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Alternative Energy Scenario

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The article should be non-technical and should be of around 2500 - 4000 words. The research articles may be upto 7000 words. But no mathematical expressions or technicalities of methods should be contained in the main text. It should be typed in MS Word in Times New Roman 12 with paragraph spacing 1.5. Figures and simple, small tables can be incorporated. There should not be any notations or equations, at least in the main text. If required, it may be put in Appendix. The article should also contain a short abstract of 150 – 200 words. Full forms of each abbreviation should be mentioned at first instance. All figures and diagrams should be in black and white. Send your manuscript along with your name, institutional affiliation, email ID and contact number to the editorial office at imikonnect@imi-k.edu.in mentioning the area viz. Marketing, Finance, OB & HR, Economics, Strategy, IT & Operations, Management Education, Others or Themed Issue.

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Alternative Energy: The Global Scenario

Rajashri Chatterjee* and Paramita Nath**

Introduction

The current challenge faced by the world in recent times is to cater to the energy needs for human well-being, economic development and alleviation of poverty. However, since our current energy system is still dominated by fossil fuels (coal, gas and oil), carbon dioxide and other harmful greenhouse gases emitted by these sources are a major contributor to global warming. The world is spending a lot of time to come out of this trade-off and possibly, the answer lies in switching to sustainable energy sources.

Renewable energy may be defined as the energy from various self-replenishing sources that is limited in flow. This energy is derived from the sources that cannot be depleted. Various forms of renewable energy that are being produced and consumed globally are solar, wind, geothermal, hydropower and biomass.

In the Paris Climate Change Agreement 2015, participating nations agreed to keep the global average temperature rise below 2 degrees Celsius. This calls for huge reduction in energy-related carbon dioxide emissions, achievable only with the introduction of renewable forms of energy such as wind, solar and hydropower. Policies on renewable energy are instrumental in its wide expansion. These policies help to mitigate institutional, economic and technical barriers faced by various nations. Around 168 countries are setting renewable energy goals. Policy mechanisms like feed-in tariff (FIT), green certificate or auctions system have been increased by 61 countries from 2010 to 2017.

Energy demand globally rose by 2.3 per cent from 2010 to 2018 both in terms of fossil fuels and alternate fuels, leading to a 1.7 per cent increase (i.e 33.1 Gigatonnes) in energy-related carbon dioxide emission [International Energy Agency, 2019]. But, major economies, such as the United States, the United Kingdom, Mexico and Japan witnessed decline in carbon emissions owing to better renewables deployment. Demand for oil, natural gas and coal increased by 1.3 per cent, 4.6 per cent and 0.7 per cent respectively in 2018 from 2010. The renewable sources have witnessed highest growth rate primarily, driven by wind, solar and hydropower. The global electricity demand has grown by 4 per cent from 2010 to 2018, to more than 23,000 TeraWatt-hour (TWh) [International Energy Agency, 2018].

The International Renewable Energy Agency (IRENA) has urged nations to contribute 36

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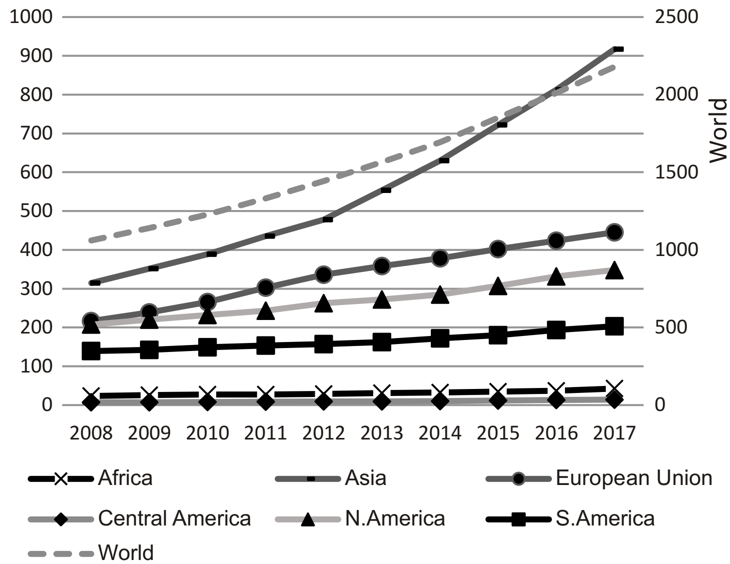
per cent of world's total energy consumption through renewable energy by 2030 as put forth by a report titled 'Remap 2030'.The investment cost on renewable energy expansion will be offset by the associated costs of fossil fuel pollution leading to a saving of US$740 billion per year. As per IRENA, renewable power generation capacity is measured as the maximum net generating capacity of power plants and other installations that use renewable energy sources to produce electricity.

Figure 1 : Renewable Energy Capacity Worldwide



Source: IRENA Renewable Energy Statistics 2018

26.5 per cent of the global electricity production in 2017 has been obtained from renewable resources. The major contributors to this share are hydro power (16.4 per cent), followed by wind power (5.6 per cent), bio power (2.2 per cent), solar PV (1.9 per cent) and marine and geothermal energy (0.4 per cent) globally[1]. This article primarily focusses on the major players of various renewable resources across the world.

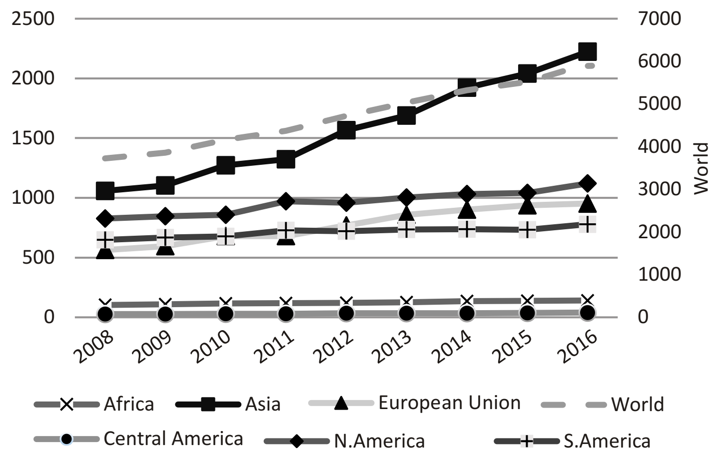
The steep increase in the total renewable energy capacity worldwide from 2008 to 2017 is depicted in Figure 1. While Asia shows maximum renewable energy capacity usage of 917.322 Gigawatts (GW), Central America demonstrated the minimum capacity usage at 14.08 GW in 2017. Thus, Asia alone contributes to about 42 per cent of the world's total capacity of renewable energy, followed by European Union contributing to 20.4 per cent of the same in 2017.

Figure 2 shows an increase of about 58 per cent in the total renewable energy production globally from 2008 to 2016. Asia contributed around 38 per cent of global total renewable energy production in 2016.

At this backdrop, this article discusses the global scenario with respect to the use and potential of renewable/alternative energy sources, the economic and social benefits of implementing various alternative energy

[1]Renewables 2018 Global Status Report

Figure 2 : Renewable Energy Production Worldwide



Source: IRENA Renewable Energy Statistics 2018

sources worldwide, the progress of developing countries in shifting to alternative energy with special reference to India vis-a-vis the developed nations of the world.

It is observed that the renewables comprises of one-third of the electricity generation in Europe, one-fourth in China and one-sixth in the United States, India and Japan[2]. The developing economies accounted for 63 per cent of the total renewable energy investment with China alone accounting for 45 per cent of global investment in 2017[3].

The Global Scenario

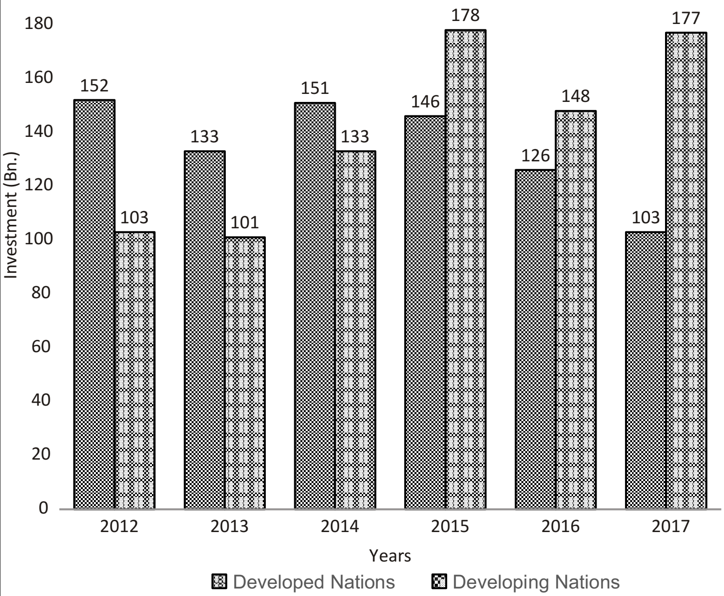
It is observed worldwide that there is a strong relation between economic growth and implementation of various forms of renewable energy. The increasing concerns of environmental pollution, depletion of ozone layer owing to green-house gases are forcing economies worldwide to invest in the alternative energy sources. The continuous depletion in traditional energy resources along with frequent changes in the crude oil prices are now acting as the major drivers for use of renewables worldwide. Countries have still not achieved economies of scale for renewables as applicable for fossil fuels. Both developed and developing countries are investing in renewable energy implementation for a successful switch from traditional sources to alternative sources.

The maximum average global investment in renewables in developing and developed countries was observed in 2015 [FS-UNEP Centre Report and BNEF Global Trends Report, 2018]. There was a decline in the investment in the following years for developed countries. However, it increased for the developing countries in 2017 (Figure 3).

The world's renewable energy capacity showed a sharp increase of 171 GW from 2017 to 2018 out of which around 61 per cent

[2]Enerdata Global Energy Statistical Yearbook 2018
[3]Renewables 2018 Global Status Report

Figure 3: Global Investments ($Bn) in Renewables in Developing & Developed Countries 2012-2017



Source: United Nations Environment's Global Trends in Renewable Energy Investment 2018, FS-UNEP Centre/BNEF Global Trends Report 2018

was installed in Asia itself. Asia accounted for a cumulative capacity of 1024 GW in 2018.

The Global Wind Energy Council (GWEC) predicts that around 55 GW global wind power capacity will be added per year till 2023. The Council also declares the commissioning of 51.3 GW new wind capacity in 2018, out of which 46.8 GW is onshore and remaining 4.5 GW is offshore.

It is observed that the global renewable capacity is 2844 GW in 2018, owing to a steep increase in hydropower, wind, solar, bioenergy, geothermal and marine. In the total renewable energy capacity for the world as depicted in

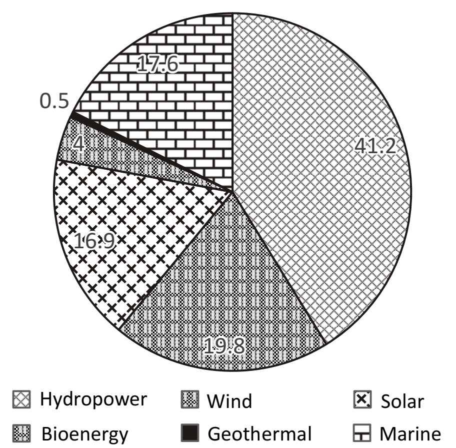
Figure 4 shows that among the various forms of electricity, hydropower is the leading renewable source for electricity generation globally, supplying 41.2 per cent of all renewable electricity.

