



Green Technology²⁰¹⁵

[Revolution in Energy Sector]



SOLAR

WASTE
TO
ENERGY

HYDRO

BIOMASS

WIND

Principal Author
Dr. Madhulika Bhati

Core Team Members
Mr. P Kumar
Mr. Rehan Ahmad
Mr. Konchok Ishey



**CSIR - NATIONAL INSTITUTE OF SCIENCE
TECHNOLOGY AND DEVELOPMENT STUDIES**

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This Report has been prepared under Twelfth Five Year Plan Project- First Study of its kind focusing on various dimensions of innovation activity in India; aiming at providing valuable inputs for S&T and Innovation decision making.

**CSIR-NISTADS*

***Post Graduate Student, Robert Gordon University, Aberdeen, Scotland*



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ABBREVIATIONS

NREP	National Rural Electrification Policies
CEA	Central Electricity Authority
WTE	Waste to Energy
DC	Direct Current
AC	Alternating Current
CIGs	Copper Indium Gallium Deselenide
CNT	Components Nanotubes
QDs	Quantum Dots
HC	Hot Carrier
NREL	National Renewable Energy Laboratory
STE	Solar Thermal Electricity
CSP	Concentrating Solar Power
LFC	Linear Fresnel Collectors
SDC	Sterling Dishes Collectors
PTC	Parabolic Trough Collectors
MWh	Mega Watt hours
GWh	Giga Watt hours
FIT	Feed in Tariff
RPS	Renewable Portfolio Standard
GaAs	Gallium Arsenide
SEMI	Semiconductor Equipment and Materials International
RMB	Renminbi
BIPV	Building Integrated Photovoltaic
RPO	Renewable Purchase Obligation
RPS	Renewable Portfolio Standard
MNRE	Ministry of New and Renewable
JNNSM	Jawaharlal Nehru National Solar Mission
SEZs	Special Economic Zones
IREDA	Indian Renewable energy Development Agency
UDH	Urban Development and Housing

CERC	Central Electricity Regulatory Commission
kVA	Kilo Volt Ampere
kW	Kilo Watt
kWh	Kilo Watt hour
SHP	Small Hydropower Plant
MW	Mega Watt
GW	Giga Watt
PLF	Plant Load Factor
PV	Photo Voltaic
SPV	Solar Photo Voltaic
USA	United States of America
MoP	Ministry of Power
GoI	Government of India
CWPC	Central Water and Power Commission
UK	United Kingdom
NFFO	Non Fossil Fuel Obligation
UNIDO	United Nations Industrial Development Obligation
IEC	International Electrotechnical Commission
E&F	Environment and Forest
TDP	Thermal Depolymerisation
MSW	Municipal Solid Waste
UV	Ultraviolet
MoEF	Ministry of Environment and Forest
MoUD	Ministry of Urban Development
ULBs	Urban and Local Bodies
JNNURM	Jawaharlal Nehru National Urban renewal mission
ELFM	Enhanced Land filling Mining
RDF	Residual Derived Fuel
NCE	National Council of Energy policy
VGf	Variability Gap funding
PPP	Public Participation Programme
WtE	Waste to Energy

1. Executive Summary

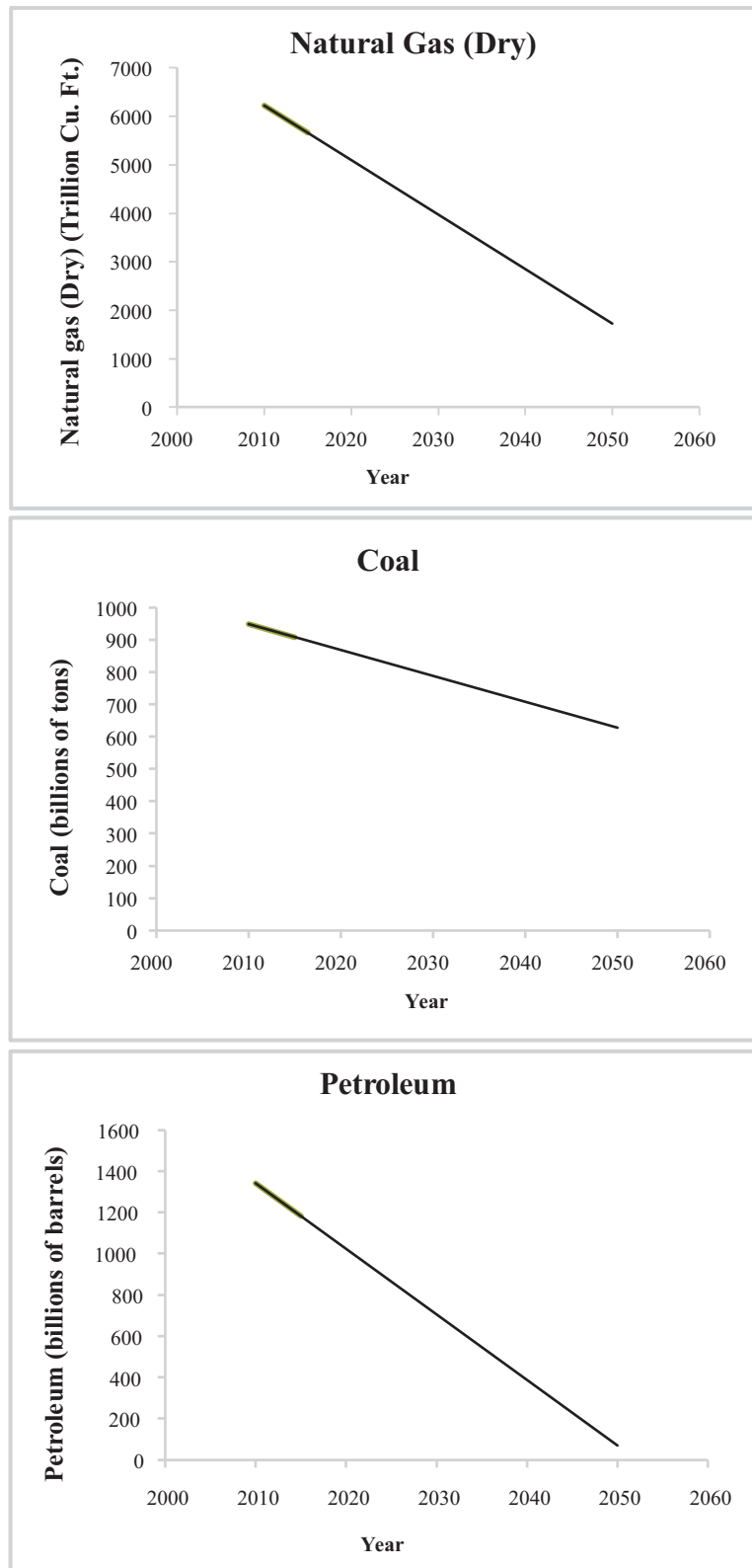
The industrial revolution that began in the second half of the 18th century was primarily based on the more conventional energy sources like coal and later oil and natural gases. These are the finite resources on the earth and continuously depleting. Several studies analyzed the approximate lifetime of world's petroleum, natural gas and coal reserves with current consumption rate which is 42 years, 56 years, and 118 years, respectively Figure (1.1). Apart from pressure on total resources and availability, the burning of vast quantities of coal and oil and other fossil fuels are responsible for environment deterioration and also significantly contributed to global warming. Thus the challenge before us to harness the energy forms in such a way and they decrease the CO₂ emission (footprint) and also preserve the environment and the ecological balance.

Green technologies sometime also known as 'Clean Technologies' such as wind technology, solar technology, small hydropower, biomass and waste to Energy technologies is considered in this category. These technologies are developed and promoted as alternative sources that make little or no contribution to climate change and provide sustainable energy services to meet the global energy demands. These green technologies have strong potential to meet the future energy demand without compromising the environment quality as they have very less carbon. At first in 1980, United Nations General Assembly put it the need of energy transition as "The international community will have to make substantial and rapid progress in the transition from the present international economy based primarily on hydrocarbons. It will have to rely increasingly on new and renewable sources of energy, seeking to reserve hydrocarbons for non-energy and non-substitutable uses".

The conception of renewable energy was further emphasized by the 150 nations of the world at the New Energy and Renewable Energy Conference by United Nations at Nairobi in August 1981. Renewable energy was defined clearly that the renewable energy was developed and utilized by using new technology and new materials. Renewable energy is different from other fossil energy for its sustainable development, restoring ability and environment friendliness. Some main types of green technologies are solar, wind, small hydro, biomass and waste to energy, etc. This renewable or green technology helps in meeting the present energy requirement without compromising future energy needs and environmental factors.

¹Guo M, Song W and Buhan, J. (2015). Bioenergy and biofuels History, status, and perspective. *Renewable and Sustainable Energy Reviews*, 42, 712–725.

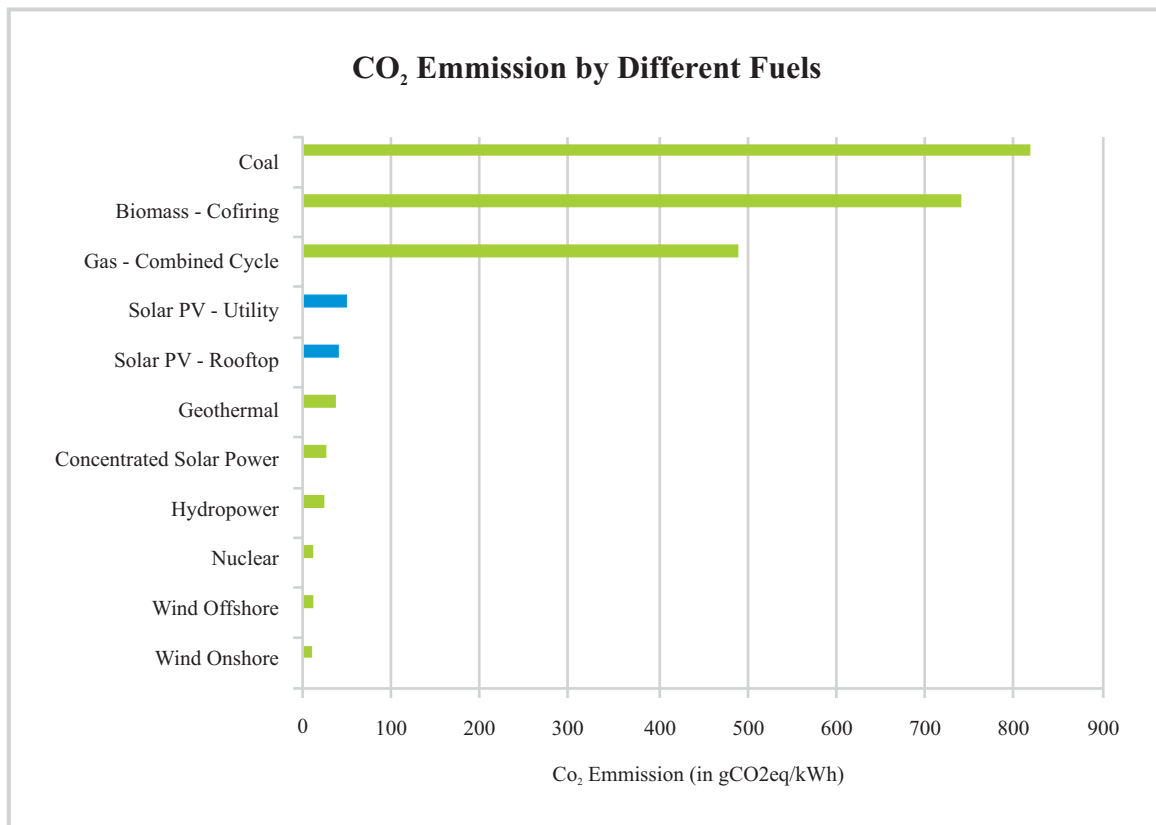
²Xinyu , G. et.al. (2011). Study on Renewable Energy Development and Policy in China. *Energy Procedia* 5, 1284-1290

Figure 1.1: Lifetime of natural Gas, Coal and petroleum Reserves

(Source: MNRE Annual Report 2014-2015)

Therefore, helps in preserving the earth and its natural sources. Green technologies use the resources that are continually replenished by nature, thereby causing no significant negative effect on the environment. Technologies for green energy helps in increasing energy security and reducing the dependence on conventional energy sources like fossil fuels³. The various forms of renewable energy can be traced back to three primary sources: Solar radiation, heat from within the earth and gravitational forces between the earth, the sun, the moon and other stars.

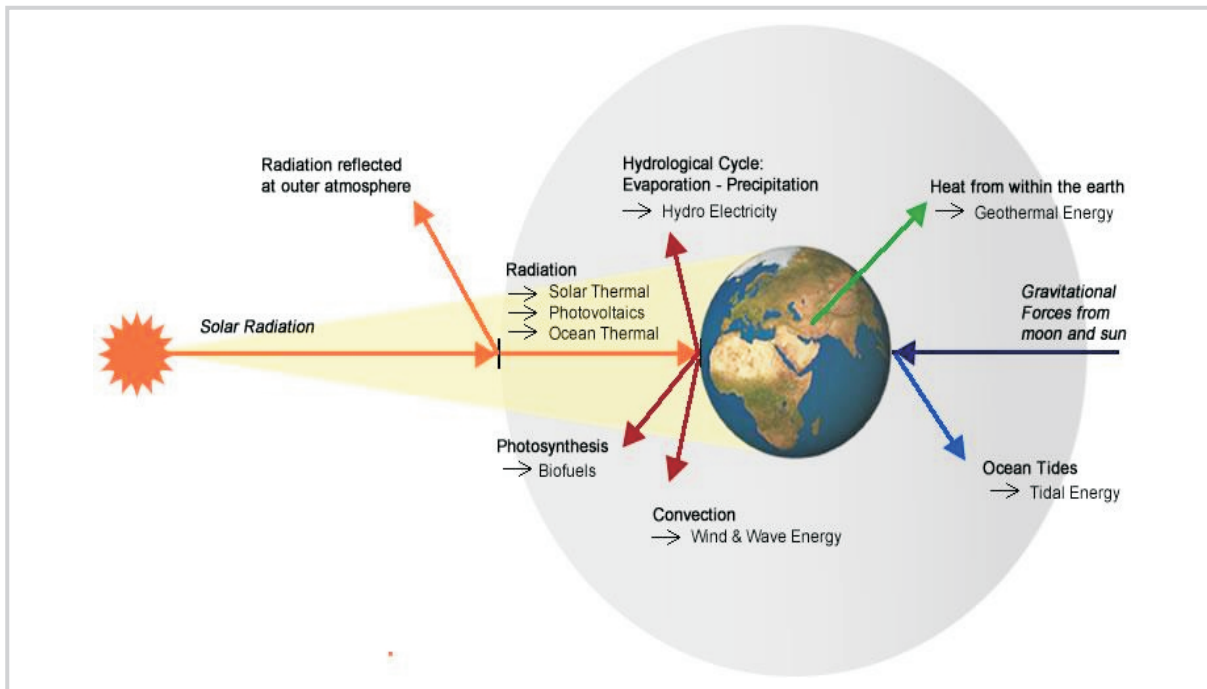
Figure 1.2: Carbon footprint of different conventional and non-conventional technologies



(Source: EIA Report 2015)

In this report, we mainly discuss the state of the art of Solar, Small hydro, Biomass and Waste to Energy (WtE) Technologies. Report provides the insight of recent advances and different kind of technologies in each sector. We also discuss the main world leaders in each technology and policy environment to promote these technologies and we further stretch it to discuss the main policy environment in India for each technology. Report highlights the challenges and policy suggestions to promote these technologies in sustainable manner.

³Omer, A.M. (2008). Energy, environment and sustainable development. *Renewable and Sustainable Energy Reviews*, 12, (9): 2265-2300.

Figure 1.3: Sources of Renewable Energy

(Source: <http://www.greenrhinoenergy.com/renewable>)

1.1. Green Technologies type

Research into renewable, non-polluting energy sources is advancing at such a fast pace, it's hard to keep track of the many type of green technologies that are now in development. In his report we provide an insight of the state of the art of technology, Policy Environment, challenges and policy suggestions of the following green technologies:

1.1.1. Solar Technologies with special emphasis of Solar PV

Solar technologies use solar energy which is an inexhaustible clean energy that provides 99.98% energy for renewable energy. This most prevalent type of solar technologies are: solar Photovoltaic (PV) and concentrated Solar Power (CSP). This chapter is planned to give a comprehensive state- of- art solar technologies and provides the necessary technical knowledge for understanding of this technology. Report also provides the in- depth analysis of policy environment as well strategies of world leader China to promote Solar PV technology and also highlights the policy environment of Solar PV in India and challenges and suggestions for its sustainable development.

1.1.2. Hydropower with special emphasis on Small Hydro Power (SHP)

It is also known as hydroelectric power; this chapter provides the comprehensive analysis development Status, challenges, issues and Policy environment in India.

⁴www.ijast.org

1.1.3. Biomass Technologies

Biomass is biological material derived from living, or recently living organisms. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material. The chapter provide the comprehensive overview of biomass conversion technologies and latest information on biomass status different part of India and Potential status of India. Chapter also emphasis on the issues and suggestions for successfully deployment of this technology in the market.

1.1.4. Waste to Energy Technologies

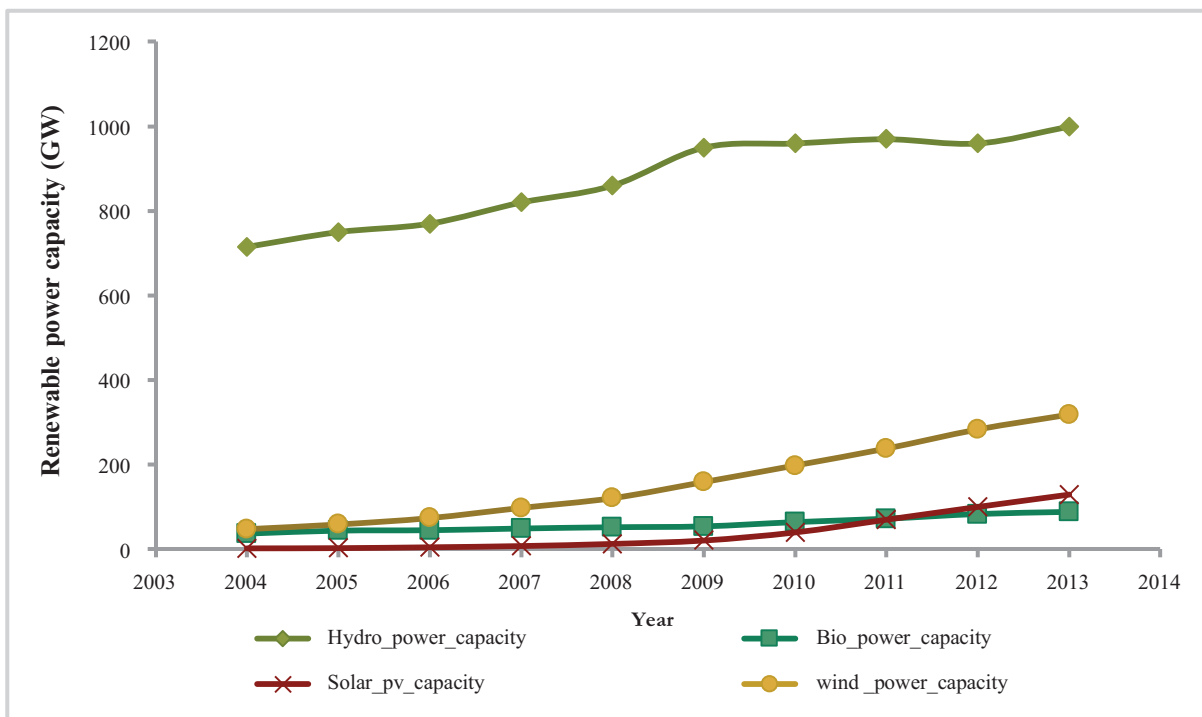
Technologies to derive energy from waste are known as Waste to energy. In India, Municipal Solid waste and Industrial Waste collectively used to produce energy. This chapters discusses the waste to energy technology in details and also provide in-depth insight about the Regulations, Policy environment to promote Waste to energy technologies. It also suggested the policy suggestions of each and every issue faces nowadays by this technology with possible reason of these issues and also provide few innovative concept which is practices by other developed nations and get success to use most of waste for energy production .Worldwide these technologies provide 21.7% of electricity generation. The scenario for renewable Energy changes day to day as the growth of globalization. Due to clean and easily accessible properties, investments in this field increases rapidly. Developed and Developing Countries are spending substantial amount to develop these technologies with aim of energy security and independency. Green technologies contribution is significantly increases in energy mix of countries. A sharp increase in global power capacity from non-conventional technologies has been shown since last decade. (Fig.1.4).

1.2. Green energy: India Overview

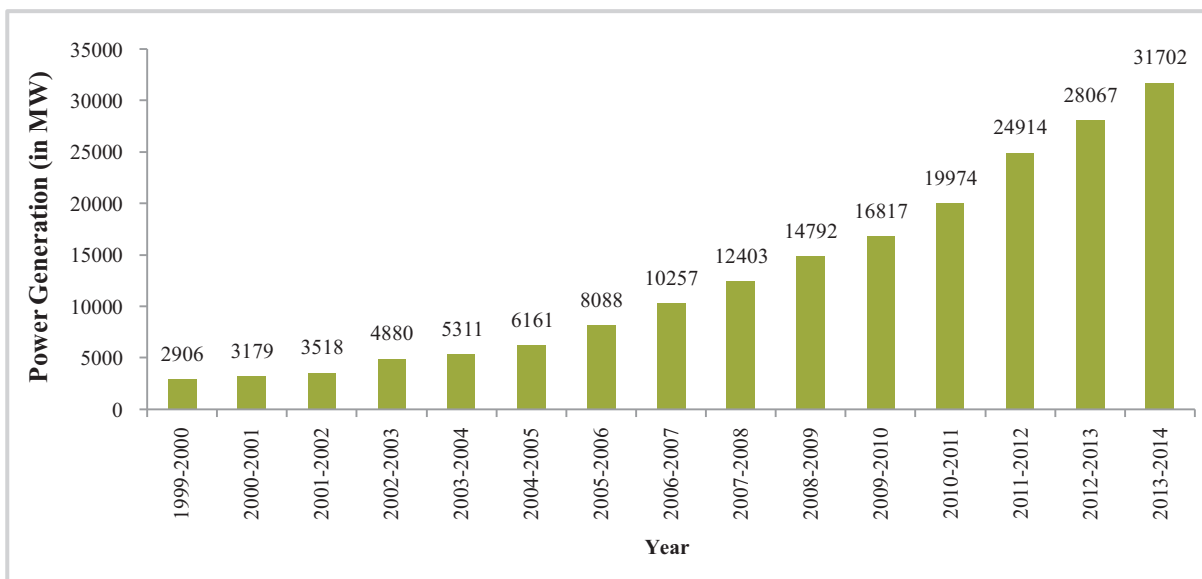
In the shadows of worlds Renewable energy market India is no longer behind it's step up so quickly to meet the target of power demand which is growing rapidly (Table). India is determined to becoming one of the world's leading clean energy producers. The Government of India has already made several provisions, and established many agencies that will help it achieve its goal. Renewable Energy, Excluding large hydro Projects already account for 12% of the total installed energy capacity. Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy. India was the first country in the world to set up a ministry of non-conventional energy resources. In early 1980s, India's cumulative grid interactive or grid tied renewable energy capacity (Excluding large hydro) has reached 29.9GW, of which 68.9% comes from wind, while solar PV contributed nearly 4.59% of the renewable energy installed capacity in India. Fig. 1.6 shows India's split of renewable energy and we can see the wind energy have a significant part in that.

⁵www.Irdindia.in

⁶www.entece.org

Figure 1.4: Global Power Capacity from non-conventional technologies⁷

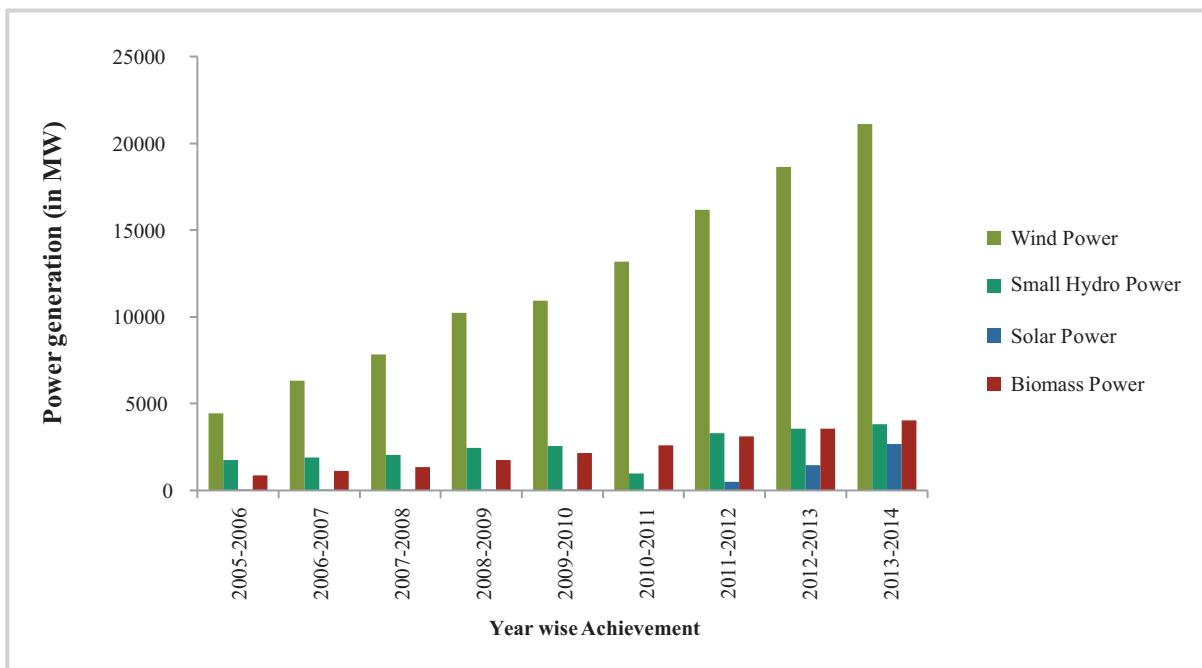
(Source: REN21 Global Status Report)

Figure 1.5: Annual Increase in Renewable Energy Generation from Green Technolog⁸

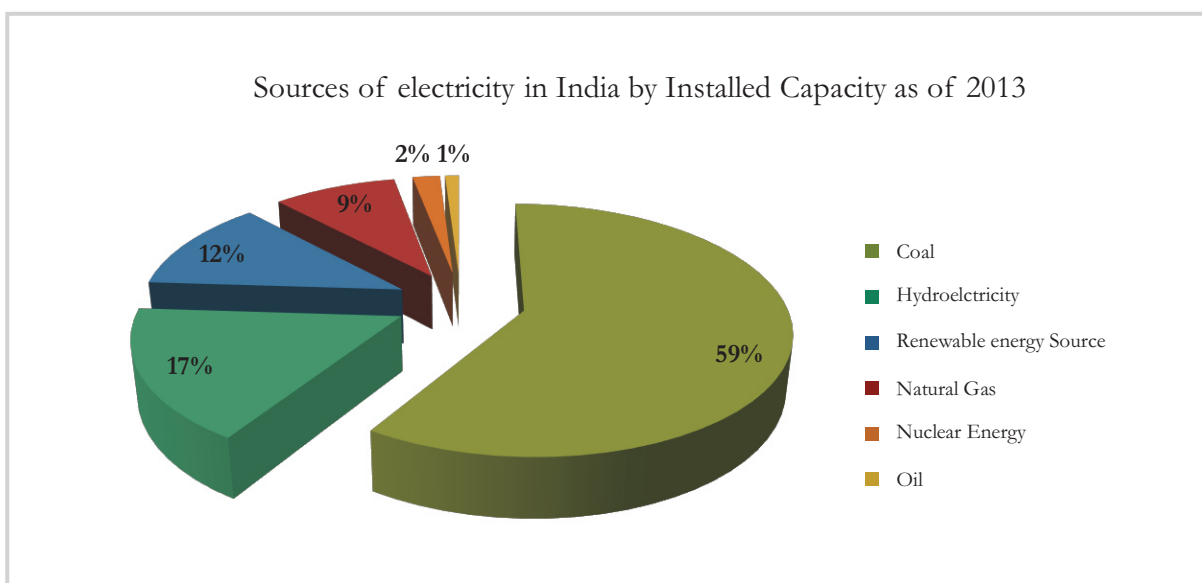
(Source: MNRE Annual Report 2013-2014)

⁷<http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx>

⁸<http://mnre.gov.in/file-manager/annual-report/2013-2014/EN/contents.html>

Figure 1.6: Contribution of various Green Technologies to produce energy

(Source: Various MNRE Reports from 2005 and 2014)

Figure 1.7: Percentage of different kinds of technology in energy mix in India

(Source: MNRE Annual Report 2013-2014)

The development of wind power in India began in the 1990s, and has significant increase in the last few years. Wind technologies are mature enough and able to achieve grid parity in various developed and developing countries like India. India becomes the country with the fifth largest installed wind power capacity in the world. Therefore report limited its discussion to solar, small hydro, biomass and waste to Energy which still have to overcome several barriers to progress in a sustainable manner. Electricity generation from renewable represents about 3% of all electricity generation in India. India produces a huge quantity of biomass materials from its agricultural residues. Waste to energy is an emerging technology.

