based on the

assumption of booming growth in the area of renewable power production through the setting up of new suitable power plants. There are, however, various obstacles faced by the renewable sector.

Solar energy

Solar photovoltaic devices, or solar cells, change sunlight directly into electricity. The main benefits of using solar energy are that it does not produce carbon dioxide or other air pollutants, and these systems installed on buildings have a minimal impact on the environment (Yadav et al. 2015). The main limitation of solar energy is that the amount of sunlight that arrives at the earth's surface is not constant. The amount of sunlight varies depending on location, time of day, season of the year, and weather conditions. Also, the amount of sunlight reaching a square foot of the earth's surface is relatively small; so, a large surface area is necessary to absorb or collect a useful amount of energy.

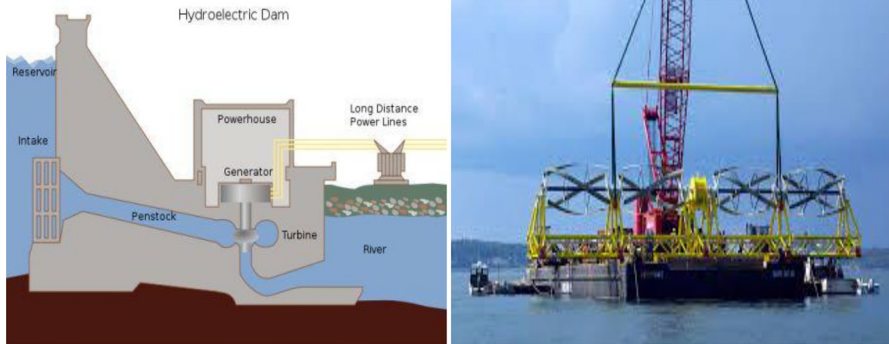
Wind energy

Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. The advantages of wind energy include its clean and renewable source of power, cost-effectiveness, rapid growth of industry, and large potential. The disadvantages of wind energy are wind reliability, threat to wildlife, and noise and visual pollution (Maradin 2021).



Tidal energy

Tidal stream generator—It makes use of the kinetic energy of moving water to power turbines, similar to wind turbines that use wind to power turbines. Tidal barrages are built to make use of the potential energy produced by the difference in the height between high and low tides.



There are advantages of clean fuel sources compared to fossil fuels used in domestic energy sources. While disadvantages like tidal power effecting on marine life where, the turbines can accidentally kill swimming sea life with the rotating blades, also some fish may no longer habitat the area if threatened by a constant rotating or noise-making objects (Khare and Bhuiyan 2022). Installing a barrage may change the shoreline within bay or estuary, affecting large ecosystems that depends on tidal flats.

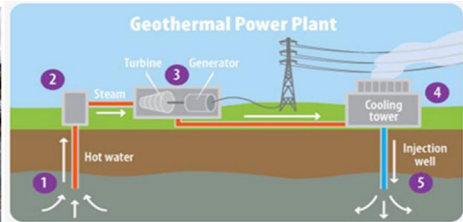
Wave energy

Similar to solar, wind, and geothermal energy, wave energy is a renewable source. As long as the Earth continues to revolve around the sun and the moon is revolving around the Earth, waves will continue to be a viable source of kinetic energy. Wave energy also produces fewer carbon emissions than energy from traditional fossil fuels, such as coal or oil, making it an **eco-friendly option**. Ocean waves contain tremendous energy potential. Wave power devices extract energy from the surface motion of ocean waves or from pressure fluctuations below the surface.



Geothermal energy

Geothermal energy is **the heat that is generated within the Earth**. (Geo means “earth,” and thermal means “heat” in Greek.) It is a renewable resource that can be harvested for human use. About 2900 km (1,800 miles) below the Earth’s crust, or surface, is the hottest part of our planet (the core). Geothermal energy comes from the heat produced by the core. Direct geothermal energy can be accessed in areas where hot springs/geothermal reservoirs are present on the surface of the Earth. Geothermal heat pumps are a series of underground pipes, an electric compressor and a heat exchanger to absorb and transfer heat. Geothermal power plants also harness the heat of the Earth through hot water and steam. In these plants, heat is used to generate electricity.



Geothermal energy has advantages such as being renewable and cleaner than burning fossil fuels, but it also has disadvantages such as cost of drilling, and need for expert handling and researching about proper location of geothermal areas.