Forms of Renewable Energy and their Usage

Solar Energy

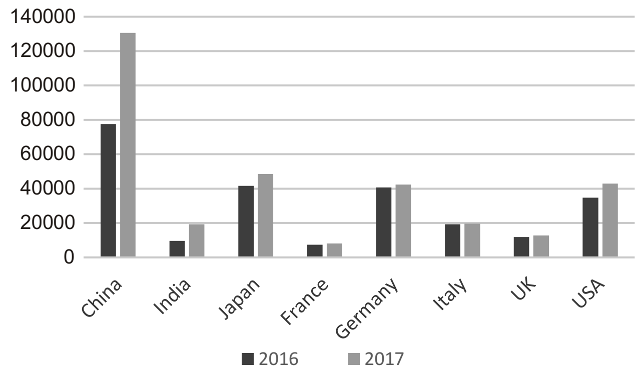
Solar radiation is emitted by the sun. Photovoltaic collectors and thermal collectors are two predominant solar energy technologies. Various advantages of solar energy usage are continuous

Figure 4: Global Renewable Capacity of Various Renewable Energy Resources, 2018



Source: IRENA Renewable Energy Statistics 2018 availability, production of both heat and electricity, lower maintenance cost of solar energy systems along with the reduction in electricity bills. There are certain disadvantages too, such as, high initial installation cost of solar energy systems, reduction in the efficiency of solar energy systems on cloudy days, excessive space requirement of solar photovoltaic panels and high cost of storage of solar energy.

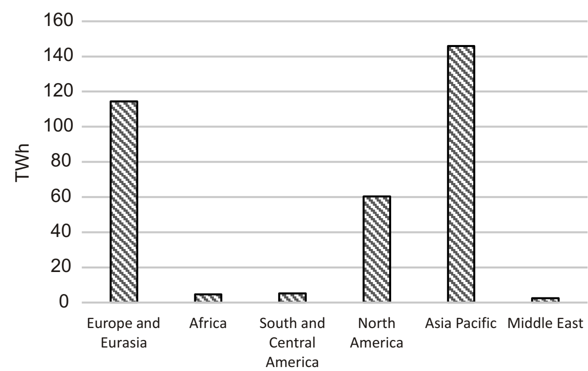
Figure 5: Solar Energy Capacity, MW



Source: IRENA Renewable Capacity Statistics Report 2018

China (130,646 MW) has emerged as a world leader in solar energy capacity surpassing Germany (42,396 MW) in 2017. USA, Japan and Germany were still much ahead of India during the years 2016 and 2017 and the total capacity of India was 19,275 MW in 2017 (Figure 5).

Figure 6: Solar PV Energy Consumption Worldwide (TWh), 2016



Source: ourworldindata.org

Figure 6 depicts that the biggest consumer of solar PV energy is the Asia Pacific with 146 TWh consumption followed by Europe and Eurasia with 114.4 Twh in 2016. The lowest consumption of solar PV energy is observed in the Middle East i.e. 2.46 TWh.

In India, one of the major achievement in the solar energy sector has been the sanction of 41 solar parks in 21 states with an aggregate capacity of over 26,144 MW. The installation of largest solar park of 2,000 MW at Pavagada is in progress. Few off grid solar initiatives are taken in the last four years such as doubling of solar street lights, distribution of 25,75,000 solar lamps to students, around 1.5 per cent increase in solar home lighting systems and setting up of several solar pumps [MNRE, 2018].

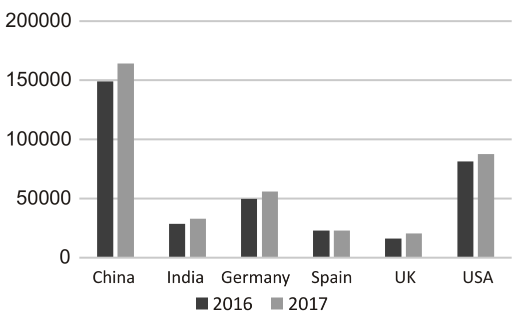
Wind Energy

Wind energy has seen phenomenal growth in its usage worldwide in recent times because clean and non-polluting technology is used in this case to generate electricity. It is unlimited and freely available in nature. However, the wind turbines may cause noise pollution causing damage to local wildlife like birds.

In 2017, China emerged as the global world leader in wind energy capacity followed by USA and Germany (Figure 7). From 2016 to 2017, China showed an increase of 10.12 per cent and India showed as an increase of 14.56 per cent. As per the World Economic Forum, China's fast technology upgradation, large land mass and long coastline are the main reasons for the tremendous progress in wind energy capacity and generation.

Around 80 per cent of the total wind capacity is produced by China, USA and Germany and remaining 20 per cent is produced by countries worldwide [REVE, 2016]. Therefore, it is clear that more initiatives should be undertaken by the developing countries of the world for a better tomorrow.

Figure 7: Installed Wind Power Capacity, MW



Source: IRENA Renewable Capacity Statistics Report 2018

In India, the Ministry of New and Renewable Energy (MNRE) has provided certain incentives to promote wind energy generation and usage such as generation-based incentives of 0.50/kWh, import duty concession on specified wind turbine parts, reliefs on excise duty and finally, income tax waiver to wind power projects.

Hydroelectric Power

Hydropower is the conversion of energy from flowing water into electricity. It is a renewable form of energy which is derived from flowing water. Various advantages of hydropower are renewability and ease of availability. Fueled by water,it is a clean source of energy. It is flexible source of electricity as the water flow can be monitored with respect to the electricity output required.

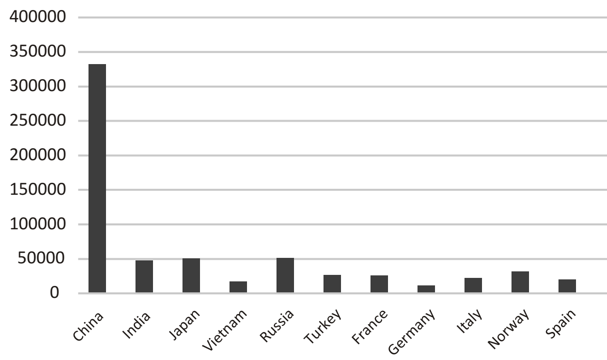
The IRENA Renewable Capacity Statistics Report 2018 shows China as the leader in total hydropower capacity in 2017 followed by Russia and Japan (Figure 8).

Three Gorges Dam in China is the world's largest hydropower plant with a capacity of 22.5 GW. It produces 80 to 100 TWh of electricity per year which can cater to the needs of 70-80 million households[4].

Owing to its vast mountain ranges and many rivers, hydropower potential of China is the largest in the world. China is the world's largest producer of hydroelectric power. It is

[4]https://www.irena.org/hydropower

Figure 8: Global Hydropower Capacity (MW), 2017



Source: IRENA Renewable Capacity Statistics Report 2018

now aggressively building dams. About 16 per cent of China's electricity is generated by hydropower in 2016. China's future plans is to increase its hydro-generating capacity by nearly two-thirds over the next five years[5].

In India, small hydro projects of 682 MW have been added over the last four years till 2017. 600 watermills for mechanical applications have also been added. Around 132 projects are still under consideration [MNRE, 2018].

Geothermal Energy

The thermal energy which is generated and stored in the Earth is called the geothermal energy. The major players in this energy sector are Iceland, El Salvador, New Zealand, Kenya, and Philippines. Geothermal energy caters to meet more than 90 per cent of the heating demand in Iceland in 2018 [IRENA, 2018]. Since, geothermal energy production does not depend on weather conditions and has very high capacity factors, geothermal power plants are capable of supplying electricity as well as providing ancillary services. The disadvantages includes pollution and improper drilling of earth may lead to release of hazardous minerals and gas in the atmosphere.

USA, Philippines, Indonesia, Turkey and New Zealand are the leading countries availing commercial exploitation with worldwide installation of around 12,800 MW at the end of 2017 [REN21, 2018]. Total geothermal energy rose worldwide from 11,209 MW in 2014 to 13,329 MW in 2018 [IRENA, 2018].

In 2013, the Geological Survey of India has identified about 340 geothermal hot springs in the country. Out of these, many are in the low surface temperature range from 37°C-90°C which is appropriate for direct heat applications. There are seven geothermal provinces in the country viz. Himalayan (Puga, Chhumathang), Sahara Valley, Cambay Basin, Son-Narmada-Tapi (SONATA) lineament belt, West Coast, Godavari basin and Mahanadi basin.

Bioenergy

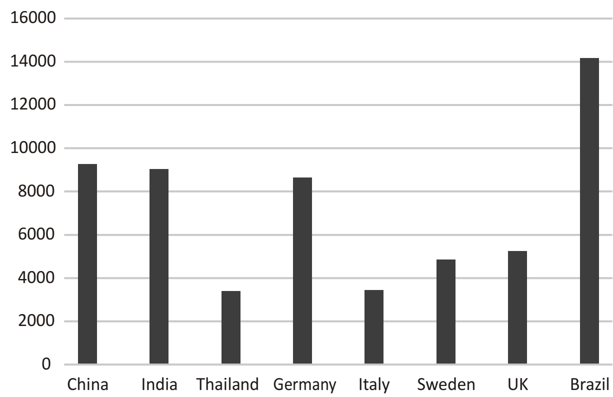
Bioenergy is a form of renewable energy extracted from living organic materials known as biomass that can be used to produce fuels for transportation, heat and electricity

[5] https://www.worldenergy.org/data/resources/country/china/hydropower/

generation. Two major conflicts that arise due to biomass production are shortage of land (either food production or bio-fuel production) and humungous greenhouse gas emissions from land management and land use change. Bioenergy is generated from bio-mass that is widely available and also a cleaner source of energy.

Europe has the major biofuel production capacity accounting to about two-third of the total global capacity [Welfle, 2017]. Brazil is a global leader in bioenergy with its capacity of 14,583 MW in 2017 followed by China and India (Figure 9).

Figure 9: Global Bioenergy Capacity (MW), 2017



Source: IRENA Renewable Capacity Statistics Report 2018

The Indian states leading in establishing biomass based power supply are Maharashtra, Uttar Pradesh and Karnataka, 2.5 lakhs biogas plants have been set up in India in the last four years till 2017 for helping rural livelihoods. India being an agriculture based country, it is very difficult to find lands for bio-mass production as most of them are already used for production of edible crops. At the same time, India being the 7th largest country in the world spanning 328 million hectares is amply bestowed with renewable energy resources including biomass.

India produces about 450-500 million tonnes of biomass per year. Biomass provides 32 per cent of all the primary energy needs in the country at present. There is about 63 million hectares (ha) waste land in the country, out of which about 40 million ha can be developed by undertaking plantations of Jatropha [MNRE, 2018].

International Experience: Select Cases

The Nordic countries like Sweden, Denmark, Iceland, Norway, Finland are major players in low carbon energy transitions. Sweden is implementing renewable technologies among all its sectors leading to a sharp increase in its economic growth and humungous reductions in wastes and greenhouse gases. It has set its target to be a completely fossil fuel-free nation by 2040. It is on its way to achieve its renewable energy targets by 2019 which was projected to be achieved by 2030 due to the installation of 3681 new wind turbines in 2018. It basically depends on wind energy utilization followed by biofuels. Sweden relies on hydropower for electricity generation and on biofuels for heating purpose. [Urban et al., 2018]. Iceland relies almost fully on geothermal energy for heating purposes and on hydropower alongwith geothermal energy for electricity generation. Finland depends predominantly on hydropower and biofuels. A major share of Norway's electricity comes from hydropower alone.[Urban et al., 2018].