2. WIND TECHNOLOGY

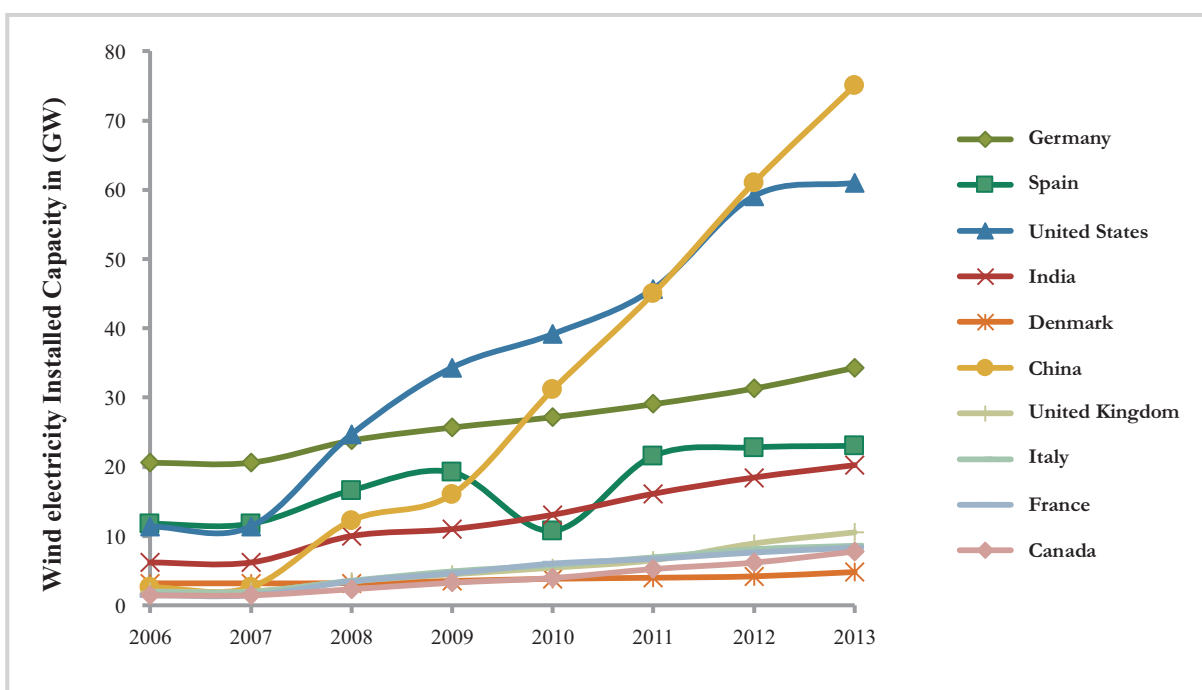
2.1 Wind Energy Status: An Indian Scenario

High growth rate of energy consumption, high share of fossil fuels like coal in domestic energy demand, heavy independence on oil for meeting need of petroleum fuels are core drivers to push towards green technologies to produce renewable energy. A number of green technologies are well established in the country but the technology that has achieved the most dramatic growth rate and success in wind energy technologies⁹.

Wind Energy is playing a substantial contribution in India's renewable energy. It has tremendous scope to contribute significantly to get the energy independency. India Government identified wind energy as a promising energy sources and they have made policy instruments like regulations, incentive schemes, legislations which support energy. Generation by wind and give emphasis the advancement in wind technologies development. Because of these supportive policy instruments India occupies fifth position in wind sectors worldwide after China, USA, Germany, and Spain (Figure 2.1). This is an indicator that wind energy has been playing significant role in renewable energy market in India¹⁰. India is progressing very well to achieve target set for grid connected energy generate by wind turbines overcoming by all barriers and create a conducive environment for successful diffusion of wind energy in India. India is well ahead to achieve all the target set in every five year plans.

⁹M. Carolin Mabel, E. Fernandez (2008). Growth and future trends of wind energy in India, *Renewable and Sustainable Energy Reviews*, 12, 1745-1757

¹⁰https://www.irena.org/DocumentDownloads/Publications/GWEC_India.pdf

Figure 2.1: Wind power capacity of top 10 countries

(Source: International Energy Statistics website)

2.2. Expansion in Wind Power Installation capacity (1981-2015)

India started its journey in wind sector by generating 2.2 MW electricity in 1990. It has been observed that period 1981-1990 showed very slow growth in this sector and able to expand the capacity only to 37MW. Wind power generation showed some momentum during 1991-2000. During Phase 3 and phase 4 wind power programme accelerated in a big way results in capacity reached 23,444 and made wind the main contributor among all other Renewable energy technologies.

Table 2.1: Wind Power Installation during 1981-2015

Phase 1 (1981-1990)	Phase 2 (1991-2000)	Phase 3 (2001-2010)	Phase 4 (2011-2015) Target 2020:
Wind power generation capacity rose from (2.2MW to 37MW)	Wind power generation capacity rose from (37MW to 1167MW)	Wind power generation capacity rose from (1167 to 10,925)	Wind power generation capacity rose from (10,925 to 23444)

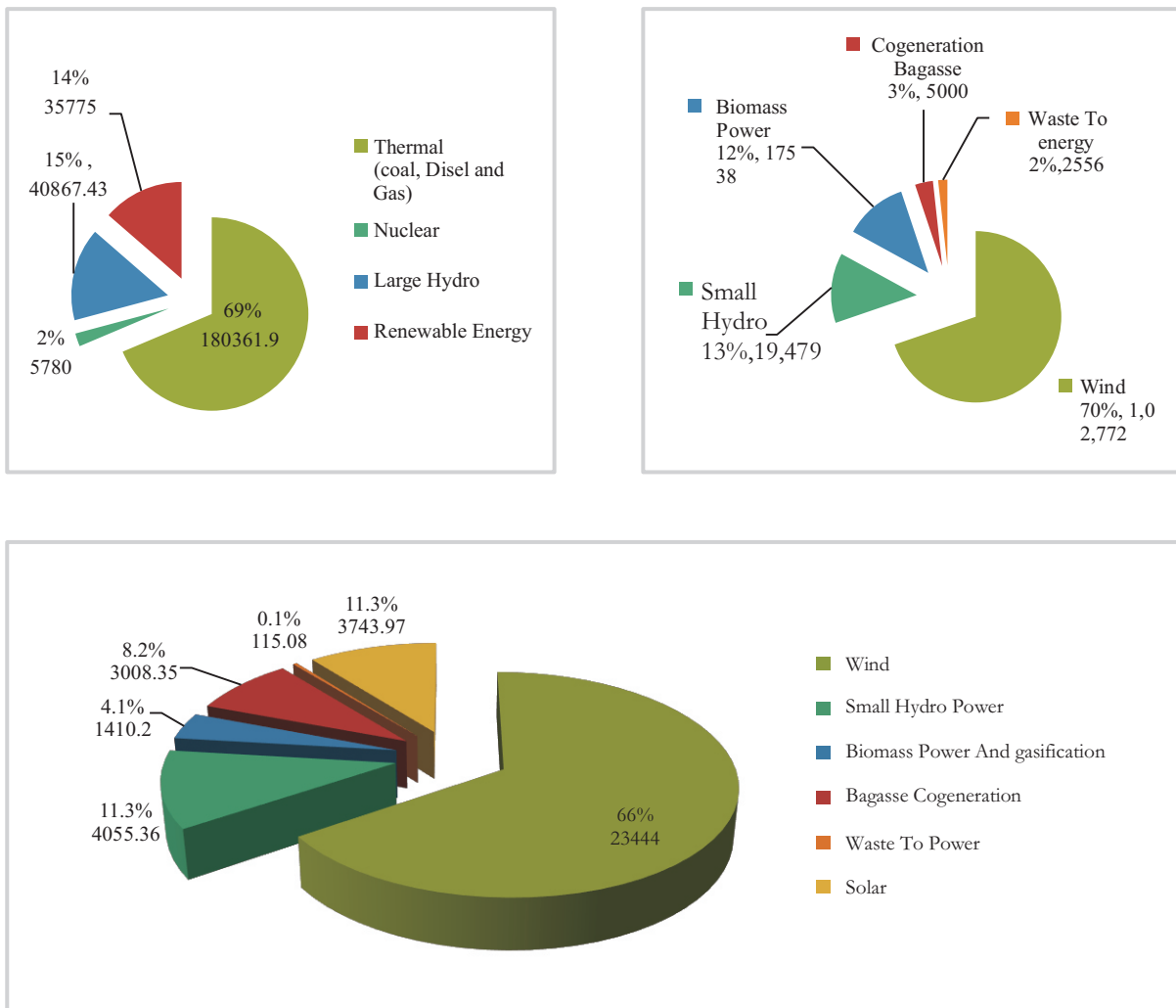
(Source: Bhattacharya, S.C; and Jana, 2009)¹¹

¹¹Bhattacharya ,S.C; and Jana, C. (2009). Renewable energy in India: Historical developments and prospects, *Energy*, 34 981-991

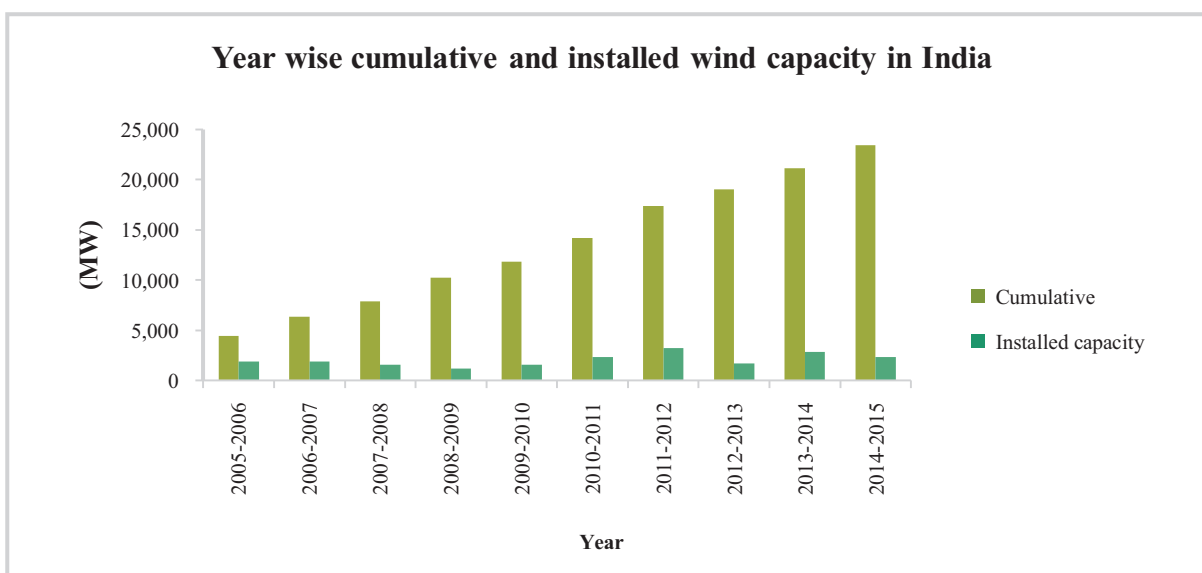
Wind power potential in India was initially estimated to be 20,000 MW and later revised upwards to 45,000 MW by MNRE excluding off-shore potential; a potential of 65,000 MW has been quoted by the Planning Commission of India inclusive of off- shore potential. According to Indian wind energy association (IWEA), the potential is 65,000 MW exclusive of off-shore wind. MNRE recent report now claimed the total wind potential in the country is as high as 102,000 MW¹².

India has the fifth largest generation portfolio worldwide with a power generation capacity of 250 GW. Current Renewable energy contribution is stand at 35GW which is 14% of total power generation capacity. Wind technology alone contributed 70% which make it largest renewable source in India

Figure 1.6: Contribution of various Green Technologies to produce energy



(Source: MNRE Annual Report 2014-2015)

Figure 2.3: Year wise cumulative and installed wind capacity in India

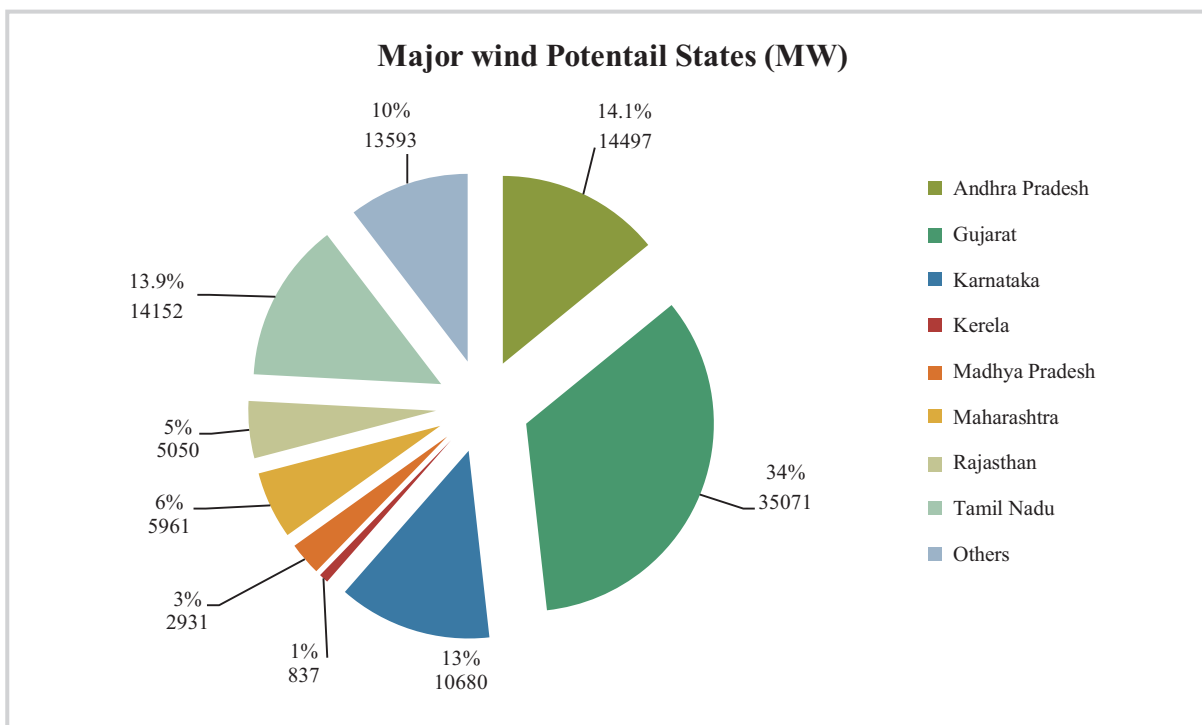
(Source: MNRE annual reports from 2005-2015)

With current installed capacity of over 23,444 MW, India ranks fifth in terms of the global installed wind power capacity. The gross estimated wind power potential in India is 1,02,000 Megawatt. Utilization of wind power is extremely site specific and the success of wind technology presumes that the energy demand exists at that point of time and location¹³.

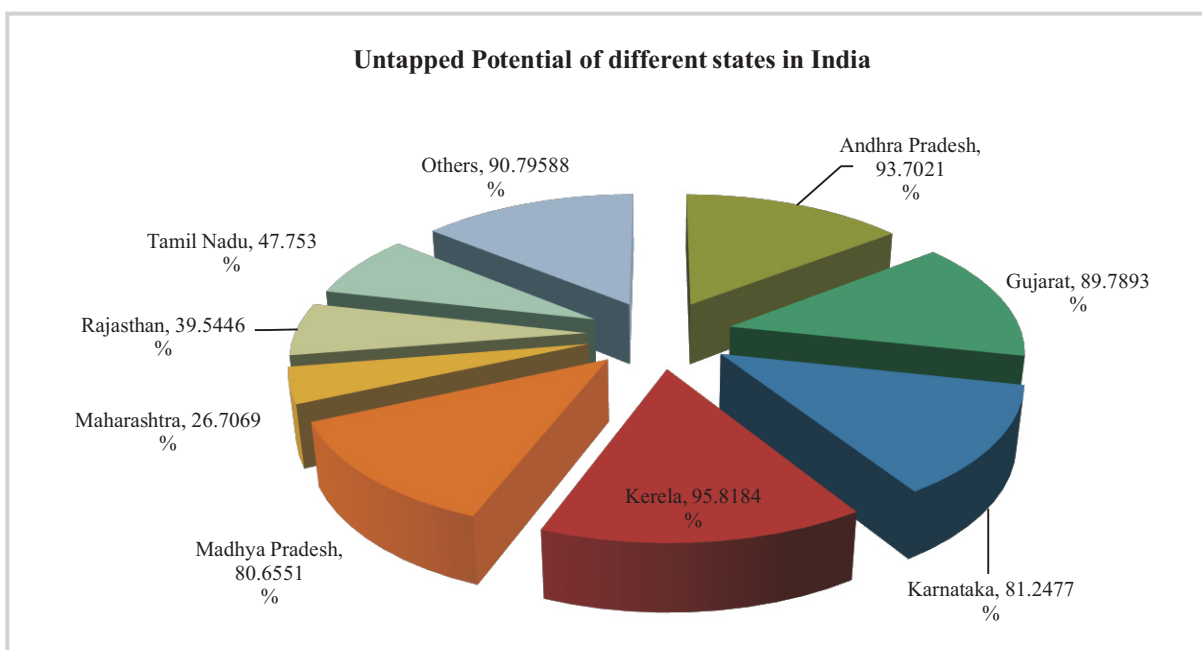
Currently eight States of India, namely, Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Rajasthan, Maharashtra, Madhya Pradesh, Kerala are implementing major wind energy programmes and major wind energy potential state. However, the six states – Maharashtra, Gujarat, Tamil Nadu, Rajasthan, Karnataka and Andhra Pradesh account for approximately 87% of the total potential. Though there are a set of incentives and guidelines for promotion of wind power at the central government level, the individual states follow their own policies. States established regulatory commissions which formulated and implemented policies for (among others) renewable power promotion such as preferential tariffs, wheeling and banking charges, third party sales, etc. There are also other state specific issues such as grid quality, availability of land for installations, distance from the generation point to feed-in point, etc. Consequently, the rates of diffusion and achievements have been different for different states¹⁴.

¹³<http://mnre.gov.in/mission-and-vision-2/achievements/>

¹⁴K. Usha Rao, V.V.N. Kishore (2009). Wind power technology diffusion analysis in selected states of India. *Renewable Energy*, 34, 983–988.

Figure 2.4: Major wind Potential States (MW)

(Source: http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2015_28mar.pdf)

Figure 2.5: Untapped Potential of different states in India

(Source: http://www.indiaenvironmentportal.org.in/files/file/Energy_stats_2015_0.pdf)

2.3. Recent Wind Energy Technology Advances:

Worldwide, wind power technologies (Wind turbine) have achieved remarkable advances due to modern technological developments. The trends of wind energy technology development indicate main improvement areas are weight of turbines and the noises they emit. A significant reduction in weight and noise level has been observed since last few years. Due to advances in the technologies wind power is competitive with that of traditional sources and expected to capture the world's 5% energy market by 2020¹⁵.

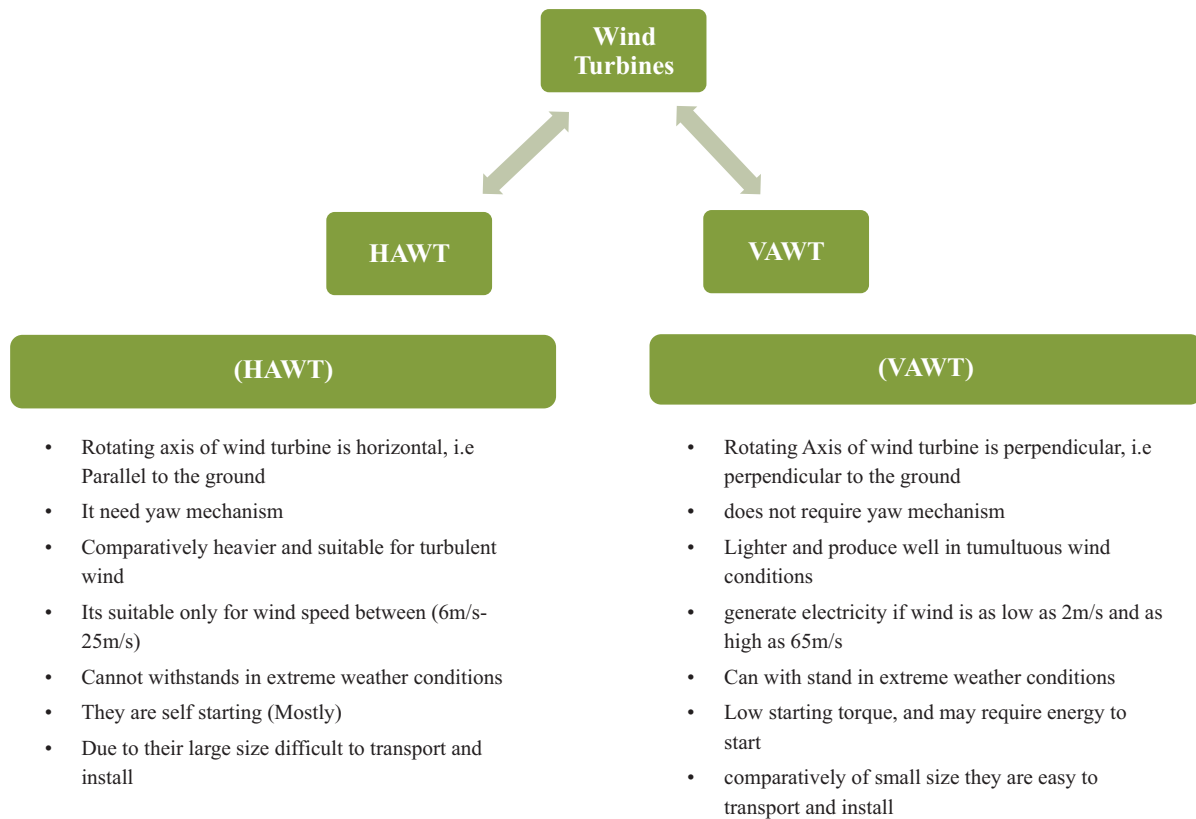
There are basically two type of wind turbine technologies are available depending upon their orientation around the axis; Horizontal Axis Wind turbine Technologies (HAWT) and Vertical Axis Wind turbine Technologies (VAWT)¹⁶.

In the modern wind turbine technology, the HAWTs are matured and currently available technologies.

Technical development in VAWT is in nascent stage. VAWT are aerodynamically more efficient than HAWTs and it is more suitable in large scale wind energy generation. Now researcher are paying more attentions in R& D of technological development of VAWT due to its superior aerodynamic efficient and performance as well as independency from wind flow and directions as HAWT very much needed so VAWT negates the need for a yawing mechanism therefore make it more economic. VAWTS can be more effective in the complex urban terrains to harness the wind energy that helps to increase the capacity of small-scale wind power generation. Advantage and disadvantage of both technologies are discussed in Figure 2.6.

¹⁵ G.Neeraj, R.M.Moharilb, P.S.Kulkarni (2009). Wind electric power in the world and perspectives of its development in India. *Renewable and Sustainable Energy Reviews*, 13, 233–247.

¹⁶ M.R. Islam, S. Mekhilefand, R. Saidur (2013). Progress and recent trends of wind energy technology, *Renewable and Sustainable Energy Reviews*, 21, 456–468.

Figure 2.6: Advantage and Disadvantage of HAWT & VAWT

(Source: A.Elshkaki, and T.E.Graedel, 2014 and M.R Islam and S.Mekhilef, 2013)^{17, 18},

2.4. Policy Environment to Promote Wind Energy

Grid-connected wind power concept was introduced in India in 1983 as a demonstration programme. Following a favorable reception for this programme, the Ministry of New and Renewable Energy (MNRE) introduced a set of measures and policies to promote wind power in a big way are as follow¹⁹:

2.4.1. Preferential Tariffs

These are the rates paid by the utility per kWh to a wind power producer. For encouraging renewable power, governments in various states have paid higher rates compared to conventional electricity (grid power) rates.

2.4.2. Wheeling charges

The costs charged by the utility for allowing the power producer to generate electricity at one

¹⁷ A.Elshkaki, T.E.Graedel (2014). Dysprosium, the balance problem, and wind power technology, *Applied Energy*, 136,548-559.

¹⁸ M.R Islam, S.Mekhilef (2013). Progress and recent trends of wind energy technology, *Renewable and Sustainable Energy Reviews*, 21, 456-468.