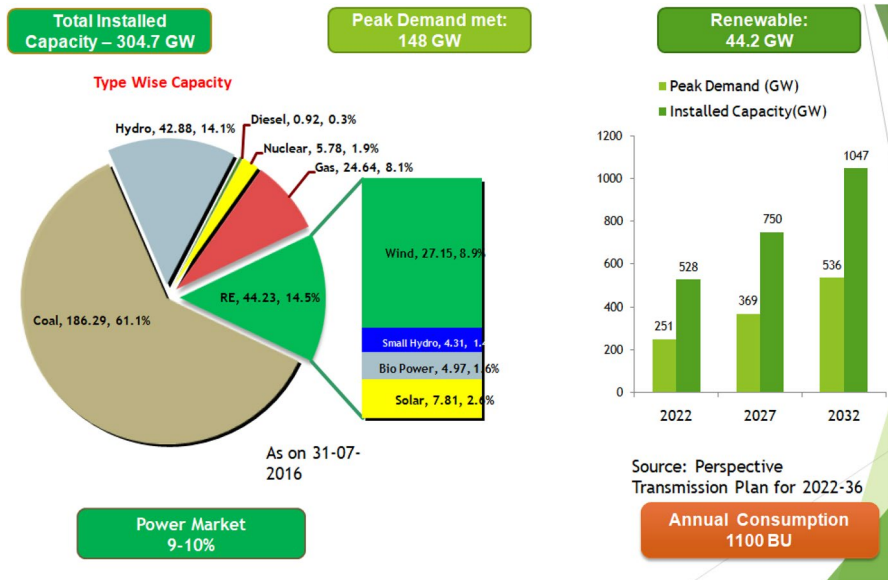
Biofuels: Unlike other renewable energy sources, **biomass can be converted directly into liquid fuels, called “biofuels,” to help meet transportation fuel needs.** The two most common types of biofuels in use today are ethanol and biodiesel (Tyson 1997), both of which represent the first generation of biofuel technology.



Biodiesel is made by combining alcohol (usually methanol) with vegetable oil, animal fat, or recycled cooking greases. It can be used as an additive to reduce vehicle emissions (typically 20%) or in its pure form as a renewable alternative fuel for diesel engines.

Biodiesel has advantages such as being easy to source and renewable, reduces greenhouse gases and dependence on foreign energy. Its disadvantages include higher cost of production (lower supply than gasoline), monoculture, shortage of food and water use.

Indian power scenario



Move towards renewable sources

It has been estimated that renewables will comprise 49% of India's power generation by 2040. Over the last few years, there has been an increase in percentage contribution of renewable energy to total installed capacity. In 2013–2014, the contribution was 12.92%, which increased to 38.56% as of January 2022. Replacing coal plants with renewable sources is expected to save India Rs. 54,000 crore (US\$ 8.4 billion) annually due to reduced power costs. About 5000 compressed bio-gas plants will be set up across India by 2023. According to the analytics firm British Business Energy, India ranked third globally in terms of its renewable energy investments and plans in 2020. In June 2021, IKEA announced the launch of programmes to help suppliers in India transit to 100% renewable power. The company has ~50 suppliers in the country. In July 2021, National Thermal Power Corporation Renewable Energy Ltd. (NTPC REL), NTPC's fully owned subsidiary, sent out a tender to domestic manufacturers to build India's first green hydrogen fuelling station in Leh, Ladakh.

Solar power generation growth

Due to its favourable location in the solar belt, India is one of the best recipients of solar energy with abundant availability. Solar power installed capacity has increased by more than 18 times from 2.63 GW in March 2014 to 49.3 GW at the end of 2021. India stands fifth among countries with maximum installed capacity of solar rooftop installations. Gujarat, Maharashtra, Rajasthan and Tamil Nadu account for 53.6% of the solar rooftop installations in India, as of January 2021. The Bhadla Solar Park in Rajasthan's Jodhpur district is the largest solar power plant in the world. Spanning 14,000 acres, the power plant is fully operational and has a capacity of 2250 MW.