Alaska is a a well-known player in solar, wind, hydroelectric and geothermal energy. The rural areas are more inclined towards renewable energy alternatives owing to high oil prices. Around 20.2 per cent of installed electric capacity comes from renewable energy facilities of the state. There is a huge usage of biomass fuels such as wood, sawmill waste, fish byproducts and municipal waste in Alaska to generate renewable energy. Alaska has initiated tax incentives on renewable and hybrid energy.

Costa Rica ran almost 250 days totally on renewable energy. Data from World Bank highlighted 100 per cent electricity generation from hydropower by Albania and Paraguay in 2013.Artificial intelligence is extensively used for renewable energy production in Europe. European Union, is on the verge of de-carbonization of its energy system by 2050.

India's Position and Performance on the Global Platform

The population of India is expected to surpass that of China by 2022. This growth in population signifies substantial rise in India's share of global primary energy demand. Improvements in energy efficiency will assist in cutting the growth in energy demand. Renewable energy sources offer a sustainable route to address the energy security concerns. The year end review 2018 of the Ministry of New and Renewable Energy (MNRE) put forth that India has been ranked fifth globally for overall installed renewable energy capacity, fourth for wind power installed capacity and fifth for solar power installed capacity.

India's renewable energy consumption is expected to move up fifteen folds[6] by 2040. The potential of renewable energy in the country is huge and largely unexploited. India ranked fourth on the EY Renewable Energy Country Attractiveness Index 2018 preceded by Germany in the third position, United States in the second and China occupying the topmost position. India is thus among the top five attractive renewable energy markets in the world. Again, the nation is ranked eleventh globally in the Climate Change Performance Index 2019 due to an improved performance in renewable energy, comparatively low levels of per capita emissions and an ambitious mitigation target for 2030.

While India made 9.1 GW Solar PV additions in 2017 leading to a total Solar PV capacity of 18.3 GW at the end of the year 2017 [REN21, 2018], China added an astounding 53.1 GW in the same year leading to a total Solar PV capacity of 131.1 GW at

[6]https://www.bp.com/en/global/corporate/energy-economics/energy-outlook/country-and-regional-insights/india-insights.html

the end of 2017. From the point of view of Concentrating Solar Thermal Power, while India's total capacity at the end of 2017 has been 225 MW, China's capacity has been just 20 MW. In terms of wind power, India occupied 6 per cent of the total global wind power capacity as on end-2017; China occupied around 35 per cent whereas Brazil occupied 2.4 per cent of the total capacity of the world.

India ranked fourteenth in 2017 globally in the production of biofuels with 1 billion litres production. India's first biomethane-fuelled bus commenced operation in 2017. Among the BRICS, the countries that are in top ten in this respect are, Brazil being second on the global platform with 32.8 billion litres production and China being fifth with 4.3 billion litres production.

While from the point of view of hydropower additions India is third in the world in 2017 with an addition of 1.9 GW in the year, in terms of the total hydropower capacity the country occupied the sixth rank with a share of 4 per cent of the total capacity of the world. China, Brazil and Russian Federation occupied the first, second and fifth ranks respectively from the point of view of total capacity (with a share of 28 per cent, 9 per cent and 4.3 per cent of the total global capacity respectively).

The share of renewables in electricity generation for India in 2017 has been 16 per cent, whereas this share for China is 26 per cent and for Brazil it is as high as around 80 per cent [Enerdata, 2018]. However, the share of wind and solar in electricity generation has been 5.1 per cent for India in 2017. It has been around 6.8 per cent for China and 7.4 per cent for Brazil.

In 2017 for the eighth year in a row, global new investment in renewable energy (excluding hydropower projects larger than 50MW) exceeded US$ 240 billion. Total new investment globally has risen from US$ 158.9 billion in 2007 to US$ 279.8 billion in 2017 [REN21, 2018]. Majority of the investment in 2017 took place in solar PV and wind power. Government R&D and corporate R&D taken together has seen a rise of about 68 per cent in 2017 as compared to 2007. However, venture capital and private equity (VC/PE) investment in renewable energy fell by 68 per cent from US$ 5.6 billion to just US$ 1.8 billion during the same period. But, asset finance of renewable energy projects totalled US$ 216.1 billion in 2017, an increase of 88 per cent on US$ 115.1 billion in 2007. Small-scale distributed capacity however rose to US$ 49.4 billion in 2017 which is 3.5 times of the figure in 2007. China, India and Brazil accounted for just over half of global investment in renewables excluding large hydro in 2017, with China alone representing 45 per cent.

In 2017, India attracted an investment of US$ 10.9 billion in the renewable energy sector with the major share of investment in solar energy (61 per cent of the total investment) followed by wind (37 per cent)[7]. For China the invested amount in renewable energy in 2017 has been as high as US$ 126.6 billion with 68 per cent of the investment in solar and 29 per cent being in wind. Brazil's total new investments in 2017 has been US$ 6 billion with the majority of the share of investment in wind sector (60 per cent) followed by solar energy (35 per cent).

In India, the FDI equity inflow in the non-conventional energy sector has shown an increasing trend during the period 2015-16 till 2017-18 [MNRE, 2018]. During the period from April 2018 till June 2018, the FDI inflow has been US$ 452.89 million making the total inflow since April 2015 till June 2018 amount to US$ 3,217 million.

Potential and Progress in Renewable Energy in India

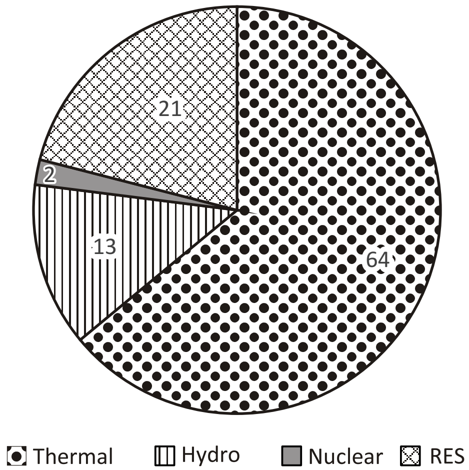
The potential for renewable power generation in India as on March 31, 2017 has been estimated at 1001 GW which includes solar power potential of 649 GW, wind power potential of 302 GW (at 100 m level), biomass power potential of around 19 GW, potential of 7 GW from bagasse-based cogeneration, waste to energy potential of 2.6 GW and small hydro power potential of 21 GW [MOSPI, 2018]. However, it should be noted here that hydro power projects up to 25 MW were categorized as renewable energy in India in 2017. The top three states in India in terms of estimated potential of wind power at 100 m level are Gujarat with 27.9 per cent of the total wind power potential for India followed by Karnataka (18.5 per cent) and Maharashtra (15 per cent). Again, the estimated potential of small hydro power (SHP) is highest for Karnataka with a share of 17.6 per cent of the total SHP potential for India, followed by Himachal Pradesh (16.4 per cent) and Arunachal Pradesh (9.8 per cent).

The estimated potential of biomass power has been the highest for Punjab with 17 per cent of the total estimated potential for India. The state is followed by Maharashtra (10.6 per cent of the total) and Uttar Pradesh (9.5 per cent). Again, the estimated potential of solar power is highest in the country for Rajasthan with a share of 21.9 per cent of the total potential for India, followed by Jammu and Kashmir (17.1 per cent) and Madhya Pradesh (9.5 per cent).

74.79 GW of renewable energy capacity has been installed in India as on December 31, 2018 from sources viz. wind, solar, SHP and bio-power against a target of 175 GW of renewable energy capacity to be installed by 2022 [MNRE, 2019]. The share of renewable energy in overall installed power capacity in India as on October 31, 2018 has been 21 per cent as shown in Figure 10. Renewable energy sources here include small hydro project, bio power, solar and wind energy.

[7] Frankfurt School-UNEP Centre/BNEF. 2018. Global Trends in Renewable Energy Investment 2018, http://www.fs-unep-centre.org (Frankfurt am Main)

Figure 10: Share of Various Forms of Energy in Overall Installed Capacity (%)



Source: MNRE, GoI, 2018 (http://www.pib.nic.in/Pressreleaseshare.aspx?PRID=1555373)

The top three states in India as on December 31, 2018 in terms of the installed capacity of various renewable modes of energy are depicted in Table 1. From the point of view of wind power, Tamil Nadu (with 24.56 per cent of the total installed capacity of grid interactive wind power in India) stood first among the Indian states followed by Gujarat (16.95 per cent) and Maharashtra (13.63 per cent). In terms of solar power, Karnataka (with 20.84 per cent of the total installed capacity of grid interactive solar power in India) occupied the first rank followed by Telangana (13.53 per cent) and Rajasthan (12.42 per cent). With respect to bio-power, the top three states include Maharashtra (with 25.49 per cent of the total installed capacity of grid interactive bio-power in India) followed by Uttar Pradesh (21.35 per cent) and Karnataka (18.15 per cent). In terms of SHP, Karnataka (27.24 per cent of the total installed capacity in India) again occupied the first rank followed by Himachal Pradesh (19.05 per cent) and Maharashtra (8.31 per cent). When the total installed capacity of grid interactive renewable power comprising of all four forms of power are taken in to account, Karnataka held the first rank among the Indian states, followed by Tamil Nadu and Maharashtra.

Table 1: Top 3 States in India in terms of Installed Capacity of Grid Interactive Renewable Power as on 31.12.18

Wind Power		Solar Power		Bio Power		SHP		All 4 Renewable Energy Sources	
States	% of total	States	% of total	States	% of total	States	% of total	States	% of total
Tamil Nadu	24.56	Karnataka	20.84	Maharashtra	25.49	Karnataka	27.24	Karnataka	17.34
Gujarat	16.95	Telangana	13.53	Uttar Pradesh	21.35	Himachal Pradesh	19.05	Tamil Nadu	16.03
Maharashtra	13.63	Rajasthan	12.42	Karnataka	18.15	Maharashtra	8.31	Maharashtra	12.44

Source: MNRE, GoI, 2019 press release (http://www.pib.nic.in/Pressreleaseshare.aspx?PRID=1564039)

As per the Paris Accord on Climate Change, India has pledged that by 2030, 40 per cent of installed power generation capacity shall be based on clean sources.

From the perspective of off-grid power, decentralized renewable power ventures using wind energy, bio-power, hydro power and hybrid systems are being set up to meet the energy needs of remote regions which are not expected to be electrified in the near future. The MNRE also supports deployment of various decentralized solar applications in the country. The off-grid solutions help in accessing modern energy services in an environmentally sustainable and timely manner.

Conventional energy resources in India being quite low in comparison to its energy needs in terms of the huge population and rapidly increasing economy, the nation can harness the vast potential of renewable energy resources to meet the needs.