¹⁹ <http://gwec.net/wp-content/uploads/2012/11/India-Wind-Energy-Outlook-2012.pdf>

point and use it at another point using the grid lines is called the wheeling Charge. Many states had a wheeling charge of 2% in early 90s, but some of them increased to 12% later.

2.4.3. Banking

This allowed the producer to produce power at one point of time and use it at a later time. Most states have banking period ranging from 6–12 months. Availability of adequate transmission facilities: Providing the transmission facilities from the point of generation to the nearest interconnection point in the grid is the responsibility of the State Government implemented through the State Transmission Utility. The quick and timely response of the state governments signified their commitment to wind power.

2.4.4. Additional State Incentives

Almost all the States have a package of incentives for industries to promote investments, and hence economic development. These constitute GoI has formulated a strategy of providing incentives to private manufacturers in this sector. Indian government is giving income tax holidays, concessional custom duty/duty free import and accelerated depreciation to the investors in this field additional subsidies, an investor decides to select a particular state depending on such incentives.

2.4.5. Third Party Sale

Some state governments allowed the wind power producers to negotiate and sell electricity to a third party other than the State Electricity Board (SEB) or the Distribution Companies (DISCOMS). This provided an additional avenue for the wind power producers to earn more revenues.

2.4.6. Land Availability

Acquiring land for installation of wind power depended on whether the land was privately owned or had to acquire from the government. In some States, availability of private lands made it easier for developers to acquire land for installations.

2.5. Major initiatives taken by Creation of Policies specific to Offshore Wind

Wind policy framing in India happens at the central and state levels. The central government through the MNRE and its agencies develop federal level policies, and the states are allowed to develop their own operational level policies and tactics. Over the years, the onshore wind policy framework has been evolving with all possible advancements. However, the offshore wind seems to have been neglected, as the challenges of developing offshore wind are far more and more complex. Considering the high potential, and the nature and magnitude of the challenges, the offshore wind needs special attention and policy framing. In the recent times, the government duly acknowledged the importance of having a separate offshore wind energy policy²⁰.

²⁰<http://www.indiaenvironmentportal.org.in/files/file/draft-national-policy-for-offshore-wind.pdf>

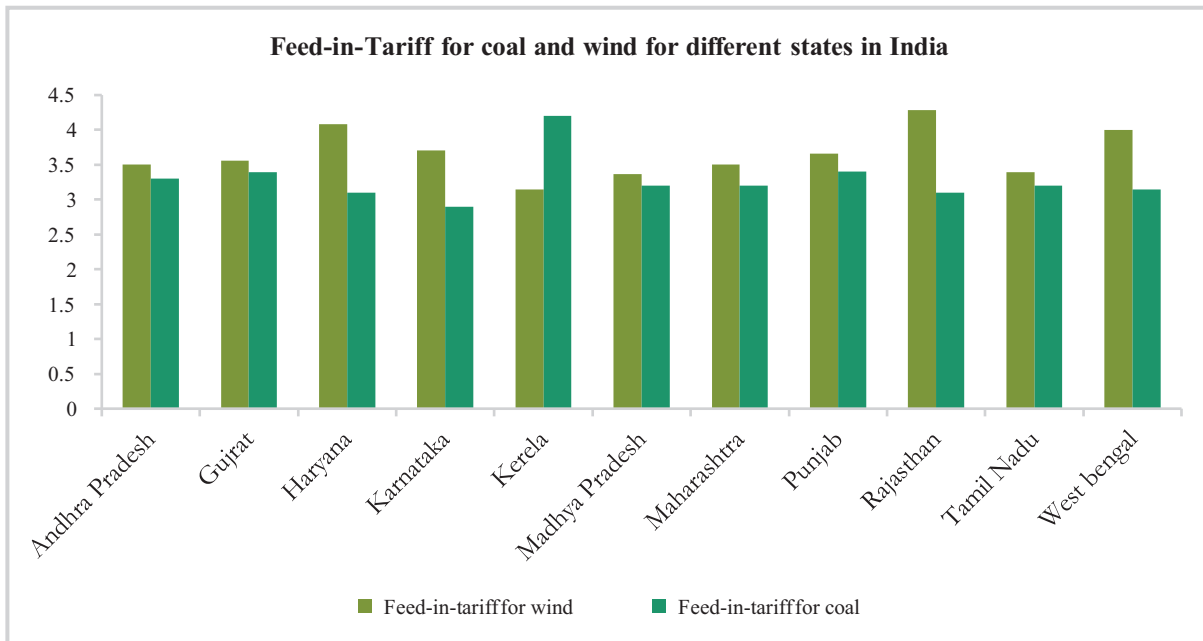
2.6. Wind Technology Future scenario: An Optimistic Solution

Wind technology seems to promising technologies which have a capability to significantly contribute in energy mix. It is also capital intensive technology like other renewable energy technologies but it has no fuel cost and counted as most cost-effective renewable technologies in terms of the cost per kWh of electricity generated. In wind technology, wind turbine is the most expensive component and responsible for 64-84% of total capital cost²¹. Initial higher wind power up front cost can be a barrier. On other side it can be stabilized for long term as there is no need to fuel once it installed. While in the case of coal there is strong possibility to increase cost of the energy due to the inflation in the cost of energy. Figure (2.7) mentioning the tariff rate of electricity from wind in different states of India and the tariff rate of electricity generation from coal. Coal rate is much higher as compare to wind. As per the report a continuous rise in electricity generated by coal, electricity produced by wind in cheaper by 45% by 2030²².

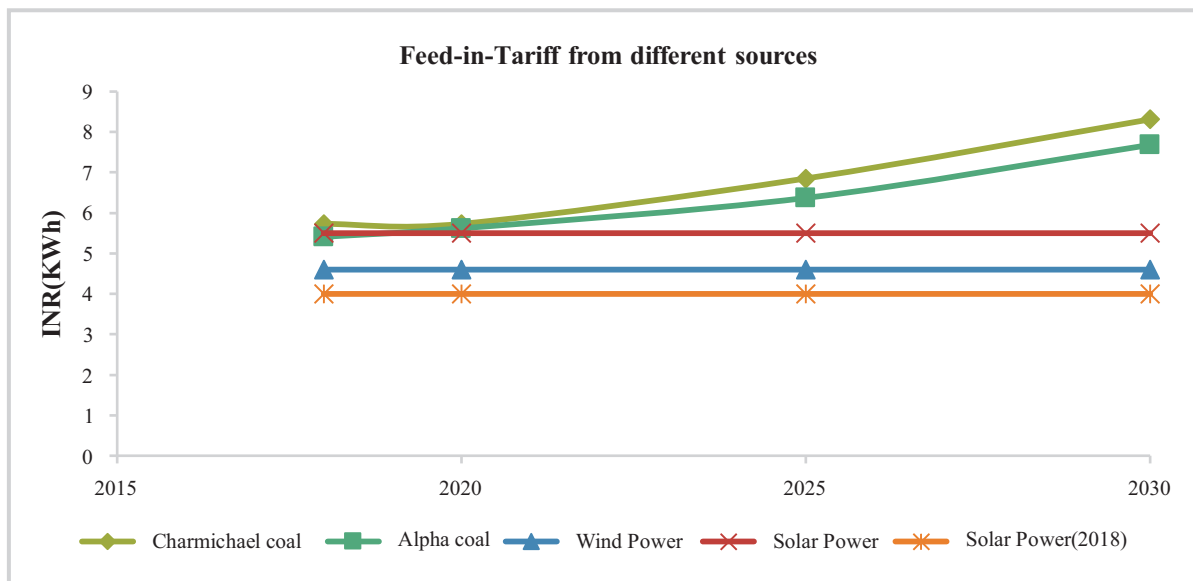
States	Feed-in-tariff for wind (Rs. KWh)	Feed-in-tariff for coal (min) (Rs. KWh)	Feed-in-tariff for coal (max) (Rs. KWh)	Feed-in-tariff for coal (AVG) (Rs. KWh)
Andhra Pradesh	3.5	2.85	4.7	3.3
Gujrat	3.56	3.39	3.39	3.39
Haryana	4.08	2.9	3.13	3.1
Karnataka	3.7	2.7	5.7	2.9
Kerala	3.14	3.3	6.9	4.2
Madhya Pradesh	3.36	2.7	4.16	3.2
Maharashtra	3.5	2.9	4.2	3.2
Punjab	3.66	3.6	4.69	3.4
Rajasthan	4.28	2.5	4.85	3.1
Tamil Nadu	3.39	2.4	4.15	3.2
West Bengal	4	2.25	4.27	3.14

²¹http://articles.economictimes.indiatimes.com/2015-02-28/news/59612945_1_clean-energy-cess-clean-energy-cess-coal-india-ltd

²²<http://www.google.co.in/urlfisa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB0QFjAA&url=http%3A%2F%2Fwww.ieefa.org%2Fwp>

Figure 2.7: Feed-in-Tariff for coal and wind for different states in India

(Source: www.cea.nic.in/reports/monthly/executive_rep/mar13/mar13.pdf)

Figure 2.8: Feed-in-Tariff from different sources

(Source: http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2014_28mar.pdf)

Due to the new government's initiatives on renewables, the Indian wind industry has a de facto target of 5 GW per annum for the rest of the decade and into the next²³. The recent announcements by the Indian Ministry of New and Renewable Energy (MNRE) indicate that India plans to achieve 60,000 MW in total wind power installations by 2022. This sets the industry an ambitious annual target of approximately 5,000 MW/year up to 2022²⁴. The long-term outlook for wind power remains positive mainly because of regulatory support, cost competitiveness and the generation-based incentive benefit. During the budget 2015 the Government of India took a major step to augmentation of emission by increase the cess on greenhouse gas –emitting coal. The cess has been increase from 100 to 200 Rs. per metric tonne on coal. It will be used for funding research and innovative projects on clean energy technology. This would result in increased the electricity tariff from 5-6 paisa per unit from the electricity generated from the coal. Currently, India power generation capacity is equal to 254 GW and coal is contributing almost 168 GW which is almost 66% of the total. So change in the prices of coal will significantly increase the price of electricity.

2.7. Outlook for 2015 And Beyond

Wind technologies has strong potential playing vital role by reducing fossil fuel import dependence and environmental benefits. There are tremendous expectations from renewables in the country, including wind^{26,27}. This will ease in evacuation of large amounts of energy from wind farms. However, grid issues remain a major issue and broke state utilities frequently curtail wind power, despite the fact that wind farms are designated as 'must run' power plants. A National Wind Energy Mission is in the works²⁸. The mission could provide a coordinated and stable policy framework to achieve highly ambitious targets for wind power. It will cover policy and regulatory aspects including incentives for onshore, offshore and small wind. Issues of repowering, tariff setting, transmission infrastructure and grid integration might also be addressed in the mission document.

Considerable progress in wind-power technology during the last decades has pushed it as an important supplier of grid-connected electricity in the worldwide energy picture. Today, wind turbines on the market show a variety of innovative concepts combined with proven technology for both generators and power electronics. But, there are still several technological challenges in wind power. Some are related to the development of utility-scale turbines of cheaper

²³ http://www.gwec.net/wp-content/uploads/2015/03/GWEC_Global_Wind_2014_Report_LR.pdf

²⁴ http://www.cea.nic.in/reports/monthly/executive_rep/mar13/mar13.pdf

²⁵ M.Swaminathan, D.Tarun (2013). Offshore wind energy policy for India: Key factors to be considered. *Energy policy*, 56, 672-683.

²⁶ Kewen Li, Huiyuan Bian, Changwei Liu (2015). Comparison of geothermal with solar and wind power generation systems. *Renewable and Sustainable Energy Reviews*, 42, 1464-1447.

²⁷ K.Sanjay, Kar et al. (2015). Wind power development in India. *Renewable and Sustainable Energy Reviews* 48, 264-275.

²⁸ (<http://www.indiaenvironmentportal.org.in/files/file/draft-national-policy-for-offshore-wind.pdf>)

construction, transport and deployment that may further reduce generation cost at both inland and offshore locations. Some others are related to finding practical and economical ways of harvesting wind energy at the small-scale level for isolated consumers or for distributed generation systems. The objective of this paper is to explore innovative concepts proposed in wind power that may help address these challenges by going beyond the classical evaluative-design process.

3. SOLAR TECHNOLOGY

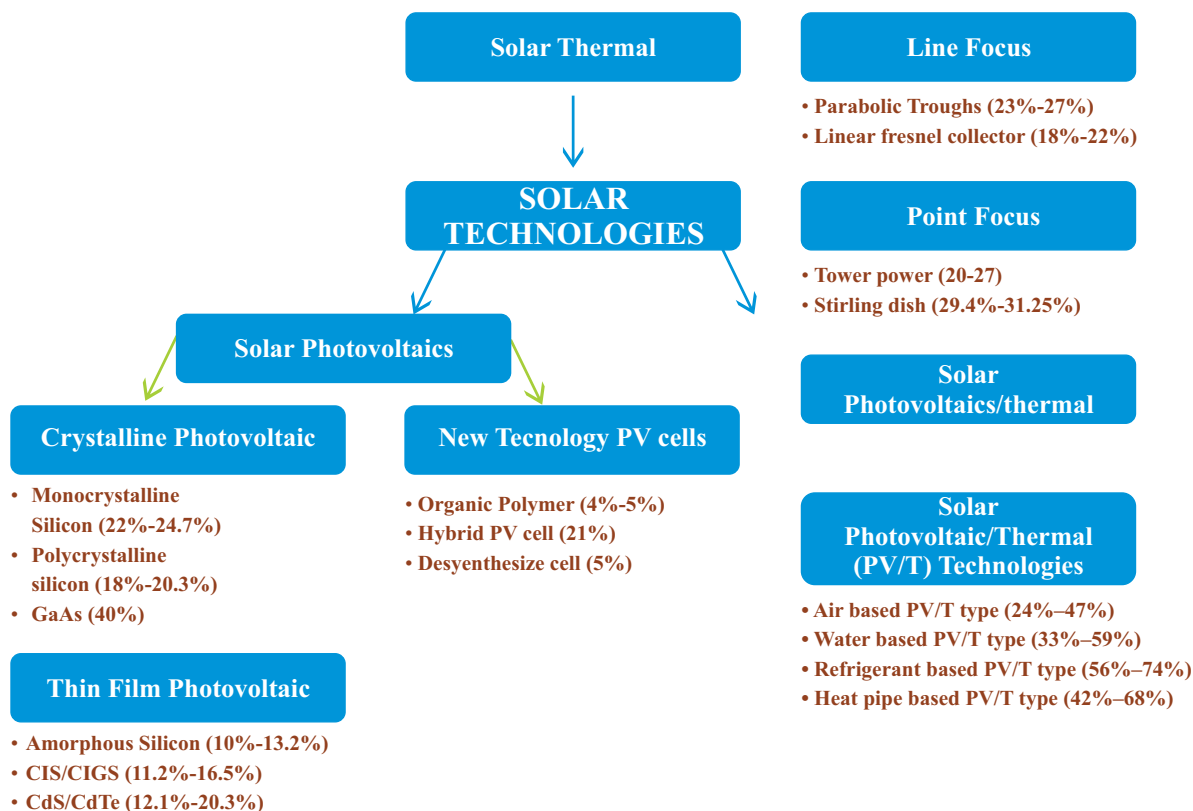
Solar technology is considered as one of the best green technology worldwide. It has obviously environmentally advantageous relative to any other conventional technologies as it used sun light as energy source which is unlimited resources means, does not deplete natural resources, does not cause greenhouse gas emission into air. Solar technologies are now the fulcrum of any serious sustainable development program, worldwide. Developed as well as developing nations are making significant investments to increase of regional/national energy independence as well as diversification and security of energy supply. Power generated by solar energy is not just relatively simpler but is also much more environmental friendly compared to power generation using non-renewable sources like coals and natural gas. Considering this, energy usage worldwide has been increasing throughout the years, moving to solar energy can be a feasible passage²⁹. Solar energy can be exploited through the solar thermal and solar photovoltaic (PV) routes. This chapter is planned to give a comprehensive state- of- art solar technologies and provides the necessary technical knowledge for understanding of this technology. It encompasses classification of solar PV technology and the manufacturing processes involved in various solar technology. Traditional solar cell technology such as single-crystal silicon technology as well as newer technologies has been described. The chapter also covers in- successful stories of world leader policies environment to encourage this technology diffusion and deployment especially the Solar photovoltaic (PV) as it is one of the most matured and field-proven technology in most of the countries among different solar technologies. It also highlights the main policies, R&D support mechanism, Legislative support, incentives and subsidy programmes which are the main drivers for the solar market in China and India. Prominent technologies nowadays available in solar sectors are mentioned in Figure (3.1). Solar photovoltaic (PV) technology is one of the most matured and field-proven technology among different renewable energy technologies.

²⁹www.sersc.org

3.1. Solar Photovoltaic Technologies Principal and Type

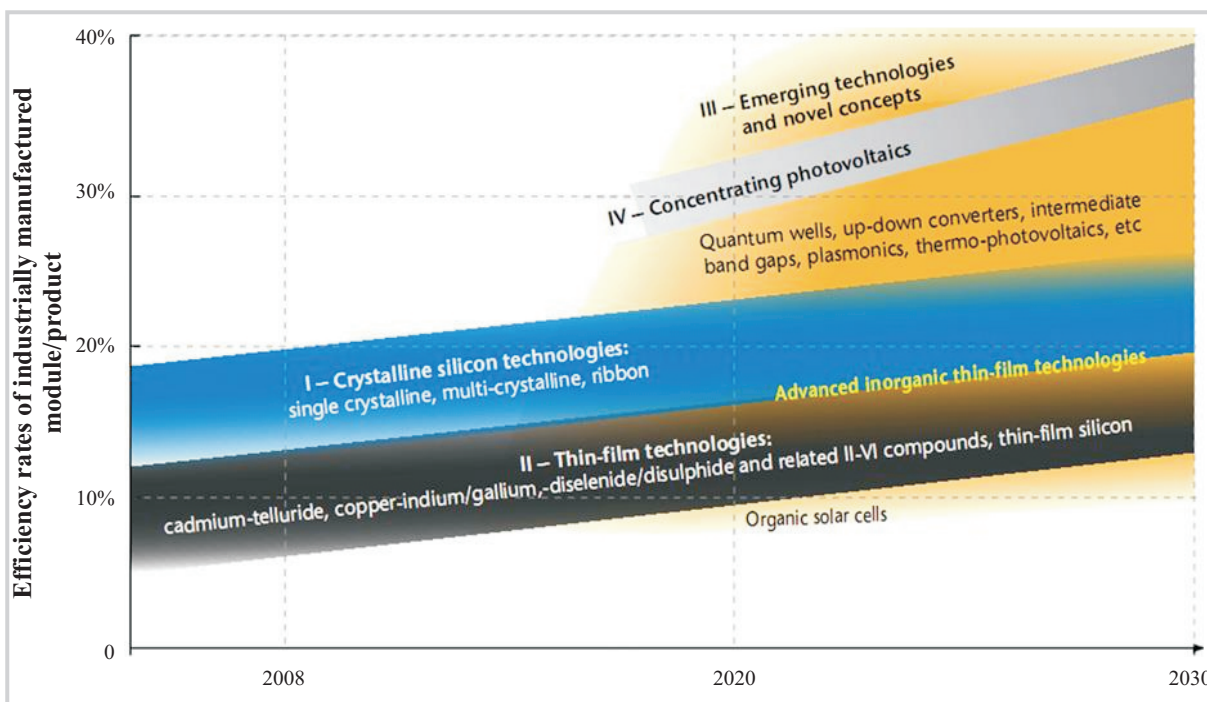
Solar PV technology converts sunlight to energy. This conversion happens directly through solar cells made up of various components that produce the photoelectric effect. This phenomenon occurs when electrons are emitted from materials as they absorb light energy. Though early PV cells were made of silver Selenite or copper, silicon has been the predominant substance used for the past 60 years. Solar cells produce DC power, which fluctuates based on the sun's intensity. This is why cloud cover, seasonal angle of the sun, latitude, and new solar tracking systems have such dramatic impacts on generation. Typically, cells are cut from large segments of bulk materials called wafers and processed as semiconductors. These cells are connected together to form modules commonly known as solar panel. Modules are connected to form arrays, which would represent the aggregate of panels on a rooftop installation. Finally, in order to be connected to a grid, inverters convert the DC to alternating current (AC)³⁰.

Figure 3.1: Different kinds of Solar Technologies



(Source: https://www.irena.org/DocumentDownloads/Publications/GWEC_India.pdf)

³⁰Philip G. Jordon (2014). The mechanics of Solar Power in Solar energy market Pg. 7-18

Figure 3.2: Photovoltaic technology status and prospects

(Source: Asim, N. 2012)³¹

3.2. The Manufacturing Process

The solar manufacturing process begins with raw materials generally either mono crystalline or polycrystalline silicon. Silicon is mined, typically from sand or sandstone, and also known as quartz.

Figure 3.3: Method from silicon to Module Production

The mined material, silicon dioxide, goes through an extensive purification process conducted in multiple steps. First, the material is heated in a furnace to get 99% pure silicon. It is then purified even further using the floating zone technique to produce solar grade silicon. Using the Czochralski method, a crystal of silicon is used as a seed, dropped into polycrystalline silicon, results in a large, pure, cylindrical ingot of silicon. Ingots sliced into wafers which further polished and treated with doping agents (as are most semiconductors). Doping agents are simply impurity atoms that create either p-type which has extra holes or n-type which contains excess free electrons. The junctions of these regions are called p–n junctions and their purpose is to increase the conductivity of the cell. Cells then connected to other cells with tin or copper connector to create modules. The cells then go through antireflective chemical coating of silicon nitride. Finally, modules are encapsulated in a silicon-or vinyl-based

³¹Asim, N (2012). A review on the role of materials science in solar cells. *Renewable and Sustainable Energy Reviews*, 16, 5834-5847.

compound and cased in aluminum or other lightweight metal frames. These frames typically receive construction grade Mylar backing and are capped with glass. Component manufacturers in photovoltaic may be involved with the production of the following chains.

Figure 3.4: Module Layout process



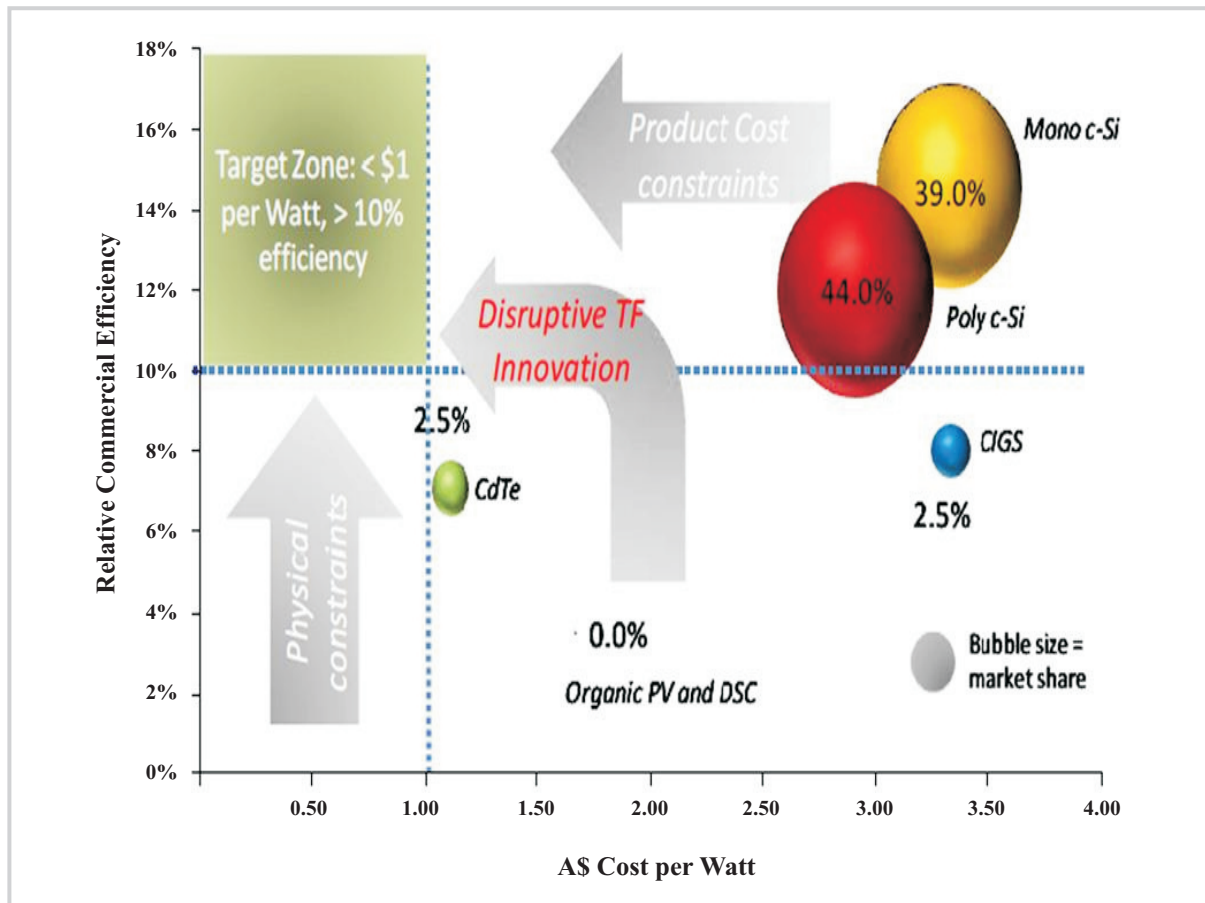
3.3. Thin Film

Thin film technology has a multitude of benefits and chief among them is lower manufacturing cost. However, Silicon is still a leading technology in making solar cell due to its high efficiency. Thin film is produced by applying single layers of semiconductors on a substrate most typically glass, or sometimes metal or plastic. This thin sheet is lighter, cheaper, yet less efficient than the thick wafer cells. However, several alternative technologies are promising if not yet ready to replace traditional PV systems. These non-silicon based technologies have the added benefit of relying on materials that are more readily available and less volatile. The most promising new thin film technologies use either Copper Indium Gallium Deselenide (CIGS) or Cadmium Telluride (CdTe). There are two basic configurations of the CIGS solar cell: the CIGS-on-glass cell requires a layer of molybdenum to create an effective electrode. This extra layer isn't necessary in the CIGS-on-foil cell because the metal foil itself acts as the electrode. A layer of zinc oxide (ZnO) plays the role of the other electrode in the CIGS cell. Sandwiched in between are two more layers—the semiconductor material and cadmium sulphide (CdS). These two layers act as the n-type and p-type materials, which are necessary to generate electrons current³². CIGS-on-glass solar panels don't offer sorted-cell assembly. Because their panels consist of cells that are not well matched electrically, their yield and efficiency effected ominously. This process is critical because it lowers the price, which is necessary given the market perception of lower overall efficiency of thin film. Traditional solar is reaching about 25% maximum efficiency (Fig. 3.4) while CdTe and CIGS are now reaching 15–20%. Further, investment in these technologies will increase these efficiencies further, drive down manufacturing costs, and increase the feasibility for many applications. Nanotechnology or sometimes referred as Third generation PV'' is used in order to increase conversion efficiency of solar cell since energy band-gap can be controlled by Nano scale components Nanotubes (CNT), quantum dots (QDs) and "hot carrier" (HC) solar cell are three devices used in nanotechnology for PV cell production. The advantages of using this technology are to enhance material mechanical characteristic, Low cost, lightweight and good electrical performances³³.