Top 10 state-wise solar installations in India (January 2022)

Rank	State	Capacity (MW)
1	Rajasthan	10,506.95
2	Karnataka	7,534.92
3	Gujarat	6,309.92
4	Tamil Nadu	4,894.49
5	Andhra Pradesh	4,386.45
6	Telangana	4,316.29
7	Madhya Pradesh	2,686.60
8	Maharashtra	2,603.21
9	Uttar Pradesh	2,224.40
10	Punjab	1,098.36

The government's National Solar Mission is an important contributor in the effort towards producing renewable energy, and interventions in rural electrification and new ultra-mega power projects are moving India towards achieving universal energy access. In November 2021, the government announced future plans to increase funding under the production-linked incentive (PLI) scheme for domestic solar cells and module manufacturing to Rs. 24,000 crore (US\$ 3.17 billion) from the existing Rs. 4500 crore (US\$ 594.68 million) to make India an exporting nation. The world's largest floating 600 MW solar energy project will be constructed at the Omkareshwar Dam in Khandwa district of Madhya Pradesh at an estimated cost of Rs. 3000 crore. The project is expected to begin power generation by FY23.

Rising power demand

India's ambitious renewable energy goals are transforming its power sector. Rising population and widespread electrification in rural homes is fuelling the demand for energy to power homes, businesses and communities. The Central Electricity Authority estimates India's power requirement to grow and reach 817 GW by 2030. The peak power demand of the country reached 183.80 GW in FY20. India's peak electricity demand recorded an all-time high of 200.57 GW on 7 July 2021. Solar power and wind generation recorded an all-time high of 43.1 GW on 27 July 2021. According to data from the Ministry of Power, India's power consumption increased by 12% in July 2021 to 125.51 billion units (BU) and recovered to pre-pandemic levels, owing to easing of COVID-19-induced restrictions and delayed monsoon. India has an electricity–GDP elasticity ratio of 0.8. Thus, 7% growth in energy supply will be required if India is to grow at 8%. This shows that electricity will continue to remain a key input in India's GDP growth.

Strategies adopted

The strategies adopted to produce renewable energy include developing renewable energy hybrid projects, ensuring round-the-clock power (RTC) supply, draft electricity rules, 2021, decentralised solar power, shift towards non-conventional energy, green cities, etc.

A target of producing 500GW of non-fossil fuel includes 450GW renewable energy; additionally, 43% of RE purchase obligation before 2030 has been set by the Indian government. This is a motivational strategy towards renewable energy development.

In August 2022, under Nationally Determined Contributions (NDC) of the Paris agreement, India announced its aim of achieving cumulative of 50% electric power from the installed non-fossil fuel plants by 2030. Also, India has set a long-term goal of reaching net zero emissions by 2070.

Also, in August 2022, the Energy Conservation Amendment Bill was passed by Lok Sabha, which mandated the use of only non-fossil energy sources including biomass, ethanol, green ammonia and green hydrogen for the energy and feedstock industries.

Strategies like providing subsidies for the setting up of renewable plants like solar power extraction panel installations, wind turbines plant, etc., encourage people to shift towards the renewables. Also, the loans provided with low interest rate incentivise people to harvest renewable energy in higher capacities and sell the surplus after personal consumption.

Just Energy Transition Partnership (JET-P) is a multilateral financing provided to developing countries by developed nations to support energy transition (Ordonex 2023). India is considered a suitable candidate after South Africa, Indonesia and Vietnam for JET-P. The 'phase-down' of coal in the Paris agreement has given significant weight to the consideration of JET-P, while India's G-20 presidency is a potential opportunity to forge a deal.

What more could be done to promote renewable energy?

- Solarisation of agricultural electricity demand
- Use of diesel-powered engines for micro, small and medium enterprises.
- Current use of coal resources should be re-aligned.
- Promoting RE for domestic cooking and heating purposes.

Funding No funding has been received for the paper.

Declaration

Conflict of interest The authors declare that they have no conflict of interest.

References

- Khare V, Bhuiyan MA (2022) Tidal energy-path towards sustainable energy: a technical review. *Clean Energy Syst* 3(1–16):100041
- Maradin D (2021) Advantages and disadvantages of renewable energy sources utilization. *Int J Energy Econ Policy* 11(3):176–183
- Ordonez JA et al (2023) India's just energy transition: Political economy challenges across states and regions. *Energy Policy* 179:113621
- Tyson KS (ed) (1997) *Biodiesel research progress 1992–1997*. National Renewable Energy Laboratory, Golden
- Yadav HK, Kumar V, Yadav VK (2015) Potential of solar energy in India: a review. *Int Adv Res J Sci Eng Technol* 2(1):63–66

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.