Conclusion

One-third of global power capacity is based on renewable energy at present [IRENA, 2019]. There is more focus in recent times on renewable energy due to energy security concerns and environmental issues. Impressive growth in renewable energy worldwide is witnessed with 171 GW of renewable energy additions made to the global system in 2018. Asia has been the largest installer of renewable energy with 61 per cent of total capacity additions. China and India are progressing more than several developed countries to curb their use of fossil fuels and increase the share of renewables. In 2017, China banned usage of coal in its 28 cities providing a great boost to the renewable energy sector. In addition to this, establishment of several renewable energy heating related targets were done in the country's 13th Five Year Plan. China has emerged to be the global leader in renewable energy. The largest market for the solar thermal-driven chillers along with solar thermal cooling installations was Asia owing to China, India and Singapore. With prices of renewable energy sources plummeting, rise in investment in the sector along with renewable energy targets set for many countries in the continent, this sector is set to experience rapid expansion in near future. Asian governments are now committed to promote the sector with favourable regulatory frameworks, financing platforms, better infrastructure, land allocation for renewable energy projects and industry-oriented research and development.

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Alternative Energy in West Bengal

Santanu Basu, IAS*

West Bengal Renewable Energy Development Agency (WBREDA), formed in 1993, aims to promote renewable energy technologies and create an environment, suitable for the commercialization of these alternative energy through various innovative projects. The WBREDA is the State Nodal Agency for implementation of non–conventional energy programmes in West Bengal. WBREDA has implemented many programmes related to solar energy, wind energy, mini and micro hydel, bio-energy, etc. WBREDA has a group of experts in the field of renewable sources of energy, who are responsible for formulation, design and proper implementation of the projects related to renewable energy sources.

IMI Konnect: *West Bengal has an alternative energy policy since 2012 in place. What is the main focus - wind, solar, tidal, biomass or waste?*

SB: WBREDA is the State Nodal Agency (SNA) for West Bengal and is responsible to promote all facets of alternative energy in the state of West Bengal. As of now, I would reckon that our main focus is on solar energy. The Government of India has fixed a target to install 175 GW of Grid connected Renewable Energy by 2022. Out of this, 100 GW is earmarked for Solar PV. Further, as per the National Energy Policy, 2018, the Government has aimed for solar power at 275 GW by 2027. West Bengal, like other states, has to adhere to the national Renewable Power Obligation (RPO) which itself is skewed towards solar in its target for West Bengal. So evidently, solar energy is at the focal point of the renewable energy space both at the national and at the state level.

In addition to solar energy, we are working with wind energy too. There is a 2 MW wind farm project of WBREDA at Fraserganj. WBREDA is formulating a programme for its capacity enhancement and replication of a similar type of project at Mousuni Island and at Gangasagar Island. The activities at tidal, biomass and waste to energy space are also gathering pace with the emergence of new technology ideas and are becoming more interesting.

IMI Konnect: *What are the challenges of using alternative energy in West Bengal? Do you think use of alternative energy is going to change the energy scenario in our state in the next 15-20 years?*

SB: West Bengal has traditionally been a coal rich and power surplus state. Thermal power has been the mainstay of its energy portfolio since inception. In such a position, the aggressive penetration of renewable energy

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and its integration poses several challenges in terms of grid integration, load balancing, managing kinks in peak-trough demand curve as alternative sources of energy are mainly intermittent in nature – diurnal for solar and seasonal for wind/tidal.

However, with rapid progress of battery storage technologies, these supply side problems would progressively cease to be deterrent for long. Further, emergence of cost cutting techniques in flue gas effluents for environmental concerns and flexibility in operations of thermal power plants in the quest for clean coal technologies, may pose a challenge to use of alternative energy.

In West Bengal, insolation[1] index is not as high as in the western parts of the country; resulting in relative inefficiencies – leading to possibilities of import of renewable energy from more solar efficient states. Wind and tidal energy potential is also limited by geography. Again, since willingness and ability to pay more for clean energy is limited for now in our state, price elasticity of demand is high in the energy space. Renewable energy combined with battery storage has to be price competitive to thermal energy to meet the challenge comprehensively. In effect, if we are to see a significant shift in energy mix scenario in favour of alternative energy in the coming decade or two; technologies to harness alternative sources have to evolve at cost competitive rates backed by effective storage to address demand side management issues.

IMI Konnect: *Please highlight the successful projects of WBREDA in the recent past.*

SB: The recently completed successful projects of WBREDA are installation of Rooftop Photovoltaic Power Plants at remotely located rural health centres in Sundarbans with battery; efforts are on for the installation of Rooftop Grid Connected PV Power Plants at 1000 schools across the state of cumulative capacity 10 MW which is near completion- installation at further 900 schools and 100 colleges is currently underway as the first project was extremely well-received by the schools; installation of similar power plants at different Government buildings under Aloshree programme of cumulative capacity 2 MW where several iconic buildings have been covered under this, like St. Xavier's and Lady Brabourne College, Jadavpur and Burdwan University, several District Courts, Judicial Academy, Police Training School at Barrackpore, several District Correctional Homes etc; installation of several Solar Trees in areas where free land is scarce; installation of Solar Water Heating System at student hostels of Backward Class Department, Government of West Bengal.

IMI Konnect: *Please elaborate on the installation of Grid Connected Roof Top Solar PV System in 1000 schools in West Bengal.*

SB: WBREDA had started installing PV Power Plants at schools from 2010. Back then, it was at schools where grid electricity was

[1]Insolation means the solar radiation that reaches the earth's surface.

either absent or not dependable. 100 schools were taken up for Solar rooftop modules in off-grid mode with battery backup. The objective of this programme was to provide solar power for daily fixed hours at those schools.

As grid power slowly reached different remote areas like Sagar Island, Gosaba, Hingalganj etc between 2012-15, WBREDA started its second stage program with 200 schools in grid connected mode during 2014-15.The objective of this programme was to reduce the electricity bill of schools in Net Metering[2] mode by pushing excess (excess after the own consumption of the school) solar power to the grid and reducing both the quantity of conventional electricity consumption and lowering the tariff bracket of the schools.

During 2017-2018, during its expansion drive, WBREDA has taken up another 1000 school programme where such power plants have been installed (each 10 KW capacity) at the rooftops of 1000 Government aided schools across the state. The project is now nearing completion. It is expected that each school can save on an average 12000 units of electricity annually, worth ₹72,000. Inspired by its successful and excellent feedback from school authorities and local representatives, WBREDA has taken up its 1000 schools Phase II (900 schools and 100 colleges) in 2019-2020 and is being rolled out now with field level inspections being underway.

IMI Konnect: *What are the benefits of setting up of grid connected roof top solar PV (GRTSPV) systems at the customers' premises under residential/institutional/ social sector?*

SB: WBREDA installs Rooftop Solar PV Power Plant in net metering mode with no storage arrangements as of now. For such installation, three phase power supply from the concerned Distribution Company (WBSEDCL/CESC) is required at consumer premises with appropriate voltage level. For such a plant, minimum capacity of Solar Photovoltaic (SPV) installation requirement now is 5 kWp. For installation of each kWp of Solar PV Power Plant, effectively 10-12 sqm shadow free (roof) space is required.

With such a system, generated excess solar power goes to the grid of the DISCOM (Distribution Company/electricity provider like CESC/WBSEDCL) at the day time. With this system, the user will use the grid quality electricity from the distribution company and the generated solar power from its solar power plant. The user will pay the adjustment amount of electricity bill (consumption of electricity from the grid minus the excess solar power as it is pushed to the grid) to the CESC or WBSEDCL. So, this is a solar system which reduces the electricity bill of the consumer, through reduction of tariff slab and reduction of quantum of electricity.

[2]Net Metering is a billing mechanism that credits solar energy system owners for the electricity they add to the grid.

IMI Konnect: *What is your opinion on energy efficiency in West Bengal compared to other states?*

SB: The West Bengal State Electricity Distribution Company Ltd (WBSEDCL) is the State Designated Agency (SDA) for energy efficiency and energy conservation programs in West Bengal. The Department of Power and Non-conventional energy sources, Government of West Bengal is presently preparing an Energy Action Plan for the state through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the position will be clearer after the report is submitted. However, West Bengal remains amongst the best states in India in terms of energy efficiency and overall performance of its power utilities both functionally and financially. Several big impact investment intensive initiatives have been undertaken by WBSEDCL to increase efficiency like strong demand side management, enforcement of energy conservation building codes (ECBC) and wide spread dissemination of LED devices.

IMI Konnect: *Are you planning for any foreign collaboration, if needed?*

SB: WBREDA is in the process of implementing activities like capacity building of installers, development of vendors, awareness generation among potential buyers in the industry and commerce sector and single window clearance for grid connectivity by net metering etc through a European Union (EU) programme. WBREDA is keen on implementing MW scale floating solar projects for which technology tie-up and funding may be sought from German KfW Bank.

IMI Konnect: *What is the future potential for the renewable energy sector in West Bengal?*

SB: The Renewable Energy Policy for West Bengal, 2012 has outlined the future projections for us in this regard. For the currently proven renewable technologies in the state, the future potential till the end of 13th Five Year Plan (2022) is a total of 2206 MW. Out of this total, wind power, mini and small hydro, cogeneration, biomass, waste to energy attained a fulfilment of 16.67 per cent, 55.83 per cent, 59.16 per cent, 36.25 per cent, 50 per cent respectively till the end of 12th Five Year Plan. However, at the end of the 13th Five Year Plan (2022), it is expected that the total cumulative capacity of solar energy will be 500 MW.

IMI Konnect: *WBREDA is operating few electric vehicles for last couple of years. What are future plans and growth possibilities in this sector?*

SB: WBREDA had done it as a pioneering Technology Demonstration Program with the help of the MNRE, Government of India. Recently, Government of India has announced the Electric Mobility mission, which envisages from 2030, no new vehicle without electrical charging system will be on road in India. Initiatives in this sector are now being looked after by the transport department, Government of West Bengal. The Power Distribution companies (WBSEDCL/CESC) have been presently mandated to set up Electric Vehicle (EV) charging stations evenly throughout the State before the EVs are rolled out in large numbers. Other relevant factors would be affordable pricing, increased mileage per charge and attractive models of the EVs for higher customer satisfaction.

IMI Konnect: *WBREDA has undertaken the Rabi Rashmi Project, first of its kind in India. Which section of people is this meant for?*

SB: It is a pilot project to showcase integrated and wholesome application of solar energy in the residential sector. The standalone bungalow buildings have Rooftop Solar PV Power plant, Building Integrated Photovoltaic (BIPV), Solar Water Heating System and Solar Passive Cooling arrangements to name a few. It was a much vaunted successful venture and the housing units were immediately sold on offer to progressive minded customers as an environment friendly option and life style statement.

IMI Konnect: *Please share your thoughts on the Municipal Solid Waste to Energy project. How much have we progressed in this?*

SB: This sector is presently being driven by the initiatives of the Municipal Affairs Department, Government of West Bengal. The main challenge here is to organize and educate the society about the necessity and benefits of waste segregation, being able to effectively collect the waste through organized municipal teams by providing suitable tipping fees and delivering the waste timely to the enabled power plant for due conversion to energy. Several projects have been formulated under this Municipal Solid Waste to Energy conversion concept with 1-2 MW capacity power plants. Quality standard of the waste and the cost of generation in comparison to coal power are the two main issues that needs to be monitored to make further progress in this field.