³²www.howstuffwork.com

³³Tyagi, v.v (2013). Progress in solar PV technology, Research and achievement. *Renewable and Sustainable Energy Reviews*, 20, 443–461.

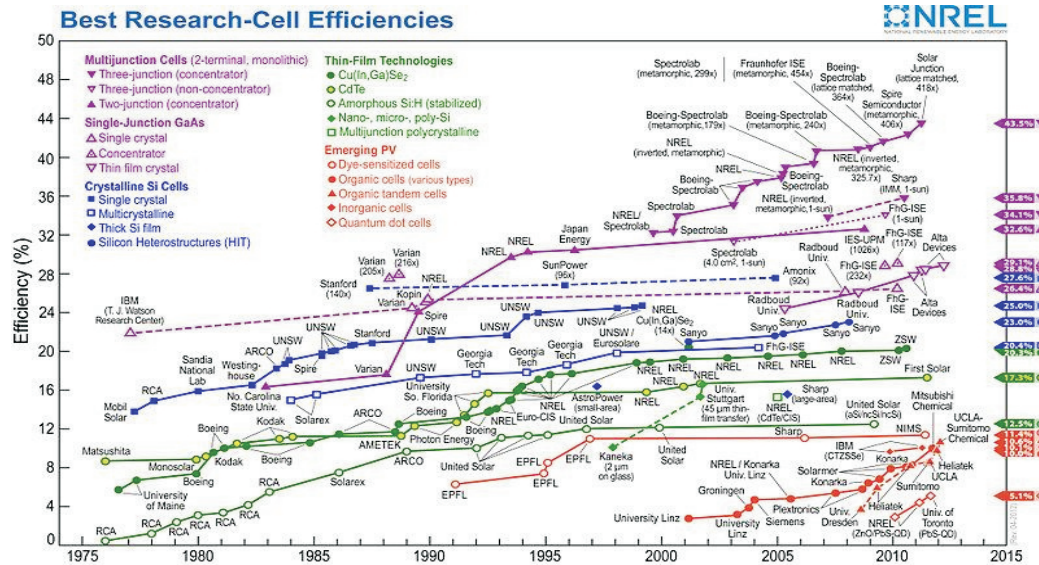
Figure 3.5: Commercial PV efficiency vs. cost per watt



(Source: R. Mahtta, P.K. Joshi, A. K. Jindal, 2014)³⁴

³⁵Asim, N. et.al. (2012). A review on the role of materials science in solar cells. *Renewable and Sustainable Energy Reviews*, 16, 5834-5847.

Figure 3.6: Solar cell materials efficiency revolution from 1975 to 2010



(Source: Asim, N. et.al, 2012)³⁵

3.4. Concentrated Solar Energy

CSP technologies only use direct normal component of sunlight intensity. Heat generated is transformed first into mechanical energy and then into electricity, also known as Solar Thermal Electricity (STE). The area of the receiver is kept smaller so that heat loss can be decreased with an increased efficiency. CSP technologies are further classified on the basis of how they focus radiance of the Sun. Line focus concentrators include parabolic trough collectors (PTC) and linear Fresnel collectors (LFC) whereas point focus concentrators include central receiver system, Sterling dishes Collector (SDC) and Tower Solar Power³⁶. Among these different types of CSP technologies, parabolic trough collectors are widely used with more than 90% market of the CSP market in the world³⁷. Concentrated solar power plants are gaining increasing interest, mostly by using the PTC, although TSP progressively occupy a significant market position due to their advantages in terms of higher efficiency, lower operating costs and good scale-up potential. These CSP technologies are currently in medium to large-scale operation and mostly located in Spain and in the USA as shown in Fig. 2.7. Although PTC technology is the most mature CSP design, solar tower technology occupies the second place and is of increasing importance as a result of its advantages³⁸. However, currently there is a trend toward employing the other CSP technologies in the future projects as a result of the improvement in their performance. The use of PTC technology in the operational CSP projects is 95.7% and has decreased to 73.4% for the under-construction projects. Meanwhile, the uses of Fresnel collector (LFC), Tower power (TSP) and Stirling dish (SDC) technologies in the operational projects are 2.07%, 2.24%, and

³⁵ Asim, N. et.al. (2012). A review on the role of materials science in solar cells. *Renewable and Sustainable Energy Reviews*, 16, 5834-5847.

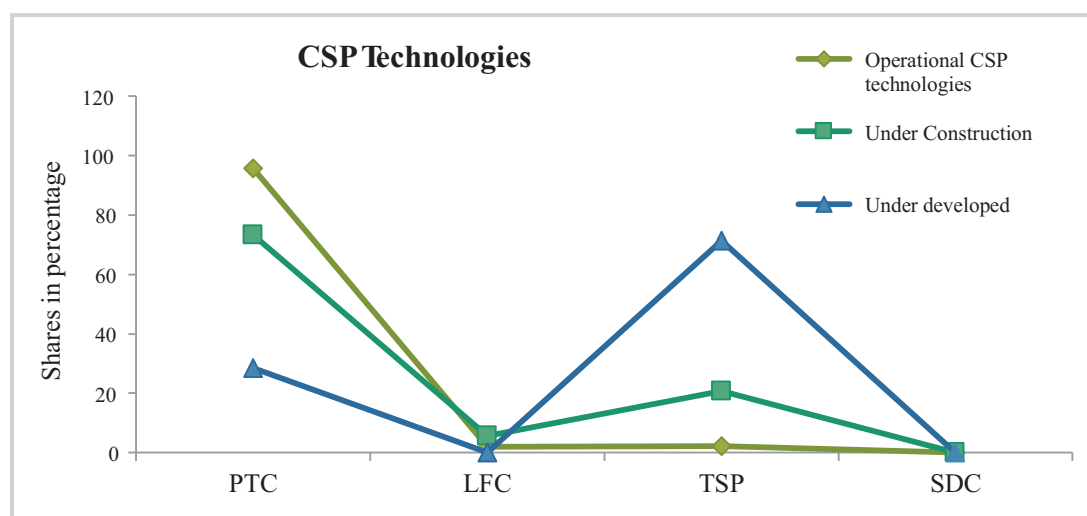
³⁶ Mahtta, R., Joshi, P.K. Jindal, A. K. (2014). Solar power potential mapping in India using remote sensing inputs and environmental parameters. *Renewable Energy*, 71, 255-262.

³⁷ H.L. Zhang, J. Baeyens, J. Degreve, G. (2013). Caceres a Concentrated solar power plants: Review and design methodology. *Renewable and Sustainable Energy Reviews*, 22, 466-481.

³⁸ Zhang, H. L., ET. Al. (2013). Concentrated solar power plants: Review and design methodology. *Renewable and Sustainable Energy Reviews*, 22, 466-481.

0% respectively and have increased to 5.74%, 20.82% and 0.052% respectively for the under-construction projects. For the development projects, the use of TSP technology has reached to 71.43%, compared to 28.57% for PTC³⁹. Although there are different type of concentrated solar technologies are available in the market and it also contributed in the energy mix but in India very few districts are left across which is appropriate for setting up a CSP plants. The modular nature of SPV plant makes it quiet less complex as compared to CSP in setting up the plants. Conclusively, it is quite obvious that there is more scope for SPV as compared to CSP in India. Therefore, in this chapter we are mainly discussing the solar PV technologies and policy environment supported to enhance the PV market⁴⁰.

Figure 3.7: Trends of Different Concentrated Solar Technologies



(Source: Barler, D., Vidu, R. and Stroeve, P. (2011))⁴¹

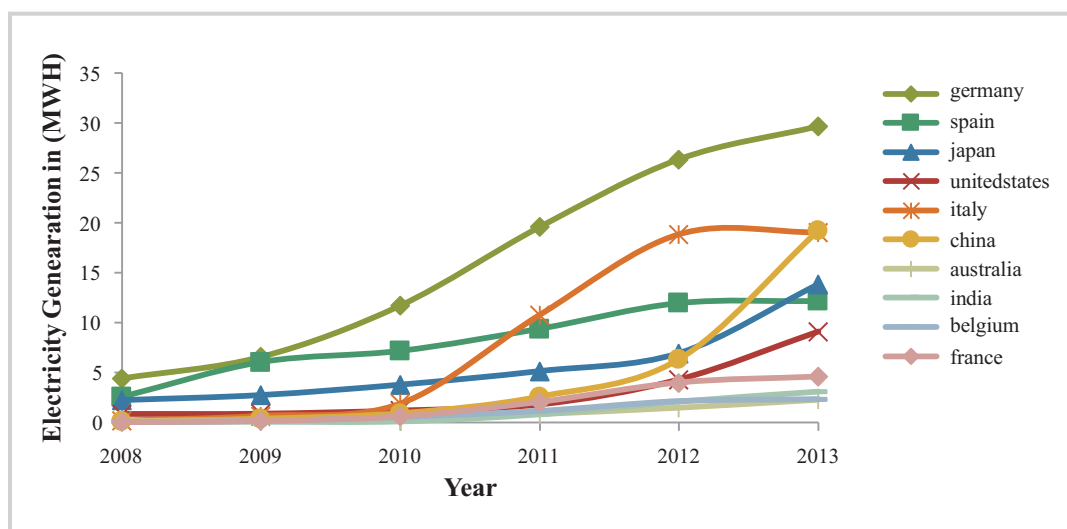
3.5. Global Overview

The top-most solar PV capacity countries such as Germany, China, Italy, Japan, Spain, USA, France, had added new installed PV capacities by 3.3 GW, 12.9 GW, 0.2 GW, 6.9 GW, 0.2 GW, 4.8 GW, and 0.6 GW respectively. Figure 3.6 showed that Germany showed the slight increase in electricity generation compared to year 2012 (electricity generation 26.38 MWH) from Solar PV and shared the highest capacity of solar PV with generated 29.68 MWH of electricity. Italy reached a total capacity of 19 GW; however, the 0.2 GW brought on line was far lower than additions in 2012. Figure 3.6 mainly shows the top 10 countries, generating electricity using Solar PV for the period from 2000-2013.

³⁹Baharoon, D.A.et.al., (2015). Historical development of concentrating solar power technologies to generate clean electricity efficiently – A review. *Renewable and Sustainable Energy Reviews*, 41, 996-1027.

⁴⁰Mahtta, R., Joshi, P.K., Jindal, A.K. (2014). Solar power potential mapping in India using remote sensing inputs and environmental parameters. *Renewable Energy Review*, 71, 255-262.

⁴¹Barler, D., Vidu, R. and Stroeve, P. (2011). *Innovation in concentrated solar power*. Solar Energy Materials & Solar Cells, 95: 2703–2725

Figure 3.8: Trends of Electricity Generation using Solar PV⁴²

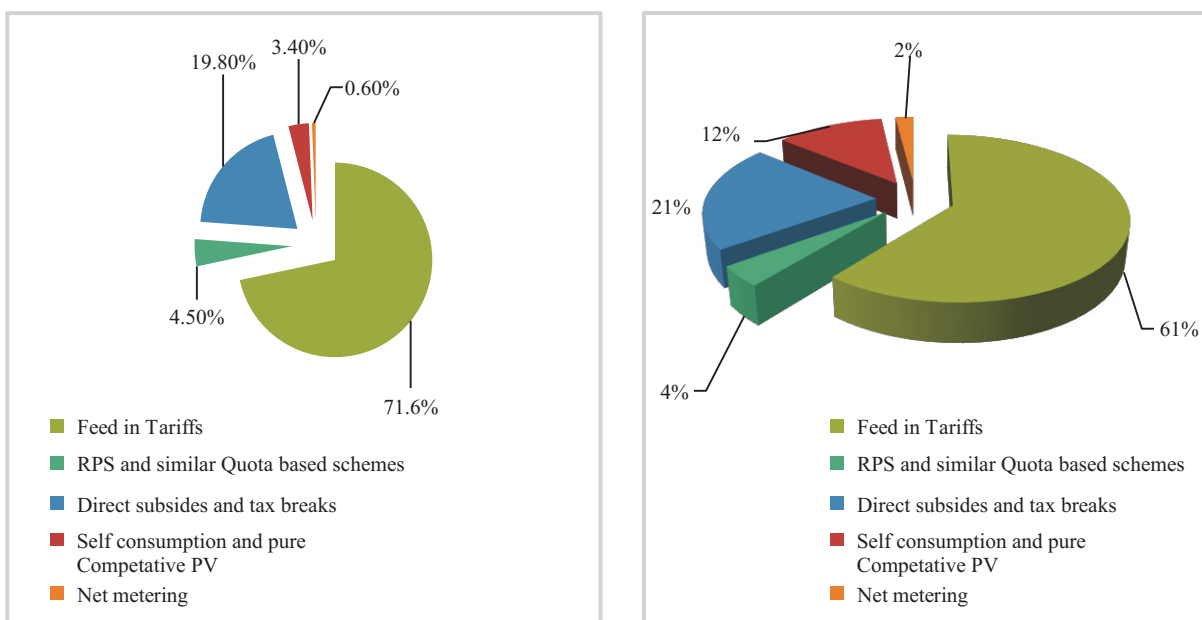
(Source: <http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm>)

The trend shows that China is progressing aggressively in generation of electricity from solar sources. China surpasses country counterparts and positioned itself in 2 positions (200% annual increase in electricity generation during the year 2012-2013) after Germany. Although India also shows its visibility among top ten countries but large amount of energy potential is still untapped.

Therefore, existing successful solar energy policies of world's leaders like Germany, China, Italy can be a lesson for developed and developing countries. For these countries, the existence of solar energy policies managed to increase solar power generation significantly. Energy policy is an important term for energy growth rates and it directly addresses the energy security for supply, environmental impacts and costs. And it is importantly supported by the research and technology development, industrial innovations and market creations; governments may improve the positioning and competitiveness of their domestic industries in world markets and simultaneously solve domestic energy needs. Various policies like Feed-in-tariff (FIT), portfolio standard (RPS), pricing laws, production incentives, tax credits, trading systems, quota requirements, etc. have been developed and implemented to promote the use of Solar technologies⁴³. These strategies have main objectives such as reducing the environmental impacts of the energy sector, reducing dependence on fossil fuels and encouraging new industrial development. Yet the renewable portfolio standard (RPS) and the feed-in tariff (FIT) are the main driver for significant motivation and interest of PV market development and instigated by many countries around the world.

⁴²<http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm>

⁴³Solangi, K.H. et al., (2011). A Review on Global Solar energy Policy. *Renewable and Sustainable Energy Reviews*, 15, 2149-2163.

Figure 3.9: Drivers of PV market development (adopted⁴⁴)

(Source: EPIA European Photovoltaic Industrial Association)

3.6. World leaders in solar technologies

Among all renewable energy sources, solar energy is plentiful and the largest potential energy source in the world. The solar radiations reaching the earth's surface vary from 0.06 kW/m² at high latitudes to 0.25 kW/m² at low latitudes. In particular, solar PV possesses a huge potential both in technical and sustainable solutions to the energy demands. The rapid falling of the solar cell costs in the past few years has been making energy generation at a widespread rate in the global scenario. However, the efficiency of solar cell is one of the important factors for stabilizing of the technology. Different laboratories of the world have achieved different efficiencies by using different materials in the period 1975-2010, which is shown in Fig. 2.4. The figure shows that by using the material GaAs, solar cell efficiency had achieved the highest by about 40% at the end of 2010. The new materials for solar cells, i.e., dye-sensitized and organic base cells were still rated at low efficiency with only 5.4%. The monocrystalline solar cell had 24.7% efficiency, polycrystalline cells had 20.3% and thin film technology had 19.9%.

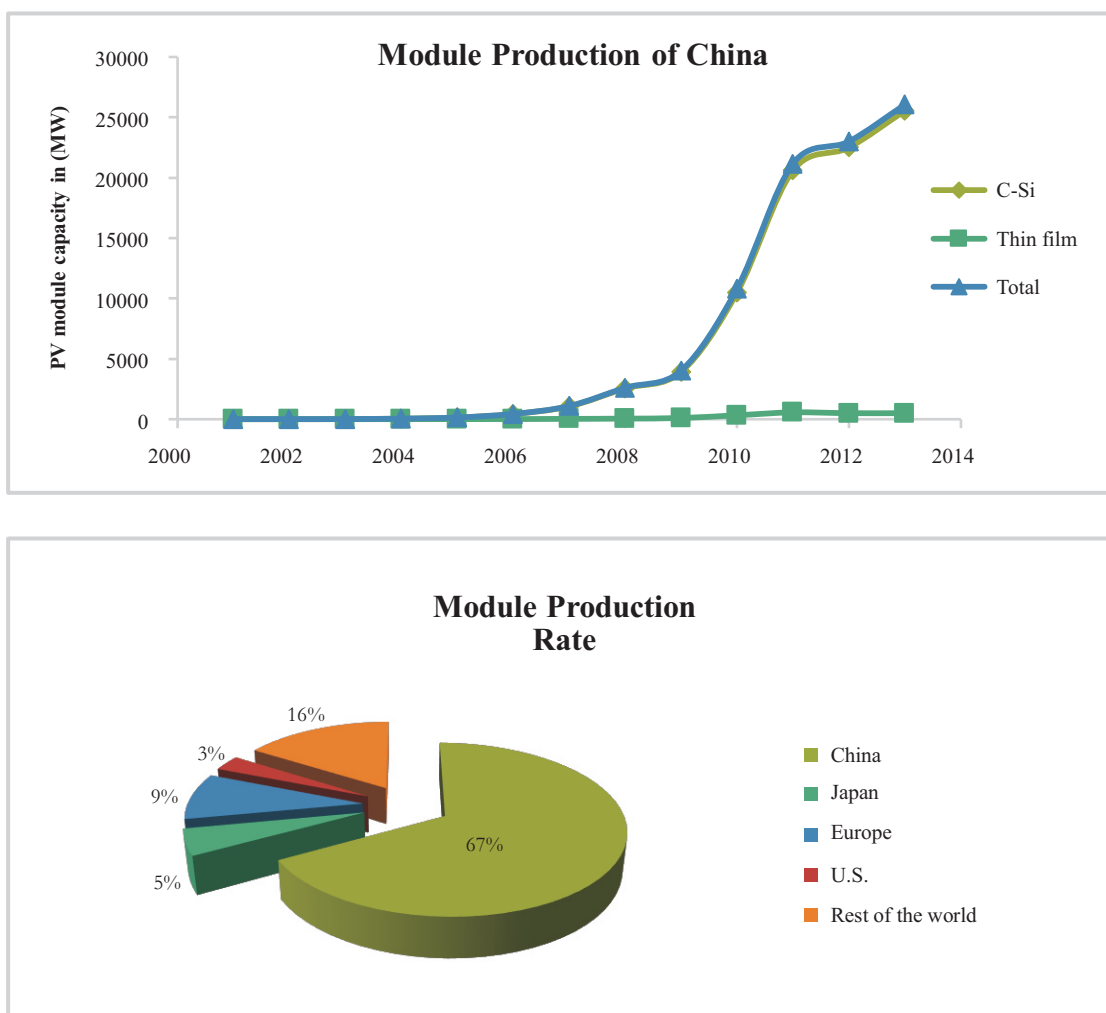
3.7. China Solar Status and Policy Environment

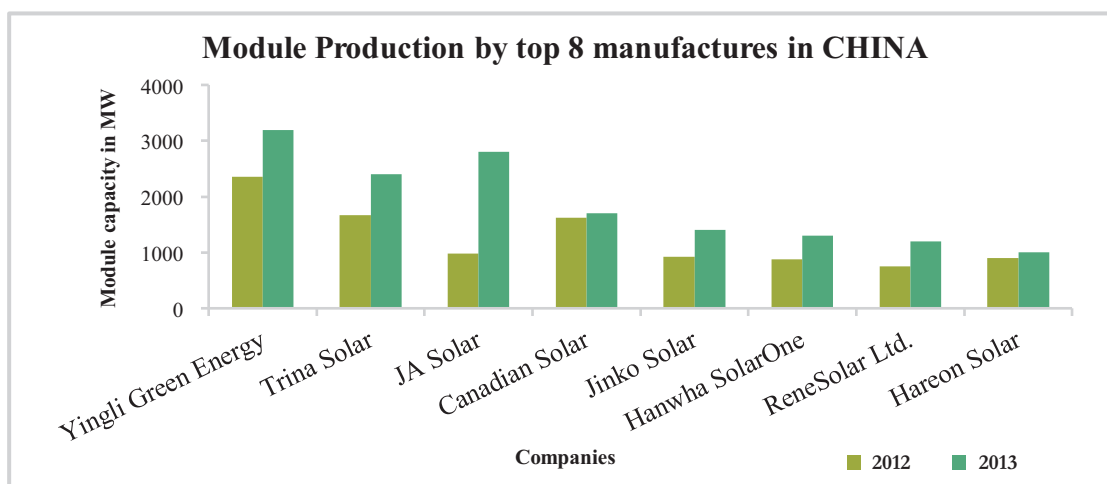
China PV sector showed tremendous development since mid1990, particularly since the early 2000s. China PV module manufacturing capacity and output in China had reached 37 GW and 22 GW, representing 37% and 54% of the world total respectively (SEMI, 2013). Since 2007, China has become the largest producer of solar PV in the world. Since 2007, China has been the largest emitter of Carbon dioxide in the world. Besides this china is not only the huge importer of the crude oil (56% imports) but also of raw coal. China is also rank first with regards to electricity consumption and installed electricity capacity. With the growing demand for energy and increasing

⁴⁴EPIA European Photovoltaic Industrial Association

environmental concern China moves forward to restructure of energy mix and renewable energy sources. In China, hydroelectric, Wind, biomass and Solar are the main green technologies for commercial production of electricity. Solar energy is safe and pollution free. Currently solar photovoltaic power generation is the strongest application. Therefore, since 2000, the Chinese government has launched a series of national policies and regulations that actively promote solar PV industry R&D, production and applications. China has promulgated and implemented “Renewable energy Law” and “Eleventh Five Year Plan. In 2007, The National Development and Reform Commission planned that till 2010 the renewable energy consumption will reach approximately 200 GW. Solar photovoltaic will contribute 300 MW and which will further increase to 1800 MW by 2020. China set the goal that primary energy consumption will increase from 8% to 15% by 2020. Appropriate Policy environment promote sustain & co-ordinate development of solar industry. These include the Energy Law (2006) & relevant Renewable Energy Policy (Mainly from 2006-2008), The support for renewable & Development (R&D) (2006-2010), The Program subsidy, The brightness program(1996), The Township electrification Program(2002), The rooftop subsidy Program(2009), The Golden Sun Demonstration Program (2009) The PV concession program (2009), The national Feed in Tariff (FIT) scheme (2011,2013) , the regulation for market access (2013) as well as Tax Preferential Policy (2013).

Figure 3.10: China Annual Module Production, Contribution and top Manufacture





(Source: www.epia.org⁴⁵; H.L. Zhang, J. Baeyens, J. Degreve, G., 2013)⁴⁶

Table 3.1: China Strategic Goal for Renewable Energy Development

Renewable Energy Category	Actual in 2006 In (GW)	Target in 2010 In (GW)	Target in 2020 In (GW)
Hydro Power	130	190	300
Wind Power	2.6	5	30
Biomass Power	2.0	5.5	30
Solar Photovoltaic	0.08	0.3	1.8
Solar Water Heater	100 million m ³	150 million m ³	300 million m ³

(Source: Kevin Lo, 2014)⁴⁷

3.7.1. The Renewable Energy Law & Related Policies

In 2005, China Promulgated the Renewable Energy Law, which became effective on January 01, 2006 & was amended in 2009. It created for the first time a national framework for the Promotion of renewable energy in China⁴⁸. The Renewable Energy Law built renewable energy development funding sourced from user side electricity prices the levy from the user side electricity price from 0.002RMB/kWh in 2006 to 0.015RMB/KWh in 2013. As a result, the Renewable Energy Development funding will increase from 28 billion RMB in 2012 to 50 billion RMB after 2013.

⁴⁵http://www.epia.org/fileadmin/user_upload/Publications/EPIA_Global_Market_Outlook_for_Photovoltaics_2014-2018_-_Medium_Res.pdf and https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapSolarPhotovoltaicEnergy_2014edition.pdf

⁴⁶H.L. Zhang, J. Baeyens, J. Degreve, G. (2013). Caceres a Concentrated solar power plants: Review and design methodology. *Renewable and Sustainable Energy Reviews*, 22, 466-481

⁴⁷Kevin Lo. (2014). Critical review of China's rapidly developing renewable energy and energy efficiency policies. *Renewable and Sustainable Energy Reviews* 29 :508–516

⁴⁸Zhang, S. and He, Y., (2013), Analysis on the development and policy of solar PV power in China. *Renewable and Sustainable Energy Reviews*. 21, 393-401.

3.7.2. R&D Supports

Energy is cited as a Chinese strategic field. It has been supported by the R&D policies of the National Science & technology Plan since 2000 by setting up multiple national science & technology plans to support the R&D of PV technology and national key Laboratories to promote enterprises technology R&D. The Ministry of Science & Technology supported R&D in PV sector mostly through various programs 863 Programs concentrating on the PV power market application including on grid utility-scale PV in desert and thin film PV, while the key technologies of R&D programme focus on the upstream such as equipment manufacturing of crystalline silicon PV. Recently in 2013, a key project of 863 program got initial results. The laboratory conservation efficiency of crystalline silicon cell was up to 20%.

Table 3.2: List of Programmes to support Solar PV R&D

Year	Program	Assistance object	Capital subsidy
2006	863 Program	R&D Program R&D of BIPV, CPV, on grid utility-scale PV in desert and thin-film PV	\$26.1943 million
2006	973 Program	Basic scientific research for long term Development	\$4.9114 million funding
2006	Key Technologies	R&D of equipment manufacturing of crystalline silicon PV49	\$3.2743 Million funding
2009	The fund for technology Based firms	Innovation and investment of small high tech Firms	\$3.2743 Million

(Source: <http://ieefa.org/wp>
http://mnre.gov.in/file-manager/UserFiles/policy_programme_wise.htm)

3.7.3. Brightness and Township electrification Programs

Both of these programs was the major driving process for solar PV market expansion in china in the late 1990s and early 2000s. In 1996, Brightness Program aimed to provide this populace with average PV capacity of 100W per person, which was at that time equivalent to China's average installed capacity per person. In 2002, National Development & Reform Commission initiated the Power supply Plan for Rural areas without electricity in the Western Provinces and regions known as Township electrification program almost 60% (688 out of 1065) town of china were targeted for the PV power stations constructions, with a total installed capacity of 20 MW.