IMI Konnect: *Do you think that there is a rise in the interest/awareness of common people towards alternative energy usage?*

SB: Yes, the perception level of the common people has certainly improved in last ten years significantly, due to sizable reduction in the price of solar PV rooftop equipments, solar agriculture pumps and increased visibility of such systems in almost all cities, towns and blocks in West Bengal. The school rooftop solar project has acted as an outreach program in the rural areas. Media attention towards electric vehicles is significant now. There is widespread global concern on environmental issues and copious literature and extensive debate on use of alternative energy which all of us are aware of.

IMI Konnect: *Apart from household or schools, do you have any programme targeted to a specific industrial sector?*

SB: Yes, WBREDA had played a pivotal role in making fishermen aware about using PV system with battery backup for lighting, mobile charging, operating radio etc at fishing trawlers when these are in operation at deep sea. Such programs were organized by WBREDA at Digha and adjoining coastal areas in 2011 and is now institutionalized and executed by the concerned district administration and Disaster Management Department, Government of West Bengal.

IMI Konnect: *Government of India has launched a programme styled as Special Area Demonstration Programme (SADP). WBREDA has already undertaken certain initiatives for implementation of the same. How far have it progressed?*

SB: Under SADP, WBREDA has installed Solar PV Home Lighting system with LED lighting fixtures in hundreds of tribal households in three districts of West Bengal - Bankura, Purulia and West Midnapur.

IMI Konnect: *How is the future ahead for development of the renewable energy sector in West Bengal?*

SB: WBREDA has undertaken several projects which are being implemented. Apart from installing solar power plants in different parts of the state, the future agenda also includes encouraging and implementing tidal, biomass and waste to energy projects in a viable manner with concerned departments. Also, the long run objective is to assist in expansion of electric vehicles, promote all facets of renewable energy and coordinate between Central and State policies and execution as state nodal agency.

Analysing the Electricity Consumption Patterns in High Value Manufacturing Industries: Case-Study of Three Indian States

Amrita Goldar* and Sajal Jain**

Abstract

This article delves into the concept of High Value Manufacturing (HVM) and identifies various metrics that define it. Using previous literature on industrial competitiveness, high-value industries have been using both 'outcome related dimensions' and 'enabling dimensions' indicators. Panel data from Annual Survey of Industries (ASI) has been used in the analysis for both the selection of illustrative states as well as the identification of HVM within them. Once the case-study states i.e. Gujarat, Maharashtra and Tamil Nadu as well as their HVM industries were identified, an examination of energy intensity patterns was done. Since by definition, these firms are at the forefront of financial, social, technological and employment creation dimension, it is hypothesized that they would reflect progressive behaviour in energy usage as well. Using unit-level details of firms with continuous data from 2000-01 to 2014-15, changes in electricity intensity of production i.e. kWh/output value (₹) were analysed and differences in the patterns for both HVM and other firms was observed.

Introduction

Energy is the most critical input to economic growth today. Global energy consumption is rising and India is no exception. According to the well-known international energy company BP, India's primary energy consumption rose by 4.6 per cent in 2017, forming a share of 5.6 per cent in the global primary energy consumption.[1] Furthermore, the Energy Statistics 2018[2] published by the

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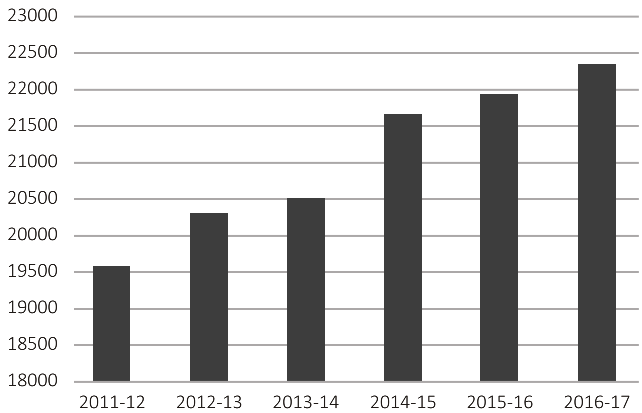
[1]https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/country-and-regional-insights/india.html

[2]http://mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2018.pdf; Note: Per-capita Energy Consumption (PEC) during a year is computed as the ratio of the estimate of total energy consumption during the year to the estimated mid-year population of that year.

Figure 1: Per-capita energy Consumption (Mega Joules)



Source: Energy Statistics 2018, MoSPI

Ministry of Statistics and Programme Implementation (MoSPI) show that the per capita consumption of energy in the country has been rising (Figure 1).

In such a scenario, it becomes necessary to analyse the energy consumption patterns for various sectors of the economy, to better prepare for the growing energy needs of the country. The manufacturing sector forms one of the vital pillars to economic development in the country and has demonstrated higher energy needs as well as consumption rates than other sectors. Moreover, the manufacturing sector has experienced tremendous development as new and innovative ventures have emerged over the last few years. Traditionally, the manufacturing sector is defined as a sector that 'transforms a raw material into finished products', but the growing concerns over sustainable industrial development necessitate the sector to shift toward High Value Manufacturing (HVM). Despite several attempts at defining HVM, the concept of HVM has no universally accepted definition. Martinez et al., (2008) define HVM industries as those that create more than just financial value for their stakeholder groups by not merely competing on cost but by contracting for capability, triggering innovation, establishing higher standards etc. and eventually contributing to a sustainable society. The HVM industries, therefore, may encompass a large set of industries with a broad inclusion of various values – financial, strategic and social – created by the sector.

This study analyses the HVM set of industries in the manufacturing sector to study the changes in their energy consumption patterns and energy-output intensities. The analysis is based on HVM industries located in three states – Gujarat, Maharashtra and Tamil Nadu. The rest of the article discusses the state selection criteria, identification of HVM industries and the results obtained.

State Selection Criteria

As previously mentioned, the analysis of the energy consumption patterns in the HVM industries is based on a set of industries in the states of Gujarat, Maharashtra and Tamil Nadu. These states were selected based on their existing industrial policies to promote innovation, competitiveness and create a favourable environment for investments in manufacturing sector along with their aggressive energy policies to promote renewable energy and energy efficiency. Hence, the methodology included review of the energy and industrial policies of different states in India.

a) Industry Based Selection Criteria

Existing literature on total factor productivity[3], labour productivity, competitiveness etc. at regional level in India suggest that Gujarat, Maharashtra and Tamil Nadu have been the front runners in case of productivity levels in industrial sector. Many studies have highlighted these states for a well-built manufacturing sector and also, higher productivity than other states in the country. In a recent study on job creation in the manufacturing sector, Kapoor (2015) found regional disparities in the growth of the manufacturing sector in the country. Some states such as Maharashtra, Gujarat and Tamil Nadu observed a higher level of industrialization in contrast to others who lagged behind. This could also be deduced from the contribution of manufacturing sector to the gross state domestic product[4] (GSDP) in Maharashtra, Gujarat and Tamil Nadu in 2010-11 which stood at 20.69 per cent, 29.38 per cent and 21.2 per cent respectively. Moreover, these states also contributed a major share in the gross value added in the manufacturing sector during the same period, signifying a more active and prominent presence of the sector. These differences affect the competitiveness of the sector, thereby of the state.

In the papers that analyse firm level data, to understand the role of competitiveness related aspects and their impact on productivity, comparative performance of various states in India has been reported. Confederation of Indian Industry (CII) and World Bank used firm level data for the year 1999-00 with an objective to establish the vitality of investment climate as a key requirement for competitiveness across industries [World Bank - CII Study on Competitiveness, 2002]. In the analysis of firms from four major industries in the manufacturing sector, they examined firm environment to conclude that some states have performed better in terms of the investment climate and hence competitiveness in general. The western states – Maharashtra and Gujarat emerged as leaders and 'better states' followed by Tamil Nadu, Karnataka and Andhra Pradesh. Further with respect to labour productivity, Maharashtra takes the lead in terms of value added per worker, contributing to higher labour productivity in the state. Interestingly, the study also explored the linkage between

[3]Total Factor Productivity is defined as the portion of output which is not explained by the amount of inputs used in production.

[4]Gross State Domestic Product is defined as a measure, in monetary terms, of the volume of all the goods and services that are produced within the boundaries of the state during a given period of time, accounted without duplication.

higher energy costs and investment climate and observed that the high energy costs in most states in the country, severely affected the competitiveness quotient. The study also revealed that a high percentage of firms invest in private power generation capacities, irrespective of the differences in investment climate.

On similar lines, Goldar & Banga (2005) analyzed firm level data from the Annual Survey of Industries (ASI) to estimate the relationship between labour productivity and real wage rate in the organized manufacturing sector. The study found out that the state of Maharashtra, Gujarat, Himachal Pradesh and Uttar Pradesh have a higher growth rate of labour productivity than other states, however, the growth rate of real wage rate lagged behind.

There have been a number of studies examining Total Factor Productivity (TFP) and cost competitiveness to examine the productivity level in India. Trivedi (2004) conducted a similar analysis at state level to estimate average labour productivity level (APL). The study found variations across different states. During 1996-2001, Maharashtra and Gujarat had the highest and West Bengal and Andhra Pradesh had the lowest APL for the manufacturing sector. West Bengal even witnessed a negative rate of employment. For the period from 1992-93 to 2000-01, the study found evidence of deceleration in the TFP growth rate in the manufacturing sector of the country. On the state level, the growth rate was found to be the highest for Gujarat and lowest for Uttar Pradesh.

Mitra et al. (2002) further extended the TFP analysis to examine the effect of infrastructure on TFP in manufacturing industries by states. They utilized industry level data of 1976-92 for 17 industries and found out that some states contribute most to the value addition of manufacturing sector as a whole. The states of Maharashtra, Gujarat, Tamil Nadu and West Bengal were found to be the most industrialized states that generated 52 per cent of the value added. On the other hand Rajasthan, Assam, Uttar Pradesh, Andhra Pradesh and Orissa, were found to have least developed industrial sector contributing 21 per cent of the manufacturing value added.

The overall competitiveness ranking of the Asia Competitiveness Institute (ACI) competitiveness index for 2010 by Khee Giap & Rao (2015) also highlighted high regional variability. Maharashtra scored highest on the index, followed by Delhi, Tamil Nadu, Karnataka and Gujarat to form the top 5 most competitive states in 2010. The north-eastern states and eastern states like Bihar, Jharkhand, Chhatisgarh and Odisha formed the bottom ten states.

Based on the above review of literature the states of Gujarat, Maharashtra and Tamil Nadu were chosen for the analysis.

b) Energy Based Selection Criteria

A large number of firms registered in India are

Table 1: Industry Summary Statistics for Selected States

	Number of Operating Firms		Value of Output (in ₹ Lakh Crore)	GVA (in ₹ Lakh Crore)
	In Frame	In Sample		
Gujarat	23506	5703	12.70	1.96
Maharashtra	28770	8953	11.19	2.39
Tamil Nadu	37959	10444	7.00	1.01
All India	231590	69029	68.8	11.64

Table 2: Electricity Consumption Trends for Selected States

	Own Generation (in '000 kWh)	Purchased from Grid (in '000 kWh)	Total
Gujarat	7010928	25554306	32565234
Maharashtra	6321253	26900711	33221964
Tamil Nadu	3256398	24243578	27499976
All India - ASI	86438134	231401615	317839749

located in these three states. Table 1 presents an overview of the importance of these three states in terms of number of operating firms, value of output and gross value added. It is thus important that energy, a critical input to the production process, provided is of high quality and is reliable and economical to ensure better productivity. This section provides an overview of the type of extant industries located in these states, their comparison with the rest of India as well as their electricity requirement. The data from the Annual Survey of Industries 2014-15 has been used for this analysis.

Using the ASI unit level data, the electricity consumption profiles show that firms located in the three states generated a total of 16588.6 GWH of electricity and purchased a total of 76698.595 GWH from the grid (Table 2); accounting for 19 per cent and 33 per cent respectively of the total demand of India.

After the selection of the states for analysis, HVM industries in these states were identified; the following sections explain the criteria and methodology for identification of high value manufacturing industries in these states.

Identification of HVM Industries

The identification of HVM industries is based on a methodology that combines two indicators to form an HVM index as used by Kathuria et al. (2014). These two indicators are defined as 'outcome related dimensions' and 'enabling dimensions'. These indicators have been combined together with the unit-level data from ASI (2010-11 to 2014-15) in this analysis.

a) Outcome Related Dimensions

Outcome related dimensions provide a quantitative measure of financial, social and strategic value. Perception of value will differ from stakeholder to stakeholder. The interest of a country will differ from an industry's or employee's interests. In this study, industry's perception of value has been examined.

i). Financial Value: Financial value can be explained in terms of revenue. However, since the concept of value added has been reported as the most common indicator of financial value, this study uses gross value added as a measure of financial value of a firm.

ii). Social Value: Social value can broadly be defined as the expenditure as a part of corporate social responsibility of a firm. However, when narrowed down to firm level and its employees, it has been defined to include welfare costs on employees by a firm. The share of welfare expenditures such as contribution to provident fund, etc. to total compensation of employees forms a strong indicator of the same and has been used as a measure for social value.

iii). Strategic Value: Strategic value, in true sense, measures the effect of industry activities on other sectors of the economy including sustainable employment creation. The study uses total number of employees as a measure for strategic value.

b) Value Enabling Dimensions

Value enabling dimensions essentially cover the skills and technology aspects of production. This approach results in identification of similar HVM products instead of similar industries. To estimate the level of skill, knowledge and technology in an industry, the study combines the data of education level of a person employed in a particular industry and the required level of education for that industry category. This analysis helped in identifying industry having higher education level requirements. In addition to this, the level of technology intensity defined as the combined share of investments on plant and machinery and computer equipment including software in relation to total fixed assets, is also computed.

Since, this study focuses on energy consumption patterns, the electricity input as a share of total input – as a measure of electricity intensity[5] – is used. The measure of electricity intensity would also help in identification of the industries that would potentially gain more from electricity supply improvement.

The derivation of HVM industries from available dataset was done in following steps:

Step 1: The HVM index was calculated for all firms in these three states by normalizing all indicators and arranging in increasing order from 0 to 100 and taking a simple average of the six values, identified earlier, assuming equal weights.

Step 2: All state firms were sorted in descending order and top 1000 firms were

[5]Electric Intensity is the strength of electric field at a point.

selected.

Step 3: Frequency distribution of all selected firms were tabulated and the top industrial groups were selected.

Table 3: List of Selected HVM Industries

Gujarat	Maharashtra	Tamil Nadu
Working of diamonds and other precious and semi-precious stones	Manufacture of diverse parts and accessories for motor vehicles	Preparation and spinning of cotton fibre including blended cotton
Manufacture of organic and inorganic chemical compounds	Manufacture or refining of sugar (sucrose) from sugarcane	Manufacture of diverse parts and accessories for motor vehicles
Manufacture of allopathic pharmaceutical preparations	Manufacture of allopathic pharmaceutical preparations	Manufacture of leather footwear such as shoes, sandals
Manufacture of bearings, gears, gearing and driving elements	Distilling, rectifying and blending of spirits	Printing of magazines and other periodicals, books and brochures
Manufacture of other agrochemical products n.e.c.	Manufacture of parts and accessories of bodies for motor vehicles	Manufacture of knitted or crocheted wearing apparel
Manufacture of medicinal substances used in the manufacture of pharmaceuticals	Manufacture of parts and accessories of three wheelers and motorcycles	Manufacture of parts and accessories of three wheelers and motorcycles
Manufacture of diverse parts and accessories for motor vehicles	Preparation and spinning of cotton fibre including blended cotton	Manufacture of all types of textile garments and clothing accessories
Manufacture of dyes and pigments from any source in basic form	Printing of newspapers	Manufacture of Portland cement, aluminous cement, slag cement and similar products
Manufacture or refining of sugar (sucrose) from sugarcane	Manufacture of bearings, gears, gearing and driving elements	Manufacture of parts and accessories of bodies for motor vehicles
Preparation and spinning of cotton fibre including blended cotton	Manufacture of other special-purpose machinery n.e.c.	Distilling, rectifying and blending of spirits

The final state wise list of HVM industries analysed in the study are as indicated in Table 3.

Estimation of Energy Consumption Changes

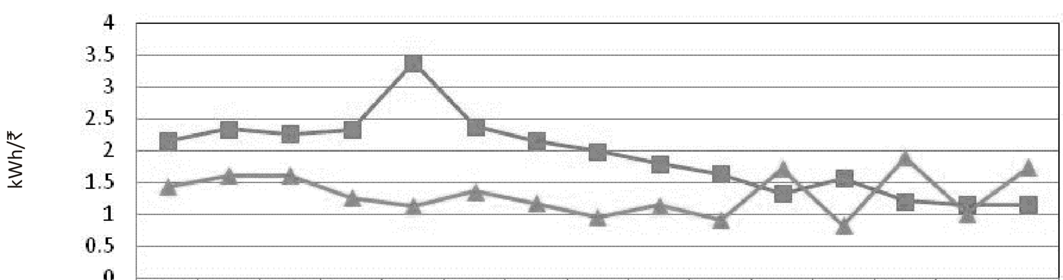
Firm-level data provided by the ASI has been used to create a larger industrial database for the analysis. ASI data with panel IDs for a fifteen-year timeframe of 2000-01 to 2014-15 (3965 firms) have been used for the analysis. The analysis has been done for 1381 firms located in these three states for which continuous 15-year data was present. Using the criteria defined in the previous section, 478 of these firms were identified as belonging to the HVM category.

Changes in electricity consumption have been evaluated using ASI firm level data. While ASI records the quantity of electricity consumed from both self-generation as well as the grid, it only records the value of electricity purchased from the grid. Therefore, electricity quantity from both the grid as well as self-consumption have been used for the analysis. The main idea behind the analysis is to look at the electricity consumption trends for industries over time and test the hypothesis that HVM firms, that are the front runners of what ideal manufacturing patterns look like, also show 'sustainable' production trends. The study defines industrial sustainability by the metric of electricity intensity i.e. electricity consumption per unit output and based on this definition the performance of selected firms and industries over a period of time has been analysed.

Results

Figure 2 shows the trend of energy intensity over time for both HVM and non-HVM firms. Remarkable decline in energy intensity of HVM firms is clearly visible. The energy intensity fell to the level of 1.146 kWh/₹ in 2014-15 from 2.143 kWh/₹ in 2000-01. The trends for non-HVM firms however were

Figure 2 : Tracking Energy Intensity of HVM Firms



	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
HVM	2.143	2.332	2.254	2.319	3.382	2.377	2.148	1.986	1.788	1.622	1.326	1.559	1.203	1.151	1.146
Others	1.426	1.602	1.609	1.256	1.13	1.356	1.173	0.943	1.138	0.913	1.72	0.819	1.893	1.006	1.736

quite erratic. While an overall fall in energy intensity can be seen, the situation post 2010 seems to be irregular. In fact, in the last couple of years in the analysis timeframe, an increase in energy intensity is observed.

In case of states, a dissimilarity in trends is observed. In Gujarat, it was found that the HVM industry has steadily maintained a low energy intensity profile throughout from 2000-01 to 2014-15 and the trend for non-HVM firms have been erratic for the state (Figure 3). On the other extreme, Tamil Nadu shows HVM firms to have a comparatively higher energy intensity as compared to Gujarat and Maharashtra, however it has been declining (Figure 4). The energy intensity of production of non-HVM firms within the state has however remained more or less constant. Maharashtra shows trends that are more in the middle of the range as compared to the other two states. While HVM firms have shown falling trends, the energy intensity figure after 2006-07 shows a very gentle downward slope. Energy intensity for non-HVM firms in Maharashtra remained constant for the longest time. However,

Figure 3: Gujarat HVM Results

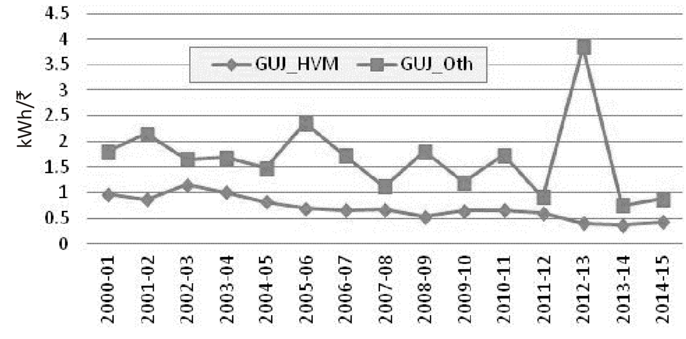


Figure 4: Tamil Nadu HVM Results

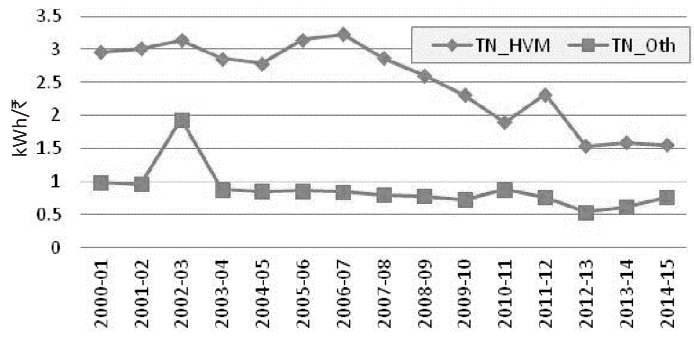
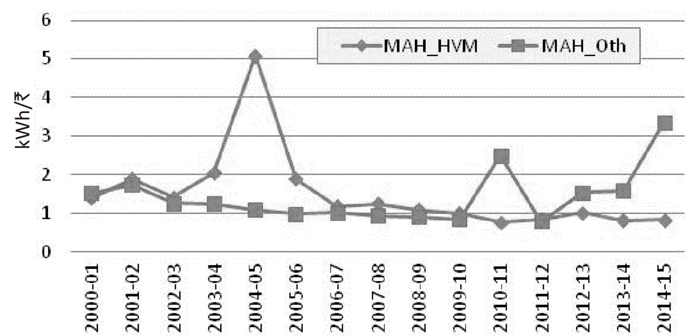


Figure 5: Maharashtra HVM Results



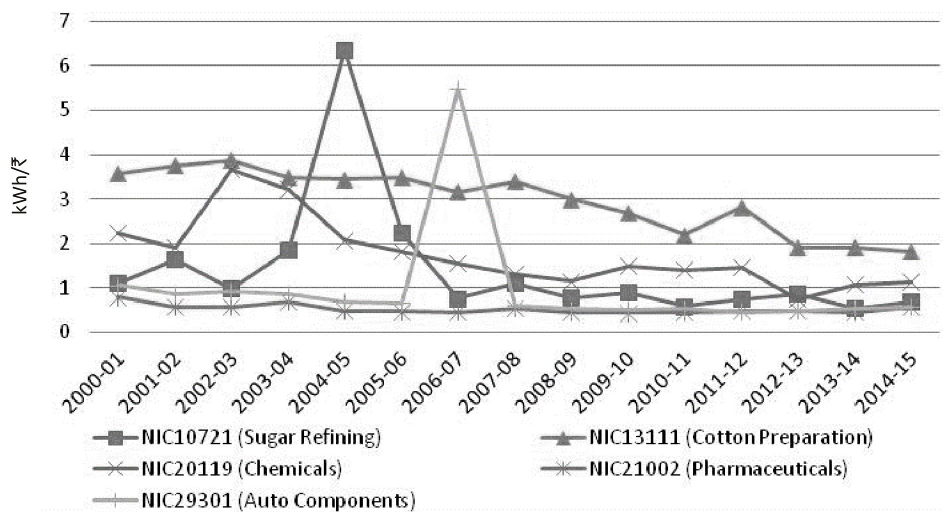
after 2009-10 they show an increasing trend (Figure 5).