Table 3.3: Brightness and Township Electrification Programs

Year	Program	Targets	Investment
1996	Brightness Program	Provides power for daily needs to the population of 23 million in china without access to electricity	About \$ 1.637 billion
2002	Township Electrification Program	Meet the power needs of public utilities and residents of unelectrified townships	\$0.7694 Billion (\$0.4846 billion is provided by government bonds)

(Source: Z.Xin gang, W, Guan, 2015)⁵⁰

⁴⁹HUO. Mo-Lin, Wei.D. (2012).Lessons from photovoltaic policies in China for future development. Energy Policy, 51, 38-46.

⁵⁰Z.Xin gang, W,Guan (2015). The turning point of sola rphoto voltaic industry in China: Will it come? *Renewable and Sustainable Energy Reviews*, 41,178-188

Table 3.4: Rooftop Subsidy program and Golden Sun Demonstration Program objectives

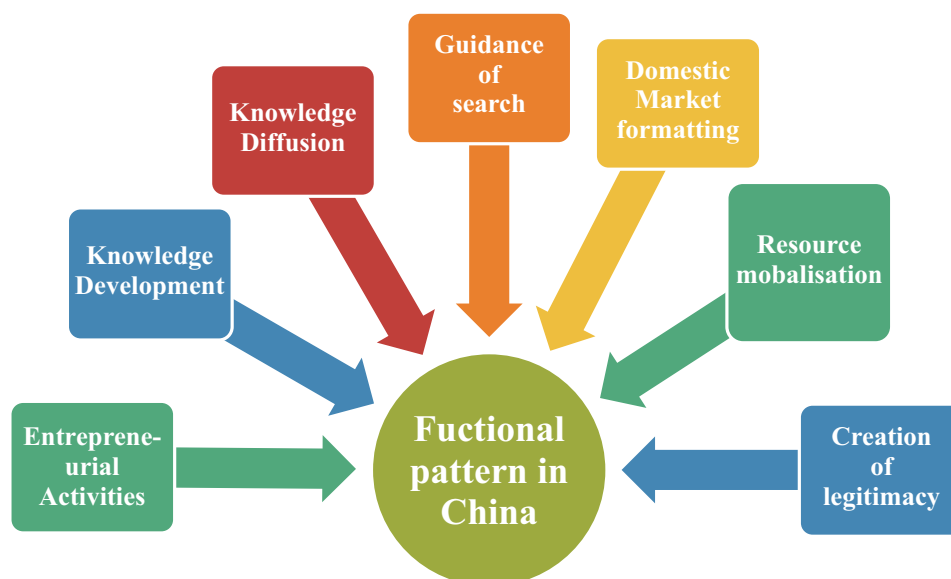
Date	Program	Projects	Subsidy
March 2009	Solar Roofs Program	The Scale of a Solar PV Project be no less Than 50KW the generation efficiency of monosilicon PV products, Polysilicon PV products and amorphous silicon PV products exceed 16%, 14%, and 6%	\$2.4555/W for rooftop Systems and \$3.274/W for BIPV systems 50% of the bidding price for the supply of critical components
July 2009	Golden sun Demonstration Program	The system size to be no less than 300KW	50% of the total cost for on-grid systems and 70% of the total cost for off Grid systems Excess electricity Could be sold to the Utility at the local Tariff of desulfurized coal generation

(Source: Z.Xin gang, W, Guan, 2015)⁵⁰

3.7.4. The Rooftop Subsidy Program and Golden Sun Demonstration Program

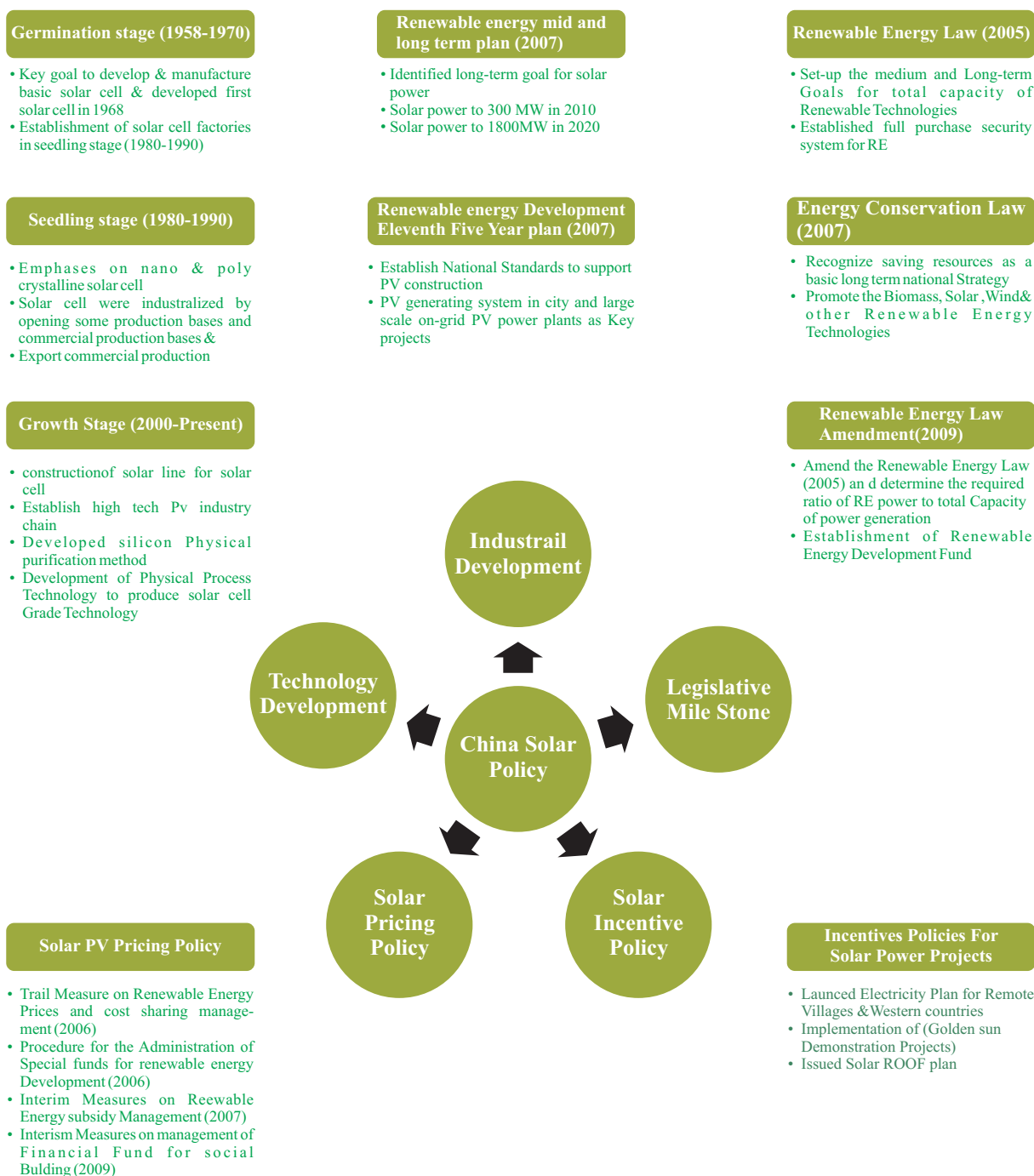
China PV industry has been a typical export oriented industry .Therefore China is struggling over supply of PV system Chinese government has rolled out measure to boost its domestic solar market. Two national solar subsidies program “The roof top subsidy Program” and the “golden sun Demonstration Program” has been initiated. Therefore the astounding successes in terms of PV manufacturing and the relatively modest development in terms of PV power deployment in China have not arisen from a single coherent policy program. Rather, China solar PV policy has changed several times since the mid-1990s and these changes have been driven by a number of different forces.

Figure 3.11: China Solar Policy Environment



(Source: Huo, Mo-Lin, Wei.D, 2012)⁵¹

⁵¹Huo, Mo-Lin, Wei.D. (2012).Lessons from photovoltaic policies in China for future development. Energy Policy, 51, 38-46.

Figure 3.12: Policy to Promote Solar energy in China

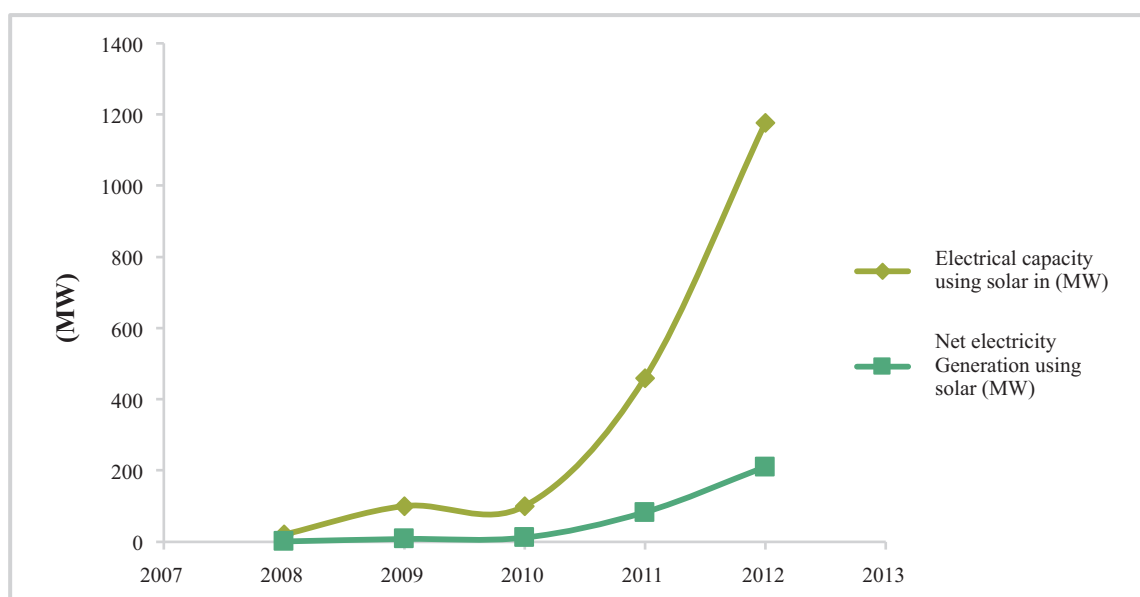
(Source: Z.Xin gang, W.Guan 2015)⁵²

⁵²Z.Xin gang, W.Guan (2015). The turning point of solar photo voltaic industry in China: Will it come? *Renewable and Sustainable Energy Reviews*, 41, 178-188.

3.8. India Solar Policy Environment

Government took several initiatives to promote renewable energy. Foremost amongst them is the Electricity Act (2003) which de-licensed stand-alone generation and distribution systems in rural areas and The National Rural Electrification Policy, 2005 and National Rural Electrification Policy, 2006 also stresses the need for urgent electrification⁵³. The New Tariff Policy (2006) stated that a minimum percentage of energy, as specified by the Regulatory Commission, is to be purchased from Renewable sources.

Figure 3.13: India Solar Capacity and net electricity generation capacity



(Source: EIA)⁵⁴

⁵³Sharma, N.K., et.al. (2012).Solar energy in India: Strategies, policies, perspectives and future+potential. *Renewable and Sustainable Energy Reviews*. 16(1), 933–941.

⁵⁴<http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=12>

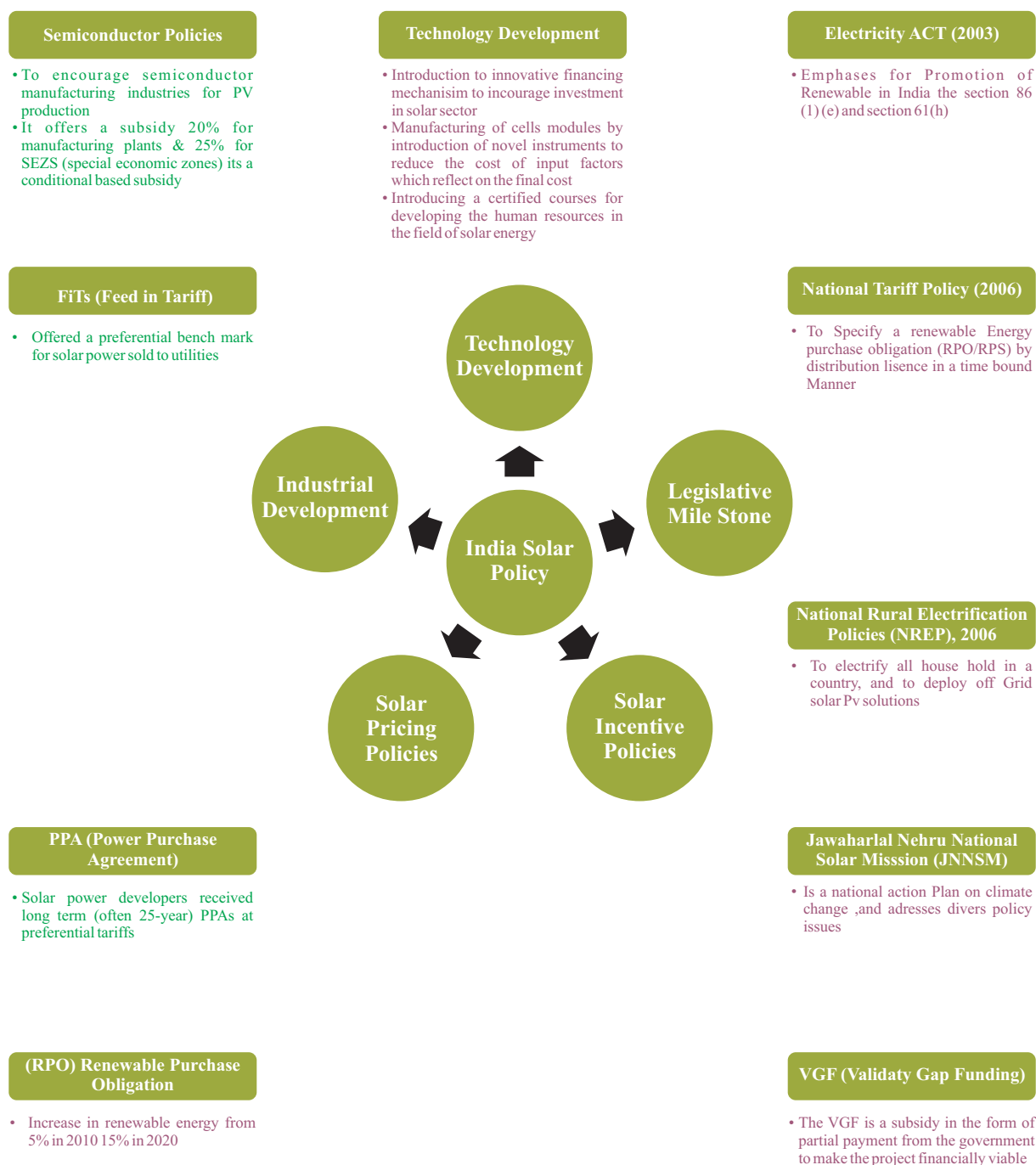
Figure 3.14: Guideline five year plan

Some of the milestones to promote the solar green technology are discussed under here:



(Source: K. Karan and K.P Krishan, 2014)⁵⁵

⁵⁵K. Karan, K.P Krishan (2014). Evolution of solar energy in India: A review. *Renewable and Sustainable Energy Reviews*, 40,475-487.

Figure 3.15: India Solar Policy

(Source: MNRE Various Reports)⁵⁶

⁵⁶ mnre.gov.in/mission-and-vision-2/publications/annual-report-2/

3.8.1. *Electricity Act 2003*

Electricity Act, 2003 seeks to bring about a qualitative transformation of the electricity sector through a new paradigm. It replaces the three existing legislations, namely, Indian Electricity Act, 1910, the Electricity (Supply) Act, 1948 and the Electricity Regulatory Commissions Act, 1998⁵⁷. The Section 86 (1) (e) and Section 61 (h) emphasis for promotion of renewable in India.

3.8.2. *National Electricity Policy 2005*

The National Electricity Policy 2005 stipulates that progressively the share of electricity from non-conventional sources would need to be increased; such purchase by distribution companies shall be through competitive bidding process; considering the fact that it will take some time before non-conventional technologies compete, in terms of cost, with conventional sources, the commission may determine an appropriate deferential in prices to promote these technologies⁵⁸.

3.8.3. *National Tariff Policy 2006*

As per the National Tariff Policy 2006 the State Electricity Regulatory Commissions (SCRC) to specify a Renewable energy Purchase Obligation (RPO/RPS) by distribution licensees in a time-bound manner.

3.8.4. *National Rural Electrification Policies (NREP), 2006*

The NREP-2006 policy aims at providing access to electricity to all households in the country and a minimum 'lifeline' level of consumption of 1 unit (kWh) per household per day. The policy also mentions that off-grid solar PV solutions may be deployed where the supply of grid electricity is infeasible⁵⁹. The Jawaharlal Nehru National Solar Mission (JNNSM) 1 is India's flagship policy on renewable energy (MNRE, 2009). It is part of India's National Action Plan on Climate Change, which focuses on India's response to climate change, and addresses diverse policy issues such as energy security and the creation of new competencies⁶⁰. JNNSM prominent goals is the deployment of 20 GW of utility scale solar power by 2022 using solar photovoltaic (PV) and solar thermal technologies⁶¹. The JNNSM plans to achieve this target in three phases, with the first targeting 1 GW by 2013, the second 4–10 GW by 2017, and the third 20 GW by 2022. Phase I was further split into two batches. Batch I targeted the deployment of 150 MW of solar PV technology and 500 MW of solar thermal technology, and Batch II targeted the deployment of 350 MW of solar PV technology. As of July 2013, Phase 1 has been completed and Phase 2 is yet to start. In Phase 1, the JNNSM reached approximately 85% of stated targets for solar PV deployment; however, with close to zero capacity online, it appears to have failed to deploy solar thermal technology⁶². The JNNSM also seeks to bolster the global competitiveness of the Indian solar manufacturing sector across the value chain. The JNNSM aspires to achieve this goal by promoting research and development, and by ensuring a market for domestic solar manufacturers. To accomplish the later, the JNNSM includes a controversial but commonly used industrial policy in its Phase 1 policy.

⁵⁷<http://indianpowersector.com/home/electricity-regulation/>

⁵⁸http://ceew.in/pdf/Appendix_F-Renewable_Purchase_Obligation_for_States.pdf

⁵⁹http://www.academia.edu/5375572/FUTURE_SCENARIO_OF_RENEWABLE_ENERGY_IN_INDIA_-_Copy

⁶⁰G. Shrimali, A. Sahoo. (2014). Has India's Solar Mission increased the deployment of domestically produced solar modules? Energy Policy, 69, 501-509.

⁶¹<http://mnre.gov.in/file-manager/annual-report/2008-2009/EN/index.htm>

⁶²https://steyertaylor.stanford.edu/sites/default/files/publications_files/has20indiad7b3s20solar20mission20increased20the20deployment20of20domestically20produced20solar20modules_15.pdf

3.8.5. Semiconductor Policy (2007)

Solar PV manufacturing includes the use of silicon materials to produce PV module which act as semiconductor. Government implemented semiconductor policy in 2007 to boost semiconductor manufacturing which offers a capital subsidy of 20% for manufacturing plants in Special Economic Zones and 25% for manufacturing plants outside of Special Economic Zones (SEZs). The subsidy is conditional and can be obtain if the net present value (NPV) of the investment is of worth 2crores or more.

3.8.6. Solar PV generation based incentives

MNRE generation based incentives, Rs. 12/kWh to eligible projects (commissioned by December 31 2009), through IREDA, for grid connected solar (both thermal and PV) plants in January 2008. It promoted grid connected power plants in excess of 1 MW of capacity at a single location. The scheme was limited to 5 MW per developer across India and a maximum of 10 MW per state⁶³. This initiative was mainly led by Central Government; however several State Governments have also taken some initiatives⁶⁴.

Table 3.5: Feed in Tariff for different states

S. No	Agencies	Year	Tariff (Without AD)	Tariff (with AD)
1	Central	2015	7.72	6.95
2	Andhra Pradesh	2014	17.91	14.95
3	Bihar	2014	8.75	7.87
4	Chhattisgarh	2014	8.69	
5	Gujarat	2014	8.97	8.03
6	Haryana	2014	5.7	
7	Jammu & Kashmir	2015	7.5	6.67
8	Jharkhand	2013	17.96	14.98
9	Karnataka	2014	8.4	9.56
10	Kerala	2014	15.18	
11	Madhya Pradesh	2014	10.44	
12	Maharashtra	2015	7.95	6.79
13	Orissa	2014	17.8	14.77
14	Punjab	2014	8.75	7.87
15	Rajasthan	2015	7.5	6.63
16	Tamil Nadu	2014	18.45	14.34
17	Uttar Pradesh	2014	15	
18	Uttrakhand	2014	11.1	10.15
19	West Bengal	2014	8.9	

(Source: http://www.academia.edu/9505934/Solar_energy_in_India_Strategies_policies_perspectives_and_future_potential)

⁶³Sharma, N.K. (2012). Solar energy in India: Strategies, policies, perspectives and future potential. *Renewable and Sustainable Energy Reviews*, 16, 933–941.

⁶⁴http://www.academia.edu/9505934/Solar_energy_in_India_Strategies_policies_perspectives_and_future_potential

3.8.7. State level initiatives

The State Electricity Boards and respective agencies for renewable energy at the state level, play a key role in implementation at a state level. Independent of these national efforts, states are promoting solar power.

3.9. Challenges and suggestions

3.9.1. Grid Parity

Grid connectivity has become the major constraint. Although several regions in India have rich solar power resources conducive to becoming sites for Giga Watt scale, they are primarily located far from electricity load centers. The geographical discrepancy between the location of solar PV installed and electricity demand makes transmission crucial to solar power development so transmission lines specifically to connect solar power facilities are frequently needed. Grid enterprises have little incentive to build and expand grids to connect to producers of renewable electricity. Connecting solar power with the main power grid requires significant investment. Besides that solar electricity accounted for only a small share of total electricity generation, grid enterprises have little incentive to invest in innovation. Lastly but not the least, renewable power is very sensitive to seasonal and climate change, and may cause grid instability and increase the complexity of grid management⁶⁵.

Recommendations

Grid parity is the tip at which the cost of generating electricity from alternative energy becomes equal to or less than the cost of purchasing power from the grid. Government should not only step forward to rapid installation of solar PV to generate electricity but they should also set ambitious target in term of reduction in transmission loss like using UDH transmission and reduce the transmission loss by 30-40%. Besides that to achieve grid parity Government should give emphasis on R and D in the formation of the area of innovative materials with high efficiency and cost effective compare to the current materials.

3.9.2. Limited innovation, shortage of skilled workforce and limited collaborations

India solar PV manufacturers have some challenges in raising the technological level of India solar technologies to that of the global leaders capable of sophisticated, world-class innovation. In addition, quality control remains a concern. International pressure and national ambitious target for rapid expansion of the solar power in energy mix has left India facing a serious shortage of skilled solar power professionals. There is also shortage of workers with an aptitude for innovation, technical design, and the ability to work interdisciplinary across the many facets of the solar industry.

Recommendation

The government should foster solar power education programs at top universities at the undergraduate, graduate and postgraduate levels, complimented by strong research and development programs in Solar power technology. Such programs should target the training of both high-level engineers as well as skilled low- and mid-level vocational workers. Research partnerships and consortiums between industry and academics in the area of solar power technology research should be encouraged and expanded with government R&D support. The Knowledge Upgrading Program for Professional Technicians, researcher could be expanded. In addition, international research collaborations in solar power technology development, as well as to promote best practices in policy design, integration, resource assessment, forecasting and site selection, should be encouraged.

⁶⁵Wang, F, et.al (2010). China's renewable energy policy: Commitments and challenges. *Energy Policy*, 38(4), 1872–187.

3.9.3. *Environmental and Occupational Health issue*

PV industry's adherence to the concept of sustainable development may not as strong as it appear after studying its life cycle from production to the end of life of the PV system. Its use of potentially toxic substances during manufacturing processes presenting health and safety problems may jeopardize its benefits. Conventional PV (silicon based) manufacturing processes results in production of toxic, flammable and explosive chemicals like lead, brominated flame retardants, cadmium, and chromium as by-product. They can have severe adverse effect on health of workers involved in manufacturing of solar cells.

Recommendations

These occupational health concern related to the growing number of hazardous materials handled in the PV industry demands an all-inclusive occupational health and safety approach in order to achieve an optimal equilibrium with sustainability.

3.9.4. *Solar PV waste as e-waste*

The disposal of electronic products is becoming an escalating environmental and health problem in many countries. Recycling of PV panel is currently not economically viable because waste volumes generated are too small; significant volumes of end-of-life photovoltaic panels will begin to appear in 2025 or 2030⁶⁶. In several countries PV panel waste is now considered potentially dangerous, akin to e-waste.

Recommendations

With the rising cost of electricity and advancement in solar PV technology, there will be an increase in the demand of solar PV technology within the residential and commercial markets. In 20–25 years these panels will reach their end-of-life and the cumulative amount of PV waste will force the solar industry to be more conscious about developing an environmental and cost sustainable method for disposing this industrial waste. However the industry should not wait until then to take action, and should start developing a recycling process that will prevent a significant amount of PV e-waste. Government also need to take initiatives

3.9.5. *Materials scarcity issues*

India is developing manufacturing capabilities for older silicon-based technologies that face no fundamental material constraints. Literature is well cited CdTe technologies as most promising and most cost effective technologies. Tellurium is one of the elements which are needed during the manufacturing of CdTe solar PV module. Current size of the industry does not meet the requirement of Tellurium needed for indigenous production. India imports a major portion of CdTe cell which can impact the policy goal of developing a domestic industry to produce solar cells.

Recommendation

Manufacturers are developing indigenous production of silicon based solar cell due to mandatory requirement to encourage domestic production. These regulations are only applied for manufacturing of solar cell from silicon and do not include other materials. Regulations need to integrate for other materials which are well cited to produce most cost effective and higher efficiency solar cell such as CdTe so that India does not miss the opportunity to get an indigenous foothold in one of the most promising PV technologies.

⁶⁶Dubey, S. et.al. (2013). Socio-Economic and Environmental Impacts of Silicon Based Photovoltaic (PV) Technologies. *Energy Procedia*, 33, 322-33.

4. **HYDROPOWER: AN INSIGHT OF STATE OF THE ART ACHIEVEMENT, CHALLENGES AND POLICY SUGGESTIONS**

4.1. **Introduction**

Hydropower is cavorting an imperative role in power sector, worldwide. It has been increasing significantly in recent years due to growing energy demand with minimum environmental impact. The Tibetan Plateau, the world's third pole, gives birth to many of Asia's major rivers. Southern Himalayan watershed nations India, Nepal, Bhutan and Pakistan are all developing massive hydro power schemes to avail the opportunity to develop and generate electricity to boost their developing economy⁶⁷. Hydro power projects are having overall install capacity of 990 GW worldwide. Small hydro currently contributes over 40GW of world small hydro capacity which is estimated to be around 100 GW. China is world leader in terms of both large and small hydro power capacity.

4.2. **State of the Art of Hydro Power Technologies and its Status in India**

Hydropower is based on a simple process taking the advantage of the kinetic energy freed by the falling water. In all hydroelectric generating stations, the rushing water drives a turbine, which converts the water's motion into mechanical and electrical energy⁶⁸. Hydroelectricity is clean energy and its generation is not linked to issues concerning fuel supply, especially the price volatility of imported fuels. It enhances our energy security and is ideal for meeting peak demand⁶⁹. It has higher efficiency (over 90%) compared to thermal (35%) and gas (around 50%). Hydropower projects are generally categorized in two segments i.e., small and large hydro. In India, hydro projects up to 25 MW station capacities have been categorized as SHP projects. While Ministry of Power (MOP), Government of India (GOI) is responsible for large hydro projects, the mandate for the subject small hydro power (up to 25 MW) is given to Ministry of New and Renewable Energy (MNRE)⁷⁰. India is endowed with immense amount of hydro-power potential and ranks 5th on global scenario in terms of exploitable hydro-potential⁷¹. First comprehensive survey was carried out by CWPC in 1953 followed by CEA in 1987. India has an enormous hydroelectric power potential of around 148700 MW (84044MW at 60% load factor). Table shows the River wise hydro potentials and probable installed capacity in each rivers at 60% load rate. Hydropower are the second highest contributors of the energy in terms of install capacity after wind energy in the Indian power which can instantly respond to fluctuations in electricity demand meeting both base-load and peak-load demands and therefore essential in order to stabilize the power grid. They allow achieving self-sufficiency by using the best possible scarce natural resource that is the water, as a decentralized and low-cost of energy production. The Indian hydropower and small hydropower rank fifth worldwide for total hydro capacity, with an existing capacity of 40.78 GW. Small hydro accounted 3.8 GW of cumulative capacity at year-end.

⁶⁷ MNRE annual report 2013-14

⁶⁸ Annual Report (2013-14). Power and energy division Planning commission.
<http://planningcommission.nic.in/>

⁶⁹ Sharma, N, K., et al. (2013). A comprehensive analysis of strategies, policies and development of hydropower in India: Special emphasis on small hydro power. *Renewable and Sustainable Energy Reviews*, 18, 460–470.

⁷⁰ CEA Report Feb. 2014(http://www.cea.nic.in/reports/monthly/executive_rep/feb14.pdf)

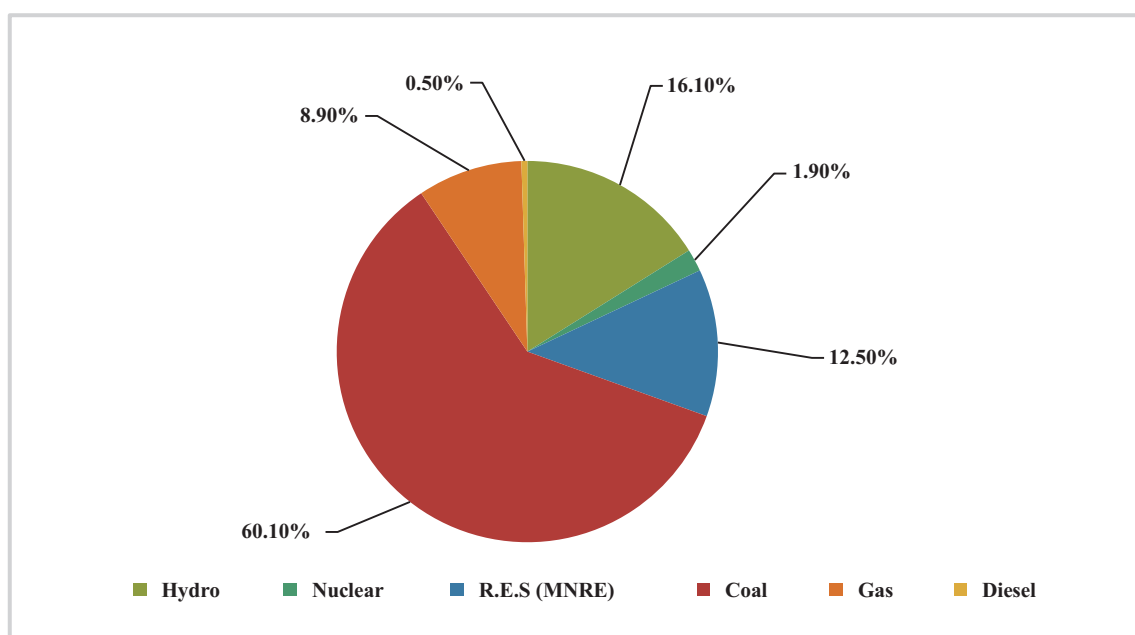
⁷¹ <http://www.mapsofindia.com/maps/india/hydropowerproject.htm>

Table 4.1: River wise hydro potentials

River/Basin	First survey (1953-1959) Reassessment (1978-1987)		
	Potential at 60% load factor	Potential at 60% load factor	Probable installed capacity
Indus	6583.00	19988	33832
Ganga	4817.00	10715	20711
Central Indian Rivers	4300.00	2740	4152
West Flowing Rivers	4350.00	6149	9430
East-flowing Rivers	8633.00	9532	14511
Brahmaputra	13417.00	34920	66065
Total	42100.00	84044	148701

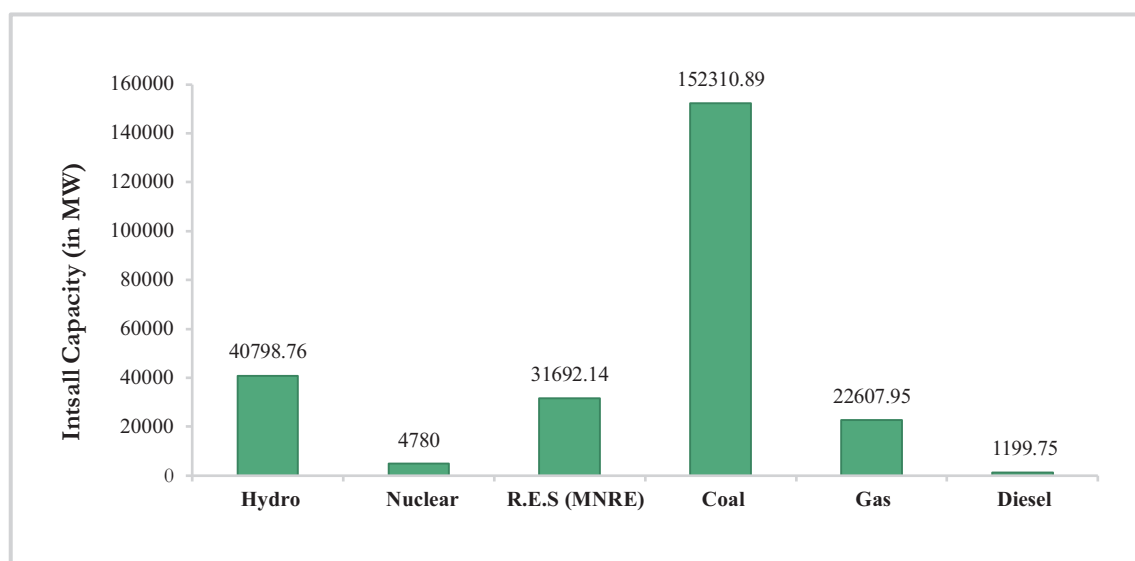
(Source: <http://indiaenergy.gov.in/doc/Large%20Hydro.pdf>)

Figure 4.1: Indian Power sector on 31-08-2014 (CEA)



(Source: CEA Report Feb 2014)⁷²

⁷²CEA Report Feb. 2014(http://www.cea.nic.in/reports/monthly/executive_rep/feb14.pdf)

Figure 4.2: Potential Achievement

(Source: MNRE Various Reports)

4.3. Revivification of hydropower in India's energy planning

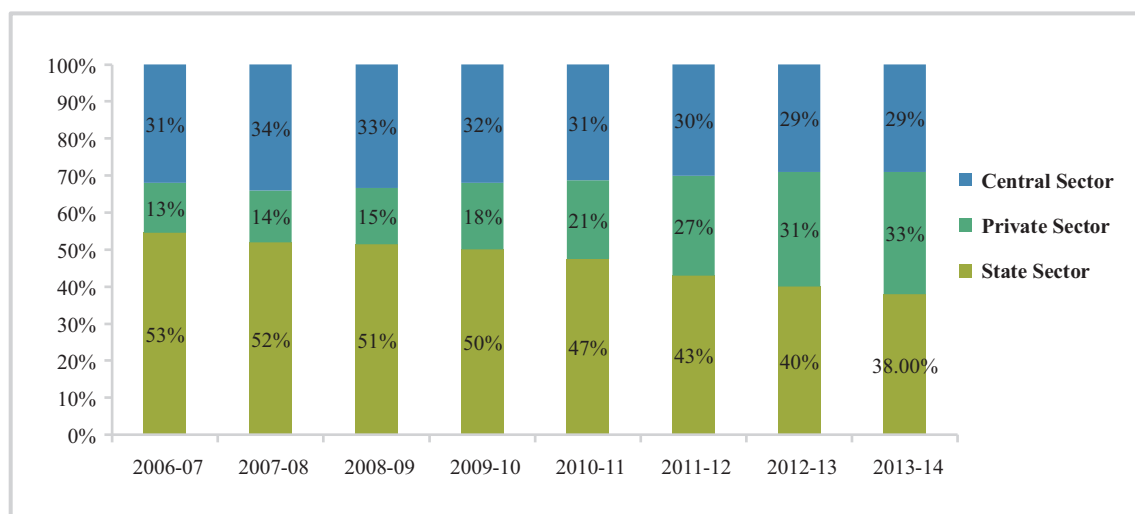
Although Hydropower is one of the major contributor of energy in India but a decline in hydropower's contribution 33% in 6th five year plan to 20% in 11th year plan in the overall portfolio has been a concern and Government of India took steps for re-emergence of hydro power by setting ambitious targets for 12th five year plan, 13th five year plan and 14th five year plan. Only 8237 megawatts (MW) of hydropower generation was envisioned in the Eleventh Five Year Plan, three times that amount (around 25316 MW) are planned during the Twelfth Plan (2012-2017), followed by 31000 MW and 36494 MW in the Thirteenth (2017-2022) and Fourteenth (2022-2027) Plans, respectively⁷³. Until 2014, a total of 40798MW of hydropower had been installed. By contrast, each of the five year plans starting from the Twelfth to the Fourteenth is expected to add new hydropower capacity of around 30000 MW, with the aim of harnessing the entire hydropower potential of the country by 2027.

4.4. Sector wise install capacity in Indian power sector

As far as ownership of the installed capacity is concerned, the State sector continues to be the largest owner with 38 per cent share in 2013-14, though there is a clear and remarkable shift in ownership pattern of the private sector since 2006-07 from 13 per cent in 2006-07 to 33 per cent in 2013-14. During this period, private sector seen as an important actor for hydropower development as its share has increased consistently and role of private sector know become more relevant in Indian power sector.

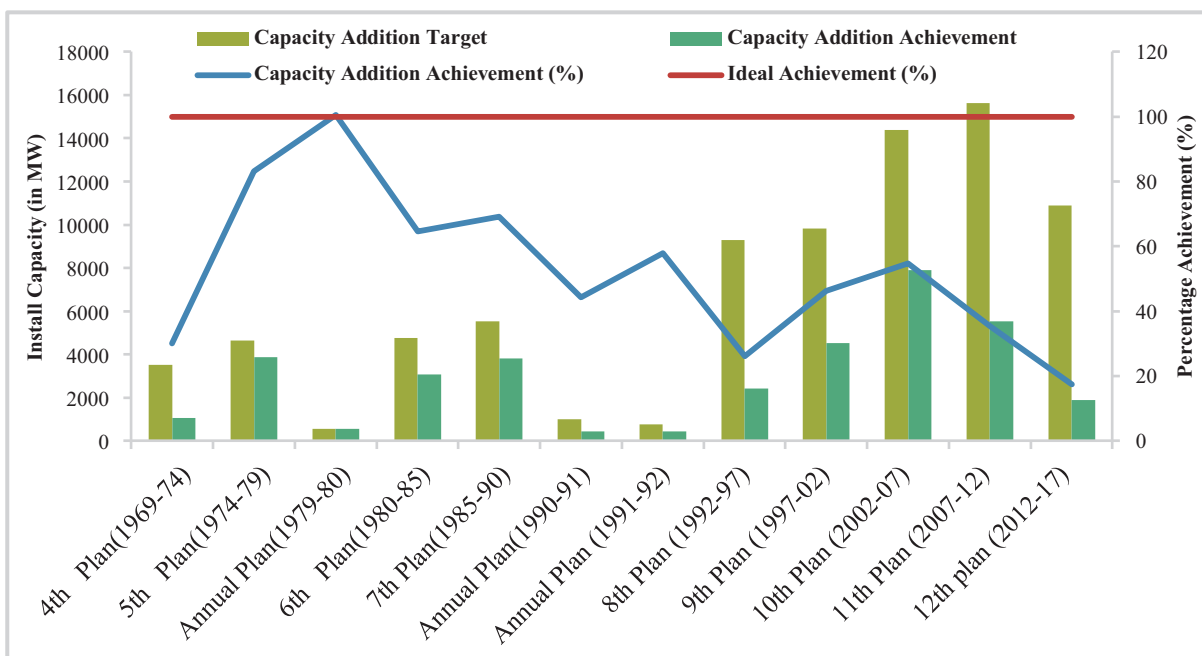
⁷³<http://ceew.in/pdf/NC-AG-Responsible-Hydropower-Development-in-India-Challenges-for-future-06Dec13.pdf>

Figure 4.3: Sector wise ownership Pattern of install capacity in India power sector (2006-14)

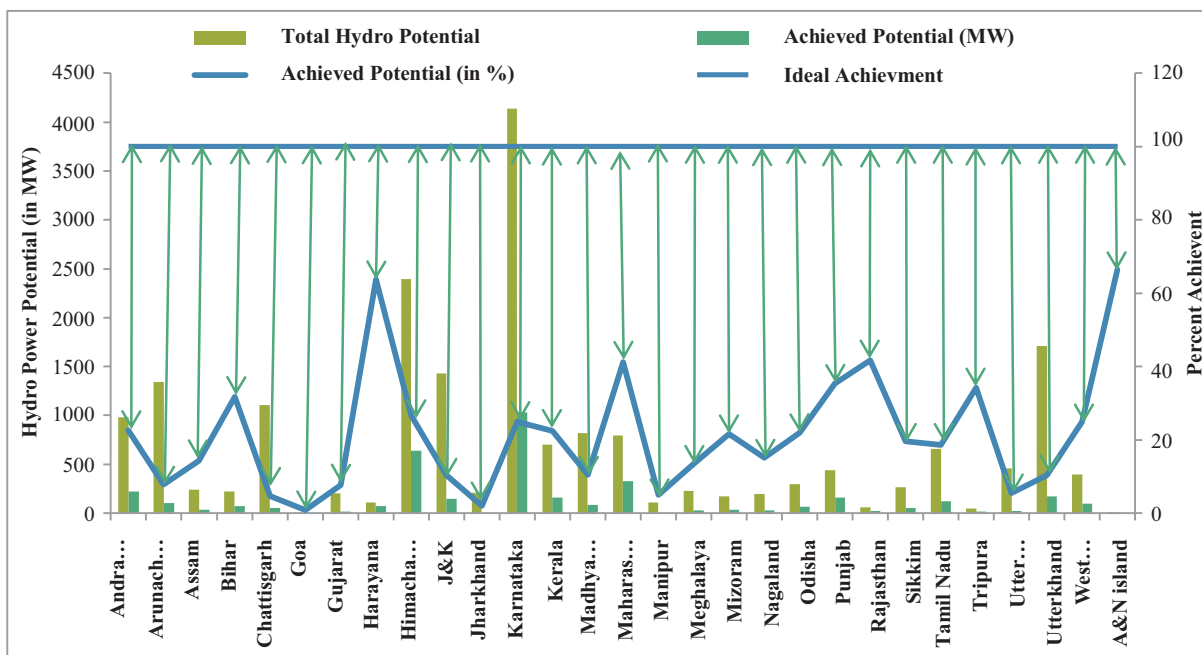


(Source: MNRE Various Report)

It can be observed from Figure 4.3 that the contribution from the state sector is also decreasing consistently during this period. The share of the central sector increased initially in 2006-07 to 2007-08 after which it also starts decreasing but quite sluggishly. Over all, the performance of the hydropower sector in accomplishing planned targets has been melancholy. There is a big gap between target and achievement in each five year plan from 4th to 11th; the same pattern is observed during the 12th year plan. We are at a mid-point of the 12th year plan and only able to achieve 20% of the target that is 10687 MW. With this speed of implementation it is really hard to achieve the 12th year plan target. Set in contradiction of this historical record, the targets for 13th and 14th five year plans seem basically well-high. As per the CEA Report, Government has target to exploit all hydro-power potential by the end of 14th year plan. State wise achievement analysis indicated that a high percentage of hydropower is still untapped in most of the states of India; most of the states achieved only 10-20% of potential, 80-90% of it is still untapped. With this realistic data from concerned ministry report, the set target to exploit all potential by 14th year plan seems unrealistic optimistic.

Figure 4.4: Gap between achieved potential and Targets during five Year Plans

(Source: [http://mnre.gov.in/information/policies-2/Annual Report \(2013-14\) power and energy division](http://mnre.gov.in/information/policies-2/Annual Report (2013-14) power and energy division)
Planning commission (<http://planningcommission.nic.in/>))

Figure 4.5: State wise Gaps in Installed Capacity and Targets

(Source: Annual Report (2013-14) power and energy division Planning commission
(<http://planningcommission.nic.in/>)⁷⁴, CEA Report Feb.)

⁷⁴Annual Report (2013-14) power and energy division Planning commission (<http://planningcommission.nic.in/>)
CEA Report Feb.

After this overall scenario of hydropower status, this chapter presents a comprehensive analysis of small hydropower development in India with special emphasis on SHP in terms of availability, current status, major achievements, future strategies and promotion policies instead of policies of the large hydropower. Since the inception of Ministry of New and Renewable sources, small hydropower considered as green technology now the data only provide by Ministry of Power on hydropower potential exclude small hydropower and it is included in renewable capacity by MNRE.

4.5. *SHP terminology and Development in India*

There is no universal consensus on the definition of small hydro development. Different countries adopt different specification. Definition of SHP varies worldwide. In India install capacity less than 25MW is considered as small hydro⁷⁵. It is considered as a matured, reliable, environmental friendly and do not create any pollution during operation and offer highly reliable power. They have very low running and maintenance cost. SHP has a long project life e.g. Turbines can last 20-30years while concrete civil works can last up to approximately 100 years.

Table 4.2: Specifications for SHP in different Countries.

S. No.	Country	Install Capacity (Up to MW)	S. No.	Country	Install Capacity (Up to MW)
1	UK(NFFO)	5 MW	6	Cambodia	15 MW
2	UNIDO	10 MW	7	Australia	20 MW
3	India	25 MW	8	China	25 MW
4	brazil	30 MW	9	Philippines	50 MW
5	Sweden	15 MW	10	New Zealand	50 MW

(Source: http://www.ahec.org.in/links/HSHS/Presentations/Links/Technical%20Papers/Overview%20of%20SHP%20Development/Mr%20G%20Baidya_Development%20of%20SH.pdf)

4.5.1. *Brief History*

The first SHP station in India was a 130 kW plant installed at Sidrapong, Darjeeling in 1897. The progress of development was very slow until Independence (1947) and even there after the situation was no different for about 12 to 15 years. In and around 1959 the situation underwent a change not because of any conscious planning but mainly because of a few dedicated people. The history of SHP development in the Himalayan Region will be meaningless without acknowledging the contribution of these great personalities⁷⁶. The topmost among them, is Mr.Allen Mankhouse from New Zealander who came to India under “Colombo Plan” of the United Nations in 1952 [6]. Another small hydro power unit of 4.5 MW came up at Sivasamudrum in 1902.in the pre independence most of the hydropower install capacity came from small and medium units. After independence focus changed to large projects and most of the hydro power electricity proportion comes from large hydro power plants.

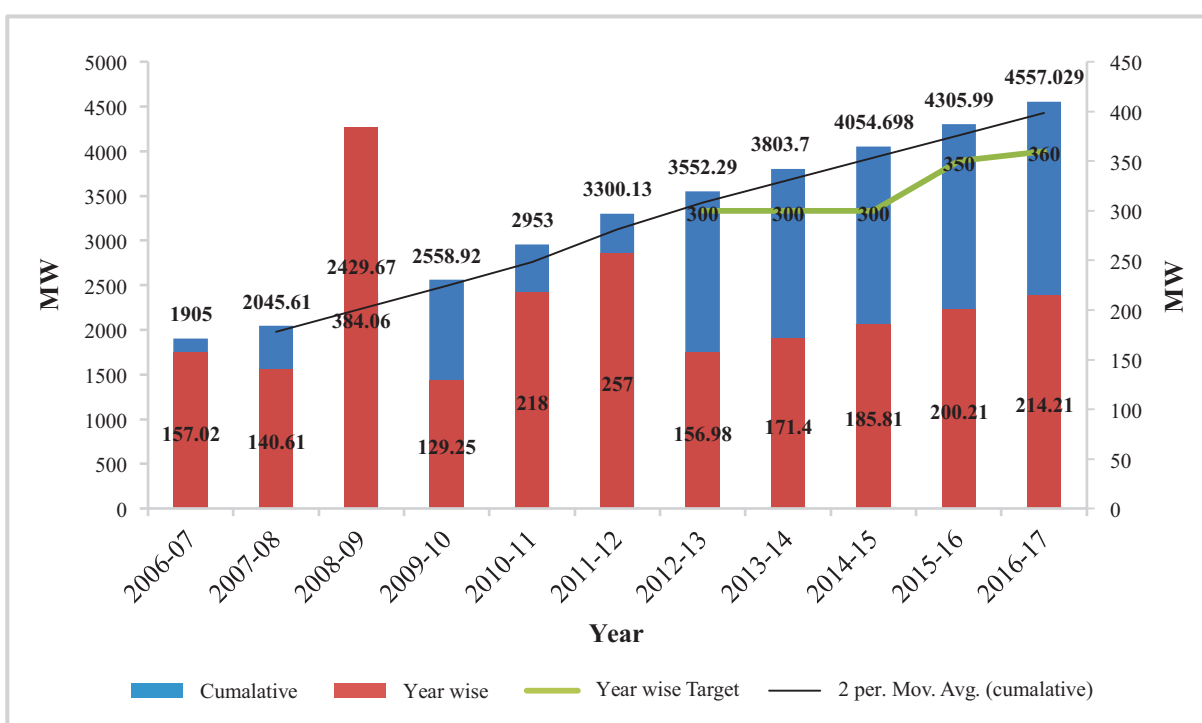
⁷⁵<http://www.worldbank.org/en/news/feature/2012/03/23/india-hydropower-development>

⁷⁶www.ahec.org.in

4.5.2. Small Hydro Power Development

The estimated potential of small hydro power in India is about 15 GW of which 1/4th (20%) has already achieved with ambitious target set by JNSSM flagship program⁷⁷. Most of the potential in north Himalayan States are river-based projects and in other States are canal based. The mandate of development of small hydro power schemes are given to the MNRE under the aegis of GoI. India has achieved 187.22MW in the current financial year 2014-15 from SHP. Government target is to achieve 5000 MW cumulative installed capacity by the end of 12th five year plan. Although initial two years the installed capacity is well –low as planned but still extrapolating the trend shows optimistic scenario to achieve the targeted capacity by the end of the 12th five year plan.

Figure 4.6: SHP Achievement and cumulative power deployment



(Source: Annual Report (2013-14) power and energy division Planning commission)

There are a host of reasons behind small hydropower's ability to fulfill the targets over the years. The Policy on Hydropower Development in 1998 identified hindered issues for deployment of hydropower and formulated a new hydropower policy in 2008 which considered all the previous issues to solve them. Several policy initiatives have been taken to accelerate the growth of the small hydro power sector⁷⁸.

4.5.3. Policy environment to promote Small hydropower in India

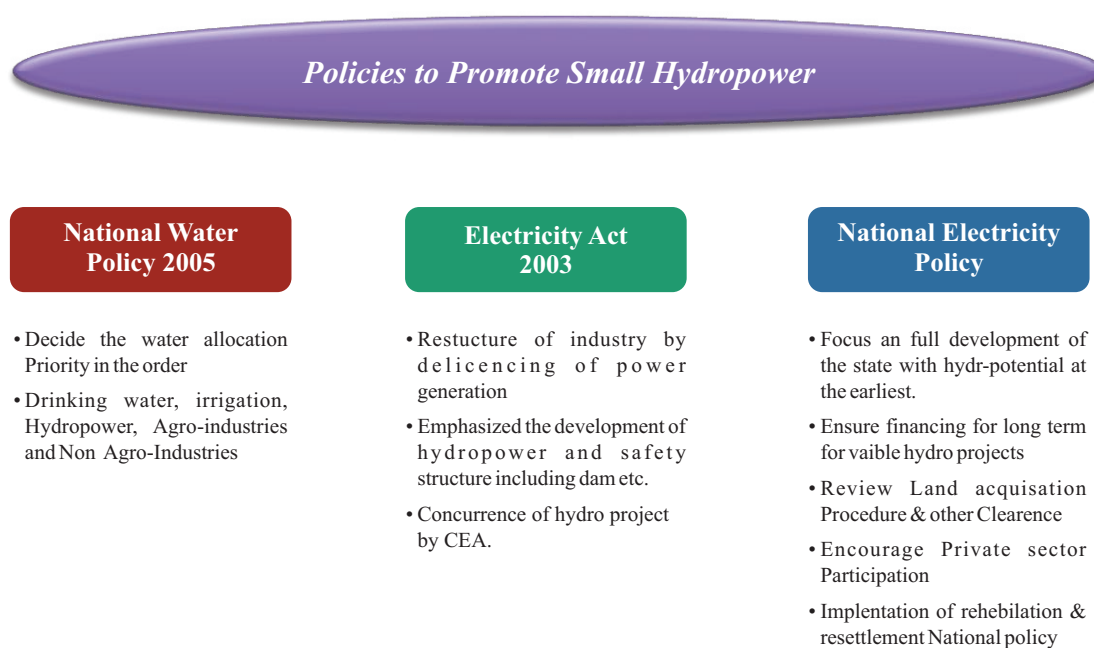
For grid stability, the ideal hydro-thermal mix ratio for Indian conditions is 40:60. In order to correct the hydro-thermal mix to meet the grid requirements and peak power shortage, in August 1998 and thereafter in November 2008, the Government of India announced a Policy on 'Hydro Power Development'. Project Affected People have

⁷⁷<http://www.eai.in/ref/ae/hyd/hyd.html>

⁷⁸http://www.powermin.nic.in/whats_new/pdf/new_hydro_policy.pdf

been made long term beneficiary stakeholders in the hydro projects by way of 1% of free power with a matching 1% support from State government for local area development thus ensuring a regular stream of benefits⁷⁹. An initiative of installing 50,000 MW large hydro projects in the country was announced by the government. By 1998, small hydro power projects established themselves as a techno economically viable option for generating power with some preferential treatments. Encouraged by the growing private sector participation in the sector and the potential of SHP projects to meet power requirements of remote and isolated areas, where grid extension is relatively expensive, small scale hydro was identified as an area to provide thrust in the overall hydropower development of the country. This led to transfer of the subject of hydro up to 25 MW from Ministry of Power (MOP) to MNRE in December 1999⁸⁰. The process of reforms is an ongoing one and Government of India has been vigorously pursuing this path for the past five to six years. Hydro Power is a renewable source of clean energy and is used to supplement the base load provided by thermal power plants and storage for wind energy through pumping. To enable the project developer in the Hydro Sector a reasonable and quick return on investment, merchant sale of up to a maximum of 40 percent of the saleable energy has been allowed. Central Electricity Authority (CEA) has issued various hydroelectric related reports and guides are available through web. Some of them are the best practices in Hydroelectric Generation; Preliminary ranking study of hydroelectric scheme; Guidelines for accord of concurrence of HE Scheme; Guidelines for formulation of DPRs for HE scheme; Draft model contract document for hydro projects; Project monitoring status reports; Project clearance status reports and Status of 50,000 MW Hydroelectric Initiative reports⁸¹.