A mapping and subsequent analysis of the energy intensity by industrial classification helps us link these industry-level results to the state-level trajectories as discussed earlier. In view of their importance and composition in the sample, there are five key HVM industries that are shown in Figure 6. These include cotton preparation and spinning, sugar refining, organic and inorganic chemicals, pharmaceuticals and auto-components. Matching these firms against the states that they are largely in, throws up some interesting facts. Sugar refining, prevalent largely in Maharashtra and to some extent in Tamil Nadu, shows a gentle downward trend. Cotton preparation, however, that is prevalent almost entirely in Tamil Nadu, shows a significantly higher energy intensity with a decreasing energy intensity trend. This is also mirrored in the overall HVM results for the state of Tamil Nadu. A falling trend is also observed in the case of chemicals. Trends for both pharmaceuticals and auto-components, despite some surges, have remained more or less constant over time.

Conclusion

Keeping industrial vibrancy and electricity demand in centre, the study looked into the industrial consumption patterns in three Indian states – Gujarat, Maharashtra and Tamil Nadu. Using various metrics for both 'outcome related dimensions' (value added, welfare expenditure and employment creation) and 'enabling dimensions' (skills embodied and technology orientation), a set of high value manufacturing industries were identified for these states.

Figure 6: Energy Intensity Trends amongst HVM Firms



Hypothesising that high value manufacturing firms would show sustainable production patterns as well, the study found wide variation between the performance patterns of HVM and non-HVM firms. The study used unit-level details of firms with continuous data from 2000-01 to 2014-15 from the Annual Survey of Industries and analysed changes in electricity intensity of production i.e. kWh/output value (₹) as its main variable of observation. The results showed that while the pattern for non-HVM firms has been widely varying over time and has an increasing trend in recent periods, the trends for HVM firms have been remarkable with respect to the decrease that they have been able to manage. The electricity intensity of production in kWh/₹ reduced from 2.14 in 2000-01 to 1.14 in 2014-15.

The story however gets a bit muddled in case of state specific patterns. The declining trend of HVM electricity consumption-production intensity was observed for all three states. However, there were stark difference between how HVM and non-HVM firms have performed on a comparative scale. For certain states HVM firms had higher intensities compared to non-HVM firms (Tamil Nadu), for some non-HVM was higher (Gujarat); while for others it was broadly the same (Maharashtra). The core of this state story was obviously governed by the performance of industries that constituted the HVM category in each state. To investigate deeper into this, comparative performance of HVM firms from five key industries was looked at – Cotton preparation, Chemicals, Pharmaceuticals, Auto components and Sugar refining.

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Converting Trash into Gas: A Journey

Atul Saxena*

Growdiesel is a renewable oil and gas exploration and production organization, primarily based in Delhi, dedicated to the cause of environment, energy and empowerment of fuel farmers. It was founded in the year 2005 by Mr. Atul Saxena. Growdiesel's core business is to produce and sell renewable clean fuels. Growdiesel is now establishing modern manufacturing facilities to produce advanced renewable cleanfuels known as Growdiesel NextGenFuels™. The biggest USP of Growdiesel NextGenFuels™ is that they are Drop-in Fuels which means they can replace fossil fuels in existing engines, vehicles, equipments and entire existing petroleum infrastructure without any modifications.

IMI Konnect: *What has been the primary motivating factor for Growdiesel to enter the Renewable Energy sector?*

AS: As in the year 2000, after spending nearly two decades as a technology consultant with United Nations, giving shape to Maaza Mango and after failing in five ventures, I eventually realized that there was a global boom coming in the field of biofuel. Biofuels were supposedly the alternative to the traditional fuels. During that time, if we talked about renewable energy sector as a whole, only wind energy had started making a mark and that too, in South India. Solar energy and biofuels were yet to take off. I saw an opportunity in the field of biofuels and started learning about it. Having worked with the UN in the past, I had enough global contacts to travel and learn about this subject. I had unofficially began working in this sector in 2001. The biggest motivating factor for me to enter this field was that these projects were Triple Bottom Line projects, i.e., projects that had Social RoI, Environmental RoI and Economic RoI. Though most of the projects just have Economic RoI. Also, we are solving two problems at once: *Waste Elimination plus Fuel Generation* by converting waste into biofuel. When I had enough resources, a team in place and a clear vision, we officially registered Growdiesel on 5th August 2006. Since then, there was no looking back.

IMI Konnect: *Please share some insights on the status of biofuel industry in India. what are its major facilitators and challenges?*

AS: Before I answer this question, we need to understand how the commercials of this industry work. Fundamentally, biofuel industry is very different from solar/wind industry. Mostly, there are players who only sell the equipment. The energy or fuel generated is the property of the person/organization who bought those

*Founder and MD, Growdiesel Ventures Limited

equipment. However, we at Growdiesel do not believe in that. Every project we undertake, we have a stake in that project and thus we have a lifelong association with our partner. This not just ensures that the project is successful for years to come but also ensures that we have heavily reduced our capital expenditure (CAPEX). Since we are not into selling equipments and doing joint ventures, we do not have any margins in CAPEX. This is a sustainable business model that we have successfully implemented. The major facilitators in our field are municipal corporations. The biggest challenge is maintaining the supply chain as people from extreme ground level are involved. Keeping everyone on the same page can turn out to be a challenging task at times.

IMI Konnect: *How enthusiastic is Growdiesel in the implementation of renewable energy sources in business?*

AS: If we talk about solar, it took off really well, thanks to the government schemes and political will. Talking about "Waste to Biofuel", the rules for Municipal Corporations came in the year 2016 that waste to biofuel projects must be promoted. We had been working since 2001 and the policy came in 2016. By 2016, we had already four commercial projects up and running. This gives us enough credentials along with first mover advantage.

IMI Konnect: *Do you think the awareness of common people about using alternative energy has grown over the years? What are the initiatives required to create such awareness?*

AS: The awareness has drastically grown. We were appointed as the official consultants to Delhi government to conduct a survey. In the eight month survey, we were supposed to provide a complete solution of how Delhi can use all its waste to generate enough biofuel for its consumption. During this survey, we discovered some facts that the millennial generation has actually started to care more for environment friendly products. Many organizations have already installed huge solar energy panels. Government schemes have indeed given a boost in raising the awareness. Talking about Growdiesel, we have done numerous conferences and adopted innovative ways to raise awareness. We have conducted street plays, educational sessions in colleges and corporates. Our projects have been inaugurated by Chief Ministers and other highly ranked officials that has given us media coverage which we again used to raise awareness.

IMI Konnect: *What is the market share of Growdiesel? What is the scenario in terms of competition and regulation?*

AS: We are a player in the oil and gas sector. Oil and gas sector is a $200 billion market in India. By 2030, it will be $1 trillion market. As of now, we are not even a drop in the ocean. The cake is so huge that even if there are over 1 lakh companies like ours, the cake wouldn't get finished.

IMI Konnect: *What is the "Waste to Fuel" project undertaken by Growdiesel?*

AS: In the year 2008, we realized that waste management was another big problem that needs to be addressed. Also, we identified that biofuels could be derived from things that people dump inside their dustbins every day. We started devising a sustainable technology which could solve this problem. Once we were ready with the technology, we started approaching a number of government organizations. After a lot of persuasion, the former Chief Minister of Delhi, Smt. Sheila Dixit invited us for a presentation in February 2010. We presented it before the IAS officers, engineers and IIT professors.

We got the opportunity to install it in her office. We took 3 months time. On 25th August 2010, she inaugurated the project at Delhi Secretariat. It's been 8 years and even today, the project is still running. We have supplied 7500 LPG cylinders equivalent of biofuel to their canteen where 3000 people eat food every day. It was a turning point for Growdiesel. We wish to achieve fuel independence for India by 2030.

IMI Konnect: *Growdiesel has undertaken a $ 2 Billion project of Indian Railways. What is this project all about?*

AS: Indian Railways had thought of implementing a project that they would establish an oil bearing plant named "Jatropha" in all the wasteland available with them. Through a two stage global bidding process, Growdiesel was finally selected as the official consultant to oversee this project, from among over twenty countries. However, the project was discontinued with a change in political regime.

IMI Konnect: *Tell us something about the "Growdiesel Opportunity Accelerator" programme.*

AS: That's an interesting question which I didn't expect but I am glad you asked. In this world, we have 2 kinds of people – Employee and Employers. When Growdiesel was appointed as the governing council member of SCGJ (Skill Council for Green Jobs), we realized that the only way to create more jobs is to create more entrepreneurs. That's when we devised this initiative "Growdiesel Opportunity Accelerator (GOA)" through which we aim to provide mentorship, funding and technical backing to all those people who want to have their own biofuel company. Each of this company will be backed by Growdiesel's rich experience.

IMI Konnect: *You are now present in select cities of India. What is your future expansion plan?*

AS: We had kept ourselves very grounded until last year when government announced the Biofuel Policy 2018. We have introduced a channel partnership model in which anyone who is interested to enter this business can get our channel partnership and we will give him/her exclusive rights for a particular area subject to some conditions. This will not only give an opportunity to that entrepreneur but also one such person will be able to create 10 – 100 direct and indirect jobs per project. This is how we plan to create jobs after we have created an employer.

IMI Konnect: *Is Growdiesel planning to move forward to venture into other alternative energy sector?*

AS: As of now, we are quite pre-occupied with 'Waste to Biofuel' sector. Currently, we have no plans to diversify in other renewable energy sector.

IMI Konnect: *What were the challenges faced by Growdiesel for taking several alternate energy initiatives in the country?*

AS: Whenever a person or a company is trying to bring a change, it faces a lot of resistance. We had our share of them. The biggest challenge, however, has been maintaining the supply chain.

IMI Konnect: *You have innovations like biofuels from organic and plastic wastes. How are these products positioned in the market?*

AS: We have a very different and unique business model in which we aim to establish in-house project for an organization which can generate its own fuel for its own consumption. This initiative will help organizations to be fuel independent. We have exited from consumer market for now.

IMI Konnect: *You also have Clean Air and Clean Water projects. What is the market potential of such products in India?*

AS: KalpVriksha, the outdoor air purifier isn't a traditional air purifier. It was an R&D project with All India Institute of Medical Science, Delhi (AIIMS, Delhi). One KalpVriksha is equivalent to 50000 full grown trees. The idea was to purify air, extract the carbon and use it further for fuel production. For us, air is the byproduct. Talking about clean water projects, these are the projects we will be taking with utmost seriousness. We are very aggressively looking to expand and take up "Waste Water to Clean Water" projects. Water, after all is the mother of all fuels. We are yet to achieve commercially tangible things here but the technology has already been tried and tested.