Figure 4.7: Policies to Promote SHP in India



(Source: http://www.powermin.nic.in/whats_new/pdf/new_hydro_policy.pdf)

⁷⁹ www.ahec.org.in

⁸⁰ www.cerpch.unifei.edu.br

⁸¹ <http://www.ighem.org/Paper2010/TSA01.pdf>

The main aim of SHP programmes to lower the cost of equipment, increase its reliability and set up projects in areas that give the maximum advantage in terms of capacity utilization. Today the SHP programme in India is essentially private investment driven. 228 private sector SHP projects of about 1230 MW capacity have been setup. Private sector entrepreneurs are finding attractive business opportunities in small scale hydro. The MNRE is giving financial subsidy, both in public and private sector to set up SHP projects. In order to improve quality and reliability of projects, it has been made mandatory to get the project tested for its performance by an independent agency and achieving 80% of the envisaged energy generation before the subsidy is released. In order to ensure project quality/performance, the ministry has been insisting to adhere to IEC/International standards for equipment and civil works. The subsidy available from the Ministry is linked to use of equipment manufactured to IEC or other prescribed international standards⁸².

4.5.4. Challenges and Policy recommendations of hydropower development

Hydropower plants can also start up and shut down quickly and economically, giving the network operator the vital flexibility to respond to wide fluctuations in demand across seasons and at different times of the day. This flexibility is particularly important in a highly-populated country like India where household electricity demand is a significant portion of total demand and this demand is concentrated in a short period of time usually in the evening.

Hydropower plays an important role in the energy and development strategies of India, such natural resource projects are inherently challenging. Environmental and social impacts are inevitable⁸³. Government are taking significant strides in understanding and addressing these impacts some of the policy suggestions to accelerate the small hydro power.

- Problems such as local agitation (law & order), land acquisition etc. need to be resolved by the concerned State Government.
- Tendency of converting storage projects (as identified by CEA) to Run-of-River projects should be discouraged.
- Project developer should seek long term open access by indicating at least the region(s) in which they intend to supply their power to enable development of transmission system.
- Efforts may be made by the concerned State Govt. / developer for projects held up for environment and forest problems to get the timely E&F clearances.

⁸² www.ahec.gov.in

⁸³ www.worldbank.org.

5. WASTE TO ENERGY

5.1. Introduction

Increase urbanization and industrialization is directly contributed to increase in quantum of waste. These wastes poses threat to environment as well as human being because of their improper disposed of. Land filling is the most common practices of managing waste today, which produce huge amount of greenhouse gases leakages in the form of CO₂ and CH₄ and leach ate Production. Thus there is urgent need to come up with environmentally, economically and socially sustainable solid waste management process. Waste to energy is such an emerging technology process which has strong potential to recover energy from waste either in electricity/heat form from the unused resources i.e., wastes. Developed as well as developing countries are taking step forward to derive energy from waste which results in many innovative technologies developed. These technologies not only help to helps to reduce the hazardous waste management but also energy security⁸⁴.

5.2. Waste Composition in India

India Municipal Solid waste can be classified in three categories: Organic, Recyclable and Inert and non-organic which constitute 51%, 17% and 32 %, respectively.

Figure 5.1: Waste composition in India

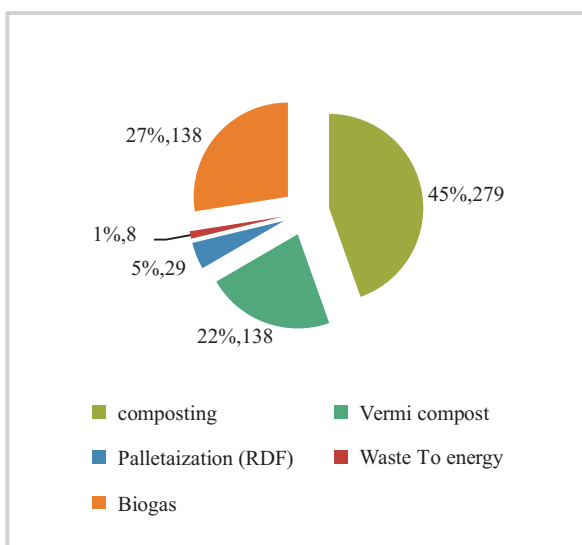
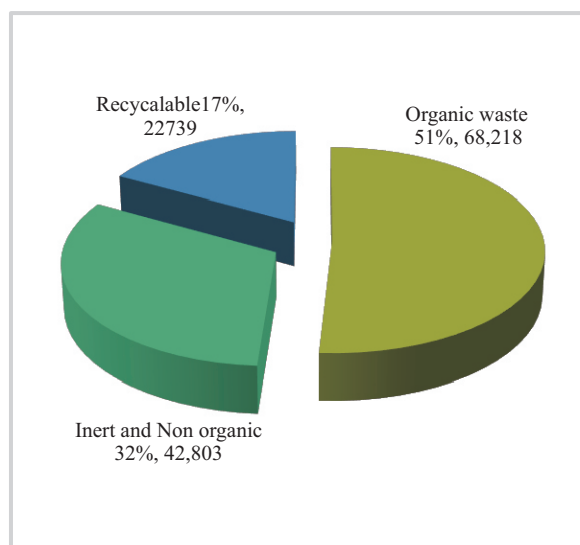


Figure 5.2: Waste Treatment in India



(Sources: Planning commission report, 2014)⁸⁵

Organic waste can easily be manageable, these organic waste can be either decomposes easily or can be used as a bio fuel, manures etc. Recyclable waste which is (739)TDP i.e 17% of the total waste generation. It can be recycle and can reused in another form but we must ensuer that during recyle it dose not cause any envoinmental adverse effect. Inert Or non organic waste (42803)TDP i.e 32% cannot be easily decomposable or recyclable this type of waste is challenging for any country. To manage this type of waste we have adopt the thermal process to generate and energy from this waste ,after the thermal processing the volume of the waste is considerably reduces. There are basically two methods to generate energy from waste i.e., Thermal processing of MSW and bio-chemical conversion

⁸⁴Singh, R.P and Tyagi V.V (2011), An overview for exploring the possibilities of energy generation from municipal solid waste (MSW) in Indian scenario, *Renewable and Sustainable Energy Reviews* 15, 4797-4808

⁸⁵http://planningcommission.nic.in/reports/genrep/rep_wte1205.pdf

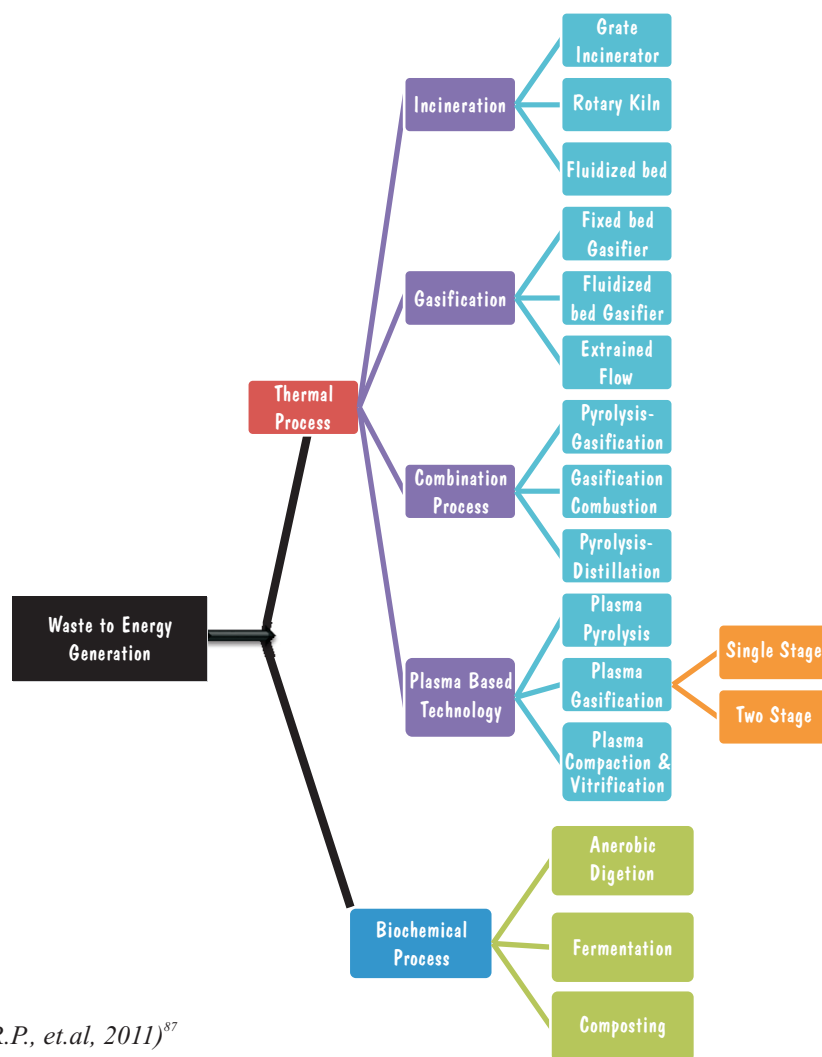
of biodegradable MSW. Thermal conversion consist incineration, pyrolysis, and gasification and plasma techniques while bio-chemical conversion includes composting, vermicomposting, anaerobic digestion/biomethanation.

5.3. Thermal Conversions Process

5.3.1. Incineration

Incineration is a process aimed at attaining the complete oxidation of all the suitable elemental species encompassed in the feedstock material. The waste are heated at a temp between 750°C to 1000°C. It can reduce the waste mass by 70% and volume by 90% before incineration. Mechanical and biological treatment is done to improve the combustible quality of waste. The incineration process has three major steps: incineration, energy recovery and air pollution control. It produces the polluted gases such as (SO_x , NO_x , CO_x). Thus the incineration of MSW may result in air pollution, unless the incinerators are well equipped with appropriate pollutant control accessories⁸⁶.

Figure 5.3: Energy generation Method from waste



(Source: Singh, R.P., et.al, 2011)⁸⁷

⁸⁶Bosman, A, Vanderreydt, I. (2013). The crucial role of Waste-to-Energy technologies in enhanced landfill mining: a technology review. *Journal of Cleaner Production*, 55, 10-23.

⁸⁷Singh, R.P., et.al, (2011). An overview for exploring the possibilities of energy generation from municipal solid waste (MSW) in Indian scenario. *Renewable and Sustainable Energy Reviews*, 15(9), 4797-4808.

Table 5.1: Average Amount of gas emission per ton during incinerating MSW

S. NO.	Gases	Average Amount Per Ton MSW
1	CO ₂	0.40-0.68Ton/ton
2	NO _x	1.09-1.34Kg/ton
3	CO	0.03-0.63Kg/ton
4	SO ₂	0.30-0.44Kg/ton

(Source: Lou, Z and Bilitewski, B. 2015)⁸⁸

5.3.2. Pyrolysis

Pyrolysis chemically decomposes organic materials by heating it in oxygen free environment. Pyrolysis typically occurs under pressure and at operating temperatures above 430 c .In practice; it is not possible to achieve a completely oxygen-free atmosphere. Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs⁸⁹. If volatile or semi-volatile materials are present in the waste, thermal desorption will also occur. Organic materials are then transformed into gases, small quantities of liquid, and a solid residue containing carbon and ash, it is cheaper as compared to incineration process. Three type of pyrolysis processes are exist which is differ in their operational parameter (temperature, Heating rate, particle sizes and residence time) named conventional pyrolysis, Fast pyrolysis and flash pyrolysis. Table insert

5.3.3. Gasification

Gasification involves the partial combustion of biomass to generate syngas(fuel gas) CO₂CO, H₂CH₄H₂O, trace amounts of higher hydrocarbons, various contaminants such as small char particles, ash and tars are also present in MSW after shredding to reduce particulate size. Several types of waste cannot be treated by gasification without pre-treatment, however agricultural, plastic and wood wastes can be. Gasification process is classified into two process

- Direct Gasification (Oxidizing Agent)
- Indirect Gasification (Without Oxidizing Agent)

A gasification system is made up of three fundamental elements:

- The gasifier, helpful in producing the combustible gas.
- The gas clean up system, required to remove harmful compounds from the combustible gas.
- The energy recovery system⁹⁰.

⁸⁸Lou, Z and Bilitewski, B (2015). Environmental impacts of a large-scale incinerator with mixed MSW of high water content from a LCA perspective. *Journal Environmental science*.

⁸⁹www.mpponline.com

⁹⁰Singh, R.P., et.al, (2011). An overview for exploring the possibilities of energy generation from municipal solid waste (MSW) in Indian scenario. *Renewable and Sustainable Energy Reviews*, 15(9), 4797-4808.

5.3.4. Plasma

Plasma based system is new method for waste treatment the high energy density and temperature can be achieved in plasma process, plasma processes allow to achieve high heat and reactant transfer rates this process is used to melt the high temperature material which is not easily done by thermal process (incineration, pyrolysis and gasification) heat is generated from this method is decoupled from process chemistry which increases process controllability and flexibility. Plasma technologies for waste treatment can be divided into different categories plasma pyrolysis and plasma gasification

5.3.5. Plasma Pyrolysis

It is a commercially proven technology Plasma pyrolysis provides solutions for complete pyrolysis of typical hospital waste such as cellulose polymer dressings, polyvinyl chloride blood bags, polyurethane and silicon rubber gloves & catheters and other disposables made of polyethylene, polymethyl methacrylate, rubber, glass etc. The system provides high temperatures combined with high UV radiation flux which destroys pathogens completely⁹¹. Plasma pyrolysis of organic waste usually results in two product streams: a combustible gas and a carbonaceous residue (char), Plasma Pyrolysis is extensive techniques for material recovery e.g. plasma pyrolysis offers potential for carbon black recovery from used tires⁹².

5.3.6. Plasma gasification and Vitrification

The first step is to process the feed stock to make it uniform and dry, and have the valuable recyclables sorted out. The second step is gasification, where extreme heat from the plasma torches is applied inside a sealed, air-controlled reactor. During gasification, carbon-based materials break down into gases and the inorganic materials melt into liquid slag which is poured off and cooled. The heat causes hazards and poisons to be completely destroyed. The third stage is gas clean-up and heat recovery, where the gases are scrubbed of impurities to form clean fuel, and heat exchangers recycle the heat back into the system as steam. The final stage is fuel production – the output can range from electricity to a variety of fuels as well as chemicals, hydrogen and polymers^{93,94}.

⁹¹ www.dav.gov.in

⁹² www.eflm-symposium.eu.

⁹³ www.westing-house-plasma.com

⁹⁴ Lombardi, L and Carnevale, E (2014). *A review of technologies and performances of thermal treatment systems for energy recovery from waste.* Waste Management

Table 5.2: Comparison of different waste to energy technologies

Techniques	Process	Secondary Energy Carrier	Gas Phase Product	Solid Phase Product	Liquid Phase Product
Pyrolysis	Thermal degradation in absence of oxygen	Pyrolysis Gas	H ₂ , CO, H ₂ O, N ₂ , N ₂ , hydrocarbons	Charcoal including ash and metal	Pyrolysis oil, water
Combustion	Full oxidation combustion	Flue gas	CO, H ₂ O, O, N,	Slag, bottom Ash (heterogeneous mixture of slag ferrous and nonferrous metal, ceramics, glass, other non-combustibles and residual matter)	
Gasification	Partial Oxidation	Synthesis Gas (combustible)	H, CO, CO, CH ₄ , H ₂ O, N ₂		
Plasma Treatment	Plasma verification of the inorganic fraction of waste feed	Synthesis Gas	H, CO, CO, CH ₄ , H ₂ O, N ₂	Vitrified Slag saleable as road aggregate, building material or as high end secondary products like interlocking block, tiles and bricks.	

(Source: Bosman. A, Vanderreydt, I., 2013)⁹⁵

5.3.7. Bio-chemical conversion

Biochemical conversion processes make use of the enzymes of bacteria and other micro-organisms to breakdown biomass. In most of the cases, micro-organisms are used to perform the conversion process: anaerobic digestion, fermentation and composting. It is an environmental safe method for obtaining energy, the bacteria decomposes the organic waste in anaerobic digestion to obtain the energy, the biogas produced during decomposition of organic waste can be used as fuel, for heating in household purposes or generating electricity

During the decomposition process this organic fraction, the temperature rises and may reach as high as 65 °C but starts to fall after 1–2 months. However the process of fermentation goes on for a long time and a number of gases are produced, including small amounts of CO and H₂S. Under anaerobic conditions methane is produced, which is efficiently converted to methanol. Methanol has a higher calorific value than Methane, 1 ton of MSW produce 2-3 times as much as methane in (3 week) then produce by land fill in (6-7 years) with the same 1 ton MSW.

5.4. MSW in India

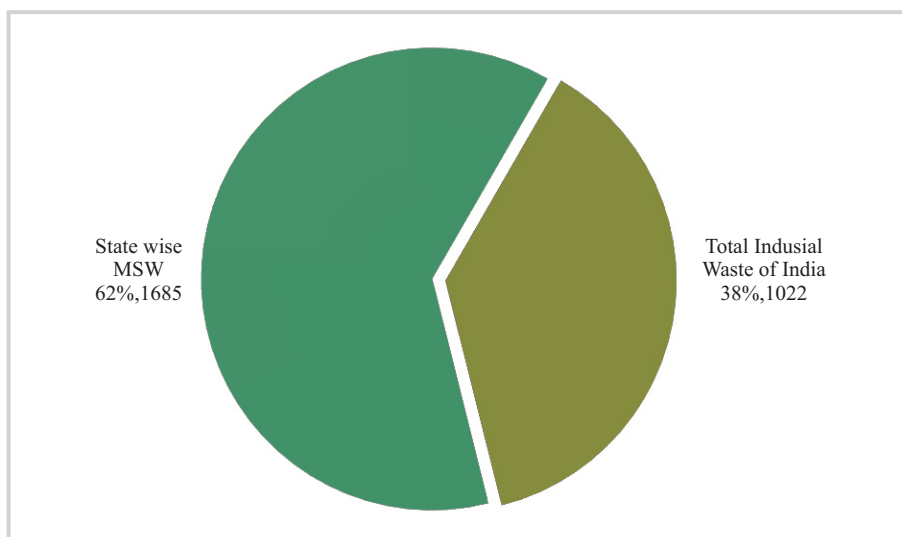
India, the second populous country in the world with a population of (1.2)⁹⁶ billion, generates approximately 90 million tons of solid waste annually. The amount of MSW generated per capita is estimated to increase at a rate of 1–1.33% annually so India has a tremendous potential to recover energy from this waste. The Indian government has enhanced the outlay for energy recovery from urban and agricultural waste in the fiscal

⁹⁵Bosman. A, Vanderreydt, I. (2013). The crucial role of Waste-to-Energy technologies in enhanced landfill mining: a technology review. *Journal of Cleaner Production*, 55, 10-23.

⁹⁶<http://populationcommission.nic.in/>

1999–2000 budget, this budget has given a new direction to India in field of “Waste to energy development”. The government also implemented several incentives and policies to enhance the waste management and energy generation from the waste. India total energy recovery potential from waste is 2707MW, 1685 from municipal solid waste and 1022 MW from Industrial Waste. Till now, India got success to achieve approximately 96.7 MW which is only 3.54% of total estimated potential. State wise potential of energy recovery is given below Table 4.3

Figure 5.4: Waste to energy potential status of India



(Source: http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2014_28mar.pdf)

5.5. Regulations, Policy environment to promote Waste to energy technologies

The major stakeholders in the management of Municipal Solid Waste include: Ministry of Environment and Forests (MoEF), Ministry of Urban Development (MoUD), Central and State Pollution Control Boards, Department of Urban Development, State Level Nodal Agency, Urban Local Bodies and Private Formal and informal Sector. List of prominent private companies are listed here. These ministries introduced several regulations; reports specially focus on municipal solid waste. Figure showed the specific guidelines⁹⁷.

⁹⁷<http://jnnurm.nic.in/wp-content/uploads/2010/12/broucher.pdf>

Table 5.3: States wise Estimated Potential and Achieved potential of waste to energy in India⁹⁸

S. No.	State	Potential (MW)	Achieved Potential (MW)	Percentage	Untapped
1	Andhra Pradesh	123	43.16	35.08%	64.92%
2	Assam	8	-	-	
3	Bihar	73	-	-	
4	Chhattisgarh	24	-	-	
5	Gujarat	112	-	-	
5	Haryana	24	-	-	
7	Himachal Pradesh	2	-	-	
8	Jharkhand	10	-	-	
9	Karnataka	151	1	0.6%	99.4%
10	Kerala	36	-	-	
11	Madhya Pradesh	78	3.90	5.0%	95%
12	Maharashtra	287	9.72	3.38%	96.62%
13	Manipur	2	-	-	
14	Meghalaya	2	-	-	
15	Mizoram	2	-	-	
16	Odisha	22	-	-	
17	Punjab	45	9.25	20.5%	79.5%
18	Rajasthan	62	-	-	
19	Tamil Nadu	151	8.05	5.33%	94.67%
20	Tripura	2	-	-	
21	Uttar Pradesh	176.5	2.8%	97.2%	
22	Uttarakhand	5	-	-	
23	West Bengal	148	-	-	
24	Chandigarh	6	-	-	
25	Delhi	131	16	12.2%	87.8
26	Pondicherry	3	-	-	
	Total	1685	96.08		

(Source: http://mospi.nic.in/mospi_new/upload/Energy_stats_2014.pdf)

⁹⁸http://mospi.nic.in/mospi_new/upload/Energy_stats_2014.pdf
<http://populationcommission.nic.in/>

Table 5.4: List of the companies' production of energy from Waste in India⁹⁹

PRODUCTION OF ENERGY FROM INCINERATION PLANTS		
S. No	States	Companies name
1	Haryana	A2Z Group of companies
2	Maharashtra	Hanjer Biotech Energies
3	Andhra Pradesh	SELCO International Limited
4	Delhi	East waste Processing Company Private Ltd.
Production of Energy from Gasification Plant		
1	Punjab	Zanders Engineers Limited
2	Gujarat	UPL Environmental Engineers Pvt limited
Production of Energy from Bio Methanation		
1	Tamil Nadu	M/s Asia Bio energy PVT limited
2	Madhya Pradesh	Cicon Environment Technologies
3	Maharashtra	Bermaco /WM Power Ltd.
4		Sound Craft Industries
5		Hydroair Tectonics Limited
6		Mailhem Engineers Pvt Ltd
7	Andhra Pradesh	Ramky Enviro Engineers Ltd

(Source: <http://www.eai.in/ref/ae/wte/comp/companies.html>)

⁹⁹<http://www.eai.in/ref/ae/wte/comp/companies.html>

Figure 5.5: Timelines of Municipal Solid Waste Guidelines, Regulations, Acts to promote Waste to energy Technology



(Source: Planning commission and JNURRM)^{100,101}

¹⁰⁰ www.jnnurm.nic.in

¹⁰¹ Planningcommission.nic.in

5.6. Other incentives scheme

5.6.1. Tipping Fee

Municipal authorities are required to pay tipping fee to a private operator who under takes the responsibility of processing the waste for the sustainability of the projects undertaken on PPP mode. This tipping fee is invested by the public sector build the efficient plants for disposal and generating the electricity which is distributed to generate more revenue¹⁰².

5.6.2. Tariff for Electricity Generation Plant

National Tariff Policy, 2006 was implemented to promote the non-conventional energy sources. As it will take some time to compete these green technology with conventional technology in term of cost. Therefore concern authority adopt a holistic approach ensuring the profit of investor, consumer and distribution licensee. Authority fixed the tariff rate for electricity generate through MSW plant in such a way so that main investor earns an adequate return on investment. It provides necessary incentives to potential investors to both invest in new as well as maintain the functioning of existing projects in a sustainable manner. It must also be ensured that both capital and revenue expenditure is minimized by ensuring that the equipment and machinery used are of high efficiency, and cost effective and that investments are made in locations that offer highest Plant Load Factor (PLF) and energy generation for the fairness for consumer The power purchase price must also be fair to the Licensee(s) and should truly reflect the costs and benefits on account of the mandatory requirement of purchase power from NCE generators¹⁰³. The history of tariffs for NCE sources and the applicability of various orders are presented in the table below. The Commission in its order dated March 2004 had proposed a single part tariff for Municipal waste projects for FY 2004-05 to FY 2008-09 where in it had allowed for a simple escalation of 5% (based on the base figure of Rs. 2.25), for subsequent years, on the base value of Rs. 3.37/kWh for FY 2004-05. The Commission in its order dated March 2009 had determined the single part tariff which would be applicable to the existing Municipal waste plants for the period FY 2009-10 to FY 2013-14 which is given below Investor may also sell the by-product produced during the course of electricity generation to increase their profit margin as well as self-financing their projects. They also have freedom to choose the technology options.