Biofuel and Bioremediation Potential of Microalgae

Ramachandra T V* and Saranya Gunasekaran**

Abstract

Escalating fuel prices, rising environmental concerns and dwindling stocks of fossil fuel have necessitated the exploration of viable alternative feedstocks. Biofuel from microalgae has been showing the prospects of a viable alternative to the conventional fossil fuels. This article assesses the prospects of biofuel from diatom consortia[1] and also the bioremediation[2] potential to treat the nutrient-rich aquaculture wastewater.

Introduction

Wastewater generated in domestic, industrial and agricultural sectors comprises mainly of 99 per cent water and 1 per cent solid (both organic and inorganic) constituents. The characteristics of wastewater, especially the proportion and properties of solid constituents alter depending on its sources of origin. For example, in domestic wastewaters, organic constituents include carbohydrates, fats, lignin, synthetic detergents, various aliphatic and aromatic chemical compounds from household pharmaceutical waste disposal [Ramachandra et al. (2013)]. On the other hand, wastewater generated in aquaculture from shrimp farms are characterized by large proportions of total suspended solids (TSS), which are mostly of inorganic origin due to eroded material from pond floor and embankments in addition to dissolved nutrients, particularly nitrogen from un-utilized protein feeds, phosphates and organic carbon from phytoplankton and detritus[3]. In addition to nutrients, shrimp wastewater also contains soluble and insoluble biochemical compounds such as pesticides,

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[1]Diatom consortia is an association of several microscopic unicellular algae of a particular category called the phylum. Bacillariophyta, occurring in marine or fresh water in single or in colonies. In such algae, each cell has a cell wall made of two halves and impregnated with silica.

[2]Bioremediation is a process that uses mainly microorganisms, plants, or microbial or plant enzymes to detoxify contaminants in the soil and other environments.

[3]Detritus is an organic matter produced by the decomposition of organisms.

disinfectants, antibiotics, immunostimulants, vitamins and feed additives. This can cause substantial sediment loading and eutrophication[4] when discharged to the surrounding water bodies as partially treated or untreated. India has the distinction of having higher aquaculture production next to China, which results in the humongous generation of wastewater and its subsequent release to the surrounding coastlines. India's coastal line with a stretch of 7,517 km has land-based aquaculture in estuarine brackish water regions contributing significantly to the global production of fishes, molluscans and crustaceans. Among aquacultures, shrimp aquaculture is becoming the fastest growing economic activity in Asia-Pacific regions with India becoming a leading exporter of commercial farmed shrimps. India's shrimp production is constantly increasing, since 2011, with an estimated annual production of 0.48 MMT (Million Metric Ton) in 2018. Figure 1 depicts the spatial extent of aquaculture ponds, shrimp productivity and an estimate of wastewater generated across the Indian states.

Microalgae help in bioremediation of wastewaters through bio-assimilation of nutrients into numerous organic molecules either fixed autotrophically or heterotrophically [Mahapatra et al., 2014; Ramachandra et al., 2013]. The autotrophic mechanism involves the utilization of CO_2 from the atmosphere and light energy from the sun during photosynthesis for biomass production in the form of carbohydrates and lipids. Mostly, inorganic mineral constituents (nitrogen, phosphorous and silica) are utilized in autotrophy, whereas in the heterotrophic mechanism, organic carbon is directly consumed by algae for nutrition, replacing the necessity of light energy.

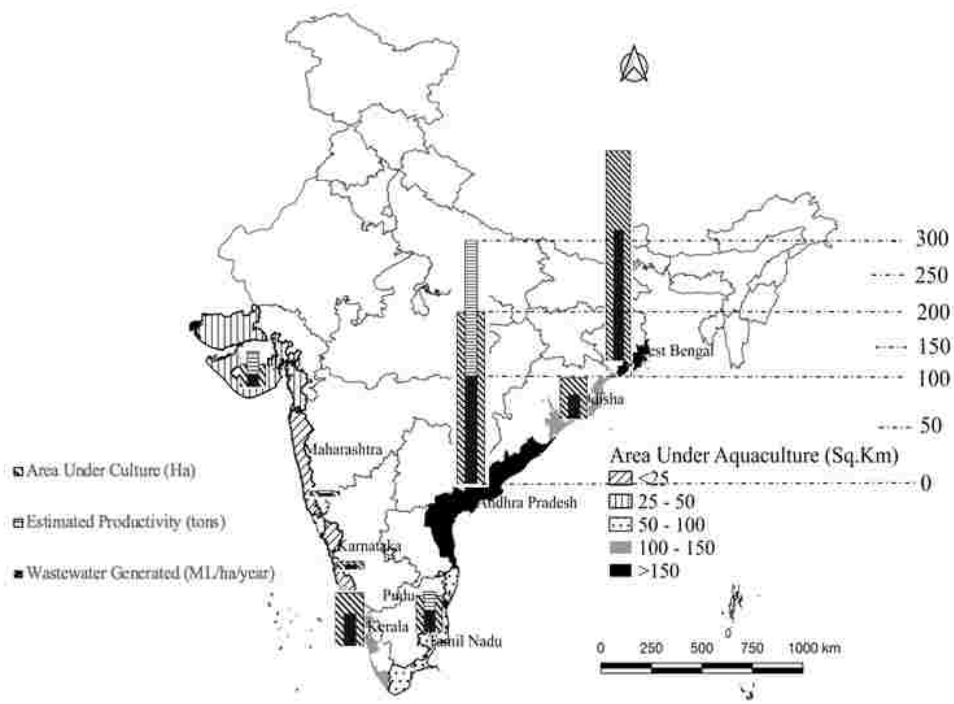
Microalgae diatoms are known to possess promising capabilities including its predominant presence in estuarine and continental shelves, accumulate 8 per cent more lipid content (per cent as of dry cell weight) than green microalgae during its exponential growth phase.

Shrimp Cultivation in India

Estimates indicate that about 343.53 ha. of land is under shrimp cultivation in Karnataka, India with an estimated productivity of 3.14 Mt/ha/yr. Uttara Kannada district with a total area of 218.06 ha. under shrimp cultivation, constitutes one of the major producers of shrimps. Uttara Kannada has the highest share (4200 ha.) of brackish water formations, out of which 1450 ha. of land are gazni lands (brackish water embayment). The local fisherfolks practise traditional shrimp farming in these gazni lands. The traditional method of shrimp cultivation is being practised extensively with no external feed inputs for shrimps' growth and such practice lowers

[4] Eutrophication refers to excessive richness of nutrients in a lake or other body of water, frequently due to run-off from the land, which causes a dense growth of plant life.

Figure 1: State-wise Aquaculture Production and Its Associated Wastewater Generation



environmental loadings and nutrient enrichment in the receiving water bodies. However, large-scale commercial activities involve semi-intensive and intensive types of shrimp farming where selective and higher seed stocking[5] is practised, which generates higher quantum of wastewater rich in total suspended solids (TSS) and dissolved nutrients such as Total Nitrogen (TN), Total Phosphorus (TP) and Total Organic Carbon (TOC). Also, intensive shrimp farming has inherent long-term management problems such as loss of coastal habitats and agricultural lands due to salinization, culture stock losses due to disease outbreaks, slow growth of shrimp fry and other socio-economic issues. This necessitates appropriate low-cost mitigation strategies to minimise organic pollution due to commercial shrimp production units. Thus, incorporation of the decentralised microalgal system near shrimp cultivation sites would aid in remediation of organic nutrients, through bio-assimilation as well as biofuel production from the microalgal

[5]Seed stocking is the selection of good quality seed for stocking into a pond and this is the first important step of the shrimp grow-out management.

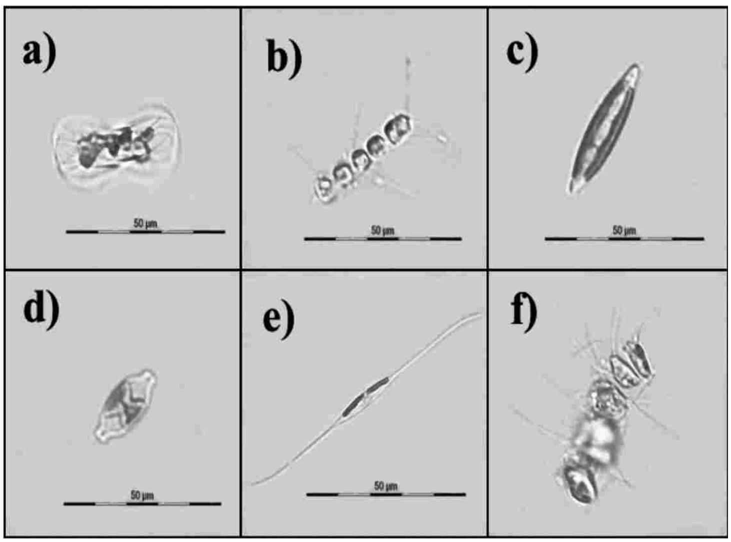
consortium. In this regard, lipid productivity potential of marine microalgae needs to be understood and the present research focussed on growing microalgal consortia, predominantly composed of benthic diatoms[6] using aquaculture wastewater under laboratory observations.

Biofuels Generation from Microalgae

Microalgae (benthic diatoms) were collected from sediments of a mangrove-rich brackish water region (14°31'9.55"N, 74°23'7.53"E) of the Aghanashini estuary. Figure 2 shows the light micrographic images of the diatoms that were present in the consortia.

Diatom consortium naturally occurring in the estuarine ecosystem were monitored in the laboratory with aquaculture wastewater in-order to understand the technical feasibility of the large-scale microalgae production. The biomass productivities of microalgae under diverse nutrient conditions varied between 32.3 – 41.6 mg $L^{-1}day^{-1}$, with lipid content ranging between 24 to 42 per cent of dry cell weight. Bioremediation potential is evident from the mean nutrient removal efficiencies of 89 per cent and 90 per cent for Total Nitrogen (TN) and Total Phosphorous (TP) respectively. Further analysis[7] provided insights to the treatment of aquaculture wastewater through microalgal biomass, extent of lipid accumulation and also the optimal day for harvest of microalgae. Moreover, the higher composition of mono-unsaturated and saturated fatty acids highlights the scope for biodiesel.

Figure 2: Light Micrographic Images of Diatoms Present in the Culture Consortium



[6]Benthic diatoms are the dominating group of benthic algae, and therefore play an important role as primary producers, especially in running water.

[7]Flow cytometric analysis of microalgal cells depicted the real-time accumulation of neutral lipids in-vivo during different phases of cell growth. Fatty acid profiling through GC-MS showed higher percentages of saturated and monounsaturated fatty acids of C16 and C18 carbon chains.

Conclusion

The removal of nutrients such as TN (~89 per cent) and TP (~90 per cent) and higher lipid content in algae, highlights the bioremediation potential with biofuel prospects of the microalgal consortia grown in aquaculture wastewater. India has the distinction of having higher aquaculture production next to China, which results in the humongous generation of wastewater and decentralized diatom based microalgae treatment system will help in treating wastewater as well as aid in ensuring energy security through biofuel.

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