**Table 5.5: Single part tariff for Municipal projects for the period
FY 2009-10 to 2013-14^{104,105}**

S. NO.	Financial Year	Tariff	Financial Year	Tariff	Financial Year	Tariff
1	2004-05	3.37	2009-10	4.04	2014-15	4.71
2	2005-06	3.48	2010-11	4.15	2015-16	4.82
3	2006-07	3.59	2011-12	4.26	2016-17	4.93
4	2007-08	3.70	2012-13	4.37	2017-18	5.04
5	2008-09	3.81	2013-14	4.48	2018-19	4.48

(Source: <http://www.mercindia.org.in/pdf/http://www.aperc.gov.in/assets/uploads/files/1bd70-nceconsultativepaper.pdf>)

¹⁰²<http://www.wsp.org/sites/wsp.org/files/publications/WSP-Municipal-Solid-Waste-Management-India.pdf>

¹⁰³www.aperc.gov.in

¹⁰⁴<http://www.mercindia.org.in/pdf/Order%2058%2042/Order%20Case%20No%20%207%20of%202012.pdf>

¹⁰⁵<http://www.aperc.gov.in/assets/uploads/files/1bd70-nceconsultativepaper.pdf>

5.6.3. Land facility

The Municipal Solid wastes (Management & Handling) Rules, 2000 specify relevant points with regard to site selection for proposed landfill sites, The land required for establishing a waste processing unit will be provided by the public authority i.e. State Government/ Urban Local Bodies (ULBs) on license basis for the concession period .the Authority will provide the land according to the technology used for disposal and generating the power¹⁰⁶

5.6.4. Viability Gap Funding

The government has proposed a target for setting up 215 waste to energy plant by 2031 to generate 1,075MW and strongly advised to tie up the PPPs ,the viability gap funding up to 40% is provided, Twenty per cent of the viability gap fund can be provided from the VGF scheme of the Ministry of Finance and balance up to 20% can be provided by Ministry of Urban Development under JNNURM or other Central schemes The States/ ULBs could provide an additional 20% interest free loan with a moratorium of five year from commencement of commercial operation.¹⁰⁷

5.7. Challenges and policy recommendations

5.7.1. Unhygienic Landfilling

Most common practices for waste management in India is landfilling. Even after introduction of Municipal solid waste Management and Handling Rules in 2000. The collection efficiency of MSW is still only about 70% and 90% of this waste is landfill without considering ideal waste management rules in an unsafe manner. Besides this growing population has reduce the availability of land for such activities. Boundaries extension of most of cities due to increase urbanization results in such sites have become a part of cities. According to literature by 2047 1400Km² land will required for disposal of Municipal Solid Waste. This sites are also lacking proper leakage preventive measures like compaction, levelling of waste and final covering by soil and also absence of proper leachate collection system and landfill gas monitoring and collection system.

Recommendation

India should adopt the concept of Enhanced Landfilling Mining (ELFM) which integrate landfilling of waste in a sustainable context. Traditional landfilling does not follow the concept of closed loop cycle. ELFM concept does not consider landfilling a final solution of waste management. Instead landfilling consider as a temporary storages places which need be further treatment or future mines for materials.

5.7.2. Lack of Segregation

In India no source of segregation is observed. Municipal Solid waste is heterogenic mixture Non segregation waste as input in process system results in failure of the process system. Large scale methanation plant has failed owing to the absence of source segregation. India 5 RDF plants are also encountered operational problem due to lack of logistic planning not because of technology.

Recommendations

Waste to Energy process systems in India has strong potential to derive energy and significantly contribute to produce energy in sustainable manner. Segregation at source is the need of hours Proper segregation of waste at source is of utmost important for the success of this technology. People need to change their mind-set so that they should not treated waste as discarded materials.

¹⁰⁶http://cpcb.nic.in/upload/NewItems/NewItem_133_MSW-REPORT.pdf

¹⁰⁷<http://www.thehindubusinessline.com/economy/policy/waste-to-energy-kasturirangan-panel-pitches-for-tax-sops-40-viability-gap-funding-for-ppp-projects/article6008584.ece>

5.7.3. Highly untapped potential

The India current Municipal solid Waste potential is approximately 1682MW. India is able to achieve 5% of total capacity so far¹⁰⁸. Most of the states of India has potential to derive energy from waste. However, only eight states (Figure 5.7) government step forward to recover energy from waste. However the scenario to achieve potential in these states is very poor as achieved potential is in the range from 1-17%.

Figure 5.6: Total potential vs. grid connecting potential

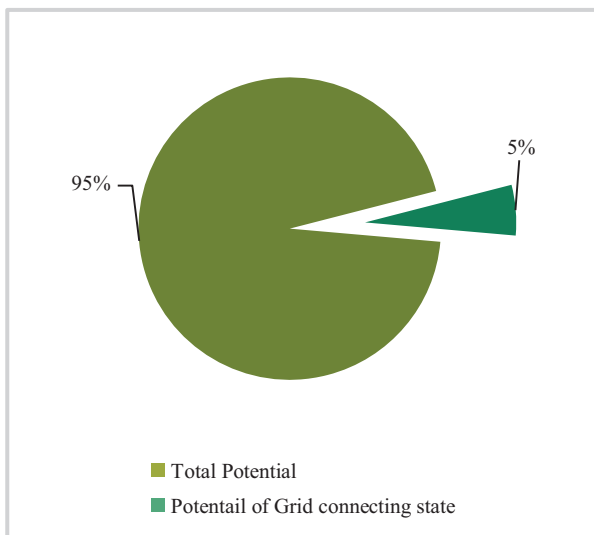
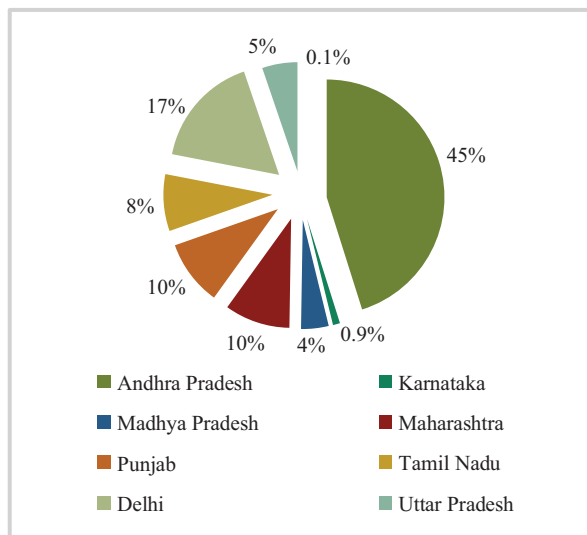
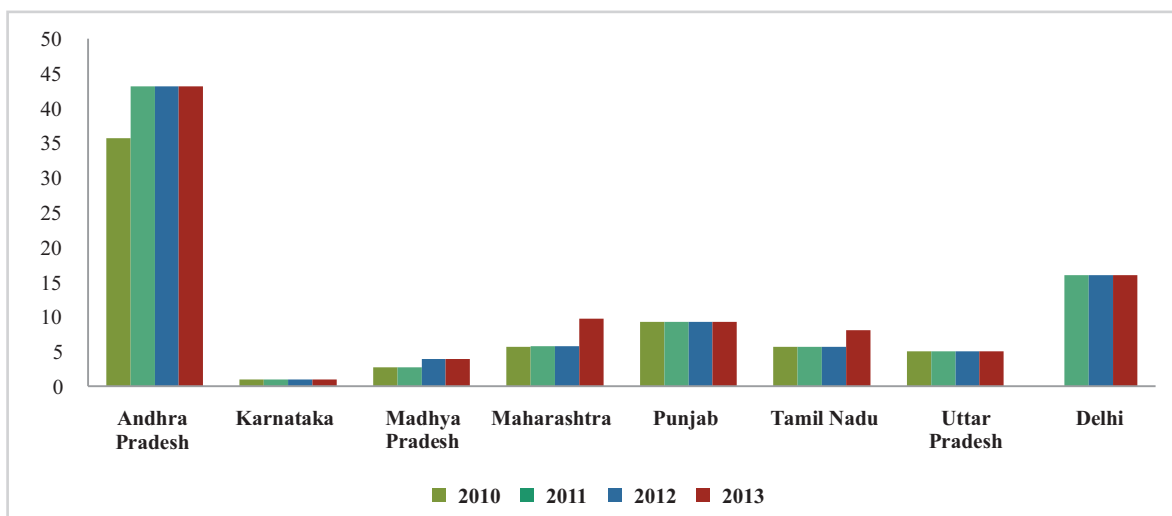


Figure 5.7: States wise Achieved Potential



(Sources: http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2014_28mar.pdf)

Figure 5.8: Waste to energy year wise and state wise grid installation in (MW)¹⁰⁹



(Source: http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2014_28mar.pdf)

¹⁰⁸http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2013.pdf

¹⁰⁹http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2012_28mar.pdf

Recommendations

Government should take initiatives to make waste to energy concept prime importance in country. Existing environmental legislation mainly focuses on disposal of waste on landfills and on conventional waste treatment techniques, hereby acting as barrier o the introduction of innovative waste process techniques. Stringent rules should implemented for source segregation, main cause of failure of most of the waste processing plant in country

Table 5.6: Budget outlay and targets for year (2011-12) and (2013-14)

S. No.	Green technologies	Budget 2011-12 (in Crore)	Target (MW)	Budget 2013-14 (in crore)	Target (MW)
1	Wind	33	2400	230	2500
2	Small Hydro	135	350	135	300
3	Solar	55	300	150	1100
4	Biomass	39	460	60	400
5	Waste To Energy	22	25	25	30
	Total	289	3535	600	4330

(Source: <http://mnre.gov.in/file-manager/UserFiles/outcome-budget-mnre-2013-14.pdf>)

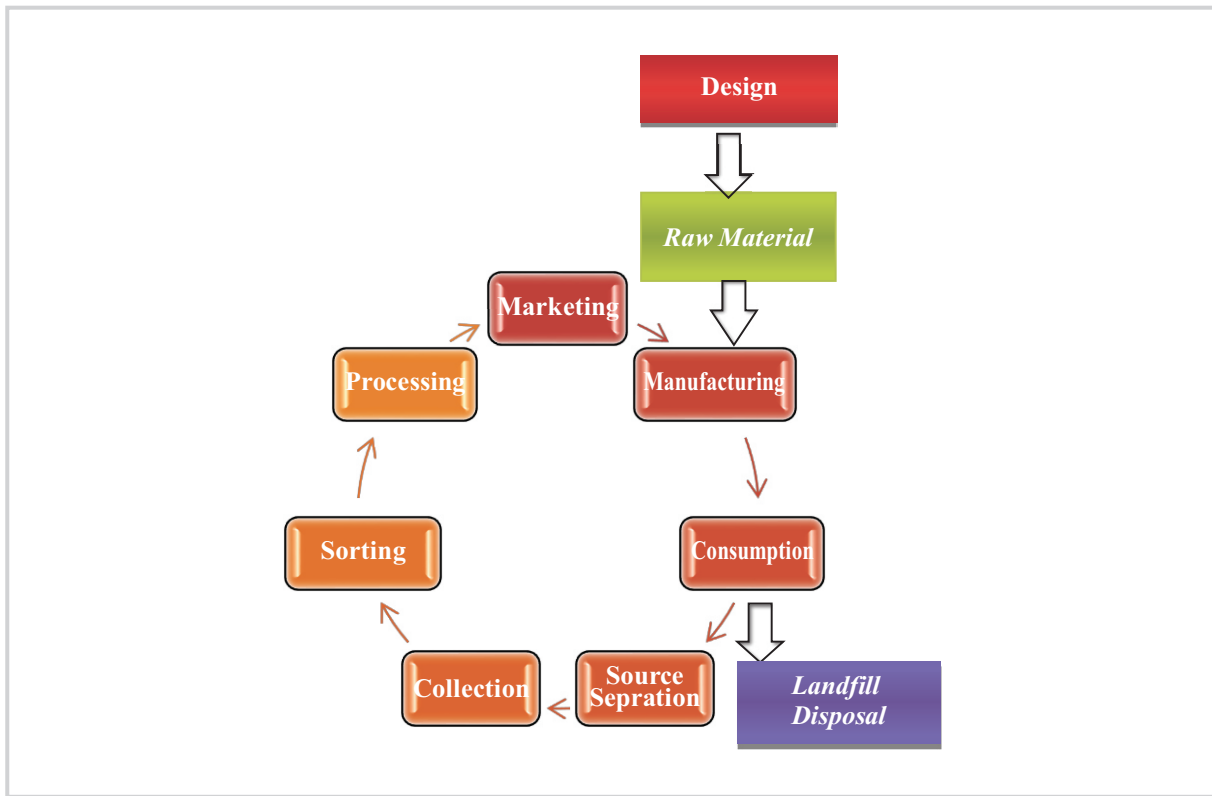
5.7.4. Lacking of sustainable waste management practices

In India, Most common practices to deal with waste is landfilling, Effective practices for safe management is yet to be enforced in India. The technical issues pertaining to the waste treatment and disposal needs to be strengthened and the technology input requirements have to be worked out to achieve sustainable development¹¹⁰.

Recommendations

Public participation is paramount for success of waste to energy concept in India. Stringent rule like 'Polluters pay Principle' can force people to follow the sustainability practices and PPP (Public Participation Programme) is another approach to manage their waste themselves. We can also learned lesson from other countries who adopt the zero waste concepts.

¹¹⁰ www.infolib.hua.edu.vn

Figure 5.9: Zero Waste Flow diagram

(Source: www.infolib.hua.edu.vn)

5.7.5. Lack of Skilled Human Resources

Several innovative technologies are required to produce energy from waste. All these technologies need pre-treatment of MSW before use it as input. It can be done adequately by skilled work force from beginning (collection, sorting and segregation) to the end of value chain (handling of machines to produce) of waste to energy technologies as each technology is sensitive towards the composition of MSW as well as environmental factors.

Recommendations

There is urgent need for adequately qualified human resources to operate and monitor such facilities. Special training programmes should be organized as a part of continuous professional development of employees. Specialized course related to waste to energy stream need to include in education stream.

Zero Waste Management

Zero waste is a visionary waste management system, to achieve a true sense of sustainable waste management practice; this concept was first used in 1973 for recovering resources from chemical although at that time the idea is not fully developed because the industries were not booming at that time. however in 1990 a number of countries targeted the zero waste concept and tried to zero waste disposal in land or for incinerations the first law was imposed by the Australia it passed a no waste 2010 bill in (1995), the success story for zero waste is continue, In 1997 the zero waste New Zealand trust was established supporting the waste minimisation (one where products are made to be reused, repaired and recycled,) in 1995 California Resource Recovery Association (CRRRA) organized a conference to promote this zero waste concept in worldwide, in year 2007 the zero waste International Alliance gave the first working definition of zero waste in 2004, which is developed later in year 2009 by reviewed panel of the zero waste International Alliance

“A goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. ZW means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them”

The Zero waste concept is yet in development stage, the zero phase is stretched into three phases and developing each phase individually.

1) First Phase (Waste prevention)

This phase mainly emphasize to use methods and techniques which is adopting green engineering principles to promote industrial symbiosis and up-cycling processes and utilize the existing resources instead of using virgin material . It is also advisable to manufacture easily degradable and recycled materials.

2) Second Phase Citizen Responsibility

Citizen determination to minimize waste is really paramount. Every individual responsibility in resource consumption and its utilization avoid using those resources which is not easily degradable, or not recyclable try to utilize the resources smartly so to generate less waste, this practice has to be done at global level so to self-monitor the waste and keep the surroundings neat and clean.

3) Third Phase (Down cycling)

In this phase, Waste should be collected and sorted at first colony level so that non-biodegradable waste can be diverted directly to processes plant to produce energy or convert this waste to degradable which can further be buried to landfilling sites if it became degradable.

6. BIOMASS

Biomass is one of the most promising green technologies which can be used to produce energy in sustainable manner. Traditionally, the main functions of agricultural land are to provide food and feed to sustain the human life and living welfare in essence. From the point of view of renewable resources, the land soil can be considered as an effective organic converter for transforming the solar energy into environmentally green and clean bioenergy by photosynthesis. Some of the other strong reasons for its use are its flexibility of operation and installation, easy and efficient scalability and low and stable price because of being often a waste product. Moreover, biomass can be converted to several forms of energy.

Agricultural residues are one of the core distinct sources of biomass energy. India has huge amount of agriculture land area, so massive residues are produced here. This residue has huge potential to derive energy. All the organic materials produced as the by-product from processing of harvesting of agricultural crop are termed as agricultural residue. These agricultural residues can further be categorized as primary and secondary residue. Residue which is obtained in the field at the time of yield are field based or primary residue, whereas those are assembled during processing are defined as processing based or secondary residue. Rice straw, sugar cane tops etc. are primary residue whereas rice husk and bagasse are example of secondary residue. Primary residues primarily used for animal feeding while surplus used for energy production whereas, whole secondary residue is generally processed to produce energy.

6.1. Biomass energy conversion technologies

In India, various feed stocks are available for conversion to the bio-fuels as well as for power generation applications by using two main processes: thermo-chemical and bio-chemical/biological. Mechanical extraction (with esterification) is the third technology for producing energy from biomass, e.g. rapeseed methyl ester (RME) bio-diesel. The thermal conversion processes consist of pyrolysis, biomass gasification, combustion and liquefaction

6.1.1. Thermo-chemical conversion

Three main processes are used for the thermo-chemical conversion of biomass i.e. combustion, gasification and pyrolysis.

6.1.1.1. Combustion

Combustion takes place in the presence of air and burning of biomass results in conversion of chemical energy into heat energy, mechanical energy with different devices like, steam turbines, furnace, etc. It showed 20-40% conversion efficiency.

6.1.1.2. Gasification

Gasification is the conversion of biomass into a combustible gas mixture by the partial oxidation of biomass at high temperatures. The low calorific value (CV) synthetic Gas is produced which can directly be used as a fuel for gas engines and gas turbines or can be used as a feedstock (syngas) for the production of chemicals like methanol, can be considered as fuels for transportation and others.

6.1.1.3. Pyrolysis

Pyrolysis converts the biomass to three fractions: liquid (bio-oil or bio crude), solid and gaseous fractions, by heating in the absence of air to. Pyrolysis can be used to produce bio-oil if flash pyrolysis is used, enabling the conversion of biomass to bio-crude with an efficiency of up to 80%. The bio-oil can be used in engines and turbines and its use as a feedstock for refineries is also being considered.

6.1.2. Bio-chemical conversion

Two main processes are used, fermentation and an-aerobic digestion, together with a lesser-used process based on mechanical extraction/chemical conversion.

6.1.2.1. Fermentation

Fermentation is used commercially on a large scale in various countries to produce ethanol from sugar crops (e.g. sugar cane, sugar beet) and starch crops (e.g. maize, wheat). Purification of ethanol by distillation is an energy-concentrated step, solid residue obtained from this process used to feed animals and bagasse which is obtained from sugar cane can be used for next gasification or as a fuel for boilers. The conversion of lignocellulosic biomass (such as wood and grasses) is more complex, due to the presence of longer-chain polysaccharide molecules and requires acid or enzymatic hydrolysis before the resulting sugars can be fermented to ethanol. Such hydrolysis techniques are not commercialized and at the pre-pilot stage.

6.1.2.2. Anaerobic digestion

Organic material is directly converted to a gas which is termed as biogas. It is a mixture of mainly methane and carbon dioxide with small quantities of other gases such as hydrogen sulphide. The biomass is converted in anaerobic environment by bacteria, which produces a gas with energy of about 20–40% of the lower heating value of the feedstock AD is a commercially proven technology and is widely used for treating high moisture content organic wastes, i.e. 80-90% moisture. Biogas can be used directly in spark ignition gas engine and gas turbines and can be upgraded to higher quality i.e. natural gas quality, by the removal of CO₂.

6.1.3. Mechanical extraction

Extraction is a mechanical conversion process in which oil is produced from the seeds of various biomass crops such as groundnuts, cotton, etc. The process produces not only oil but also a residual solid or 'cake', which is suitable for animal fodder. Three tons of rapeseed is required per ton of rape-seed oil produced. Rapeseed oil can be processed further by re- reacting it with alcohol using esterification process.

6.2. Biomass Energy Status in India

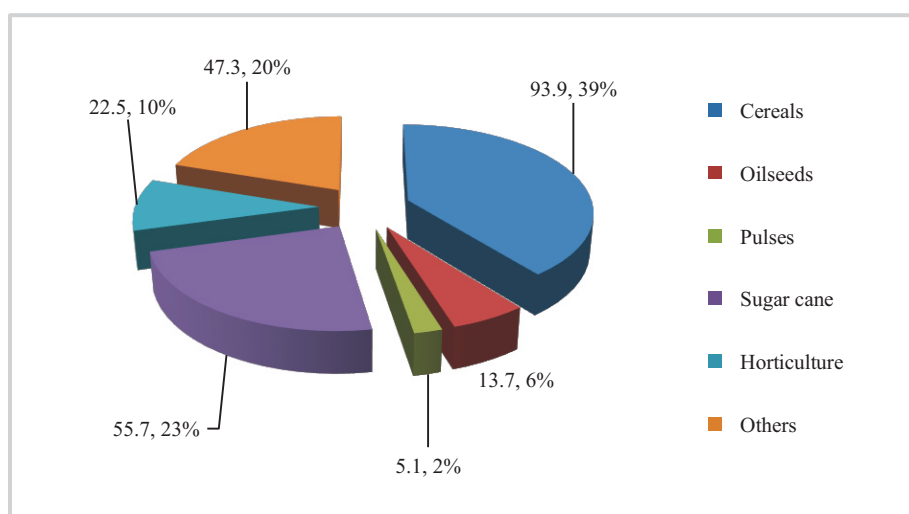
Biomass contributes over a third of primary energy in India. Biomass fuels are predominantly used in rural households for cooking and water heating, as well as by traditional and artisan industries. Total renewable energy based power generation was achieved 94,125 MW up to 31st March 2013. Out of which wind power contribute 52.20%, small hydro power 20.98%, biomass power 18.63%, cogeneration bagasse 5.31% India has a huge biomass potential ,study sponsored by the ministry has estimated the about 120 – 150 million¹¹¹ with an estimated potential about 18,000Mw apart from this additional 5,000 Mw of additional power can be generated through bagasse based cogeneration India is an Agricultural land its economy mainly depends on Agriculture, India is self-sufficient in Agriculture, most of the land in India used for agricultural purposes due to its vast agricultural resources and diversities in crop ,India has huge agricultural residues ,this agricultural residues can be used as a bio waste to produces electricity or bio fuel with further processing of these raw materials , Bio waste in India generally comes from Agricultural and animal waste in India we have abundant surplus(the waste which is left after feeding i.e. un kept waste) potential of agricultural waste (234.5) metric tonnes, which is further classified into 6 different categories,

¹¹¹<http://www.mnre.gov.in/schemes/grid-connected/biomass-powercogen/>

- Cereals: rice, wheat, maize, bajra, barely, small millet, jowar and ragi
- Oilseeds mustards and rape seed, sesame, linseed, Niger, soybean, safflower, sunflower and ground nut
- Pulses: all types of grams viz. Black gram, red Gram, Pigeon peas and lentil
- Sugar cane
- Horticulture
- Others (cotton and jute)

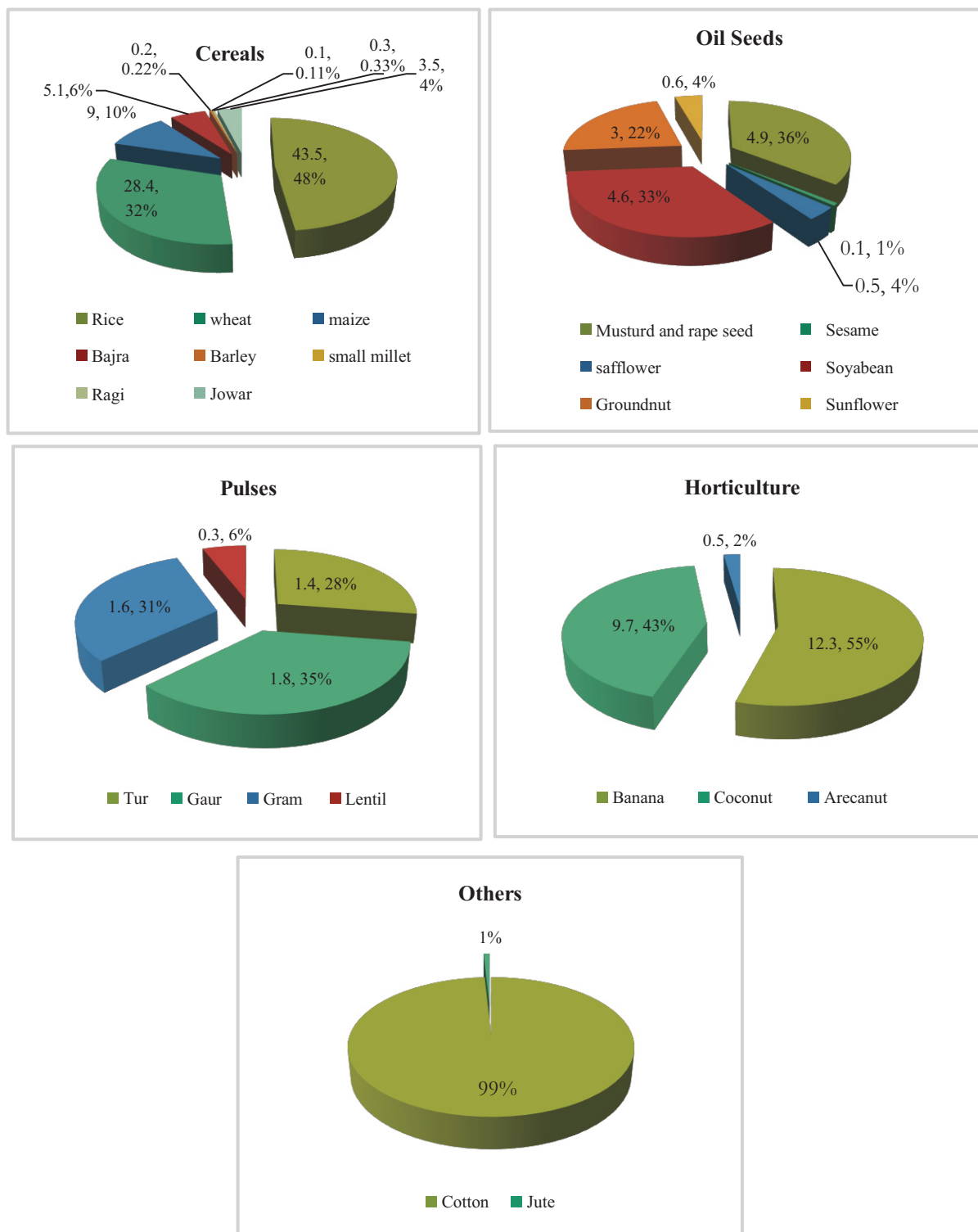
The Fig (6.1) below shows the contribution (metric tonnes) of various crop residues and their percentage in the contribution to produce energy. Cereals and sugarcane are the major contributor followed by other which includes cotton and jute. Pulses, oilseed and horticulture contributes less than 20 per cent The Above Fig (6.1) is further sub classified into different sub categories to give the clear vision of the agricultural waste scenario in India and their percentage contribution.

Figure 6.1: Contribution of different agricultural residue categories in energy production



(Source: .Moonmoon, D.dhiman, 2014)¹¹²

¹¹²Moonmoon, D.dhiman (2014).Bioenergy Potentail from Crop residue Biomass in India. *Renewable and sustainable Energy Reviews*,32,504-512

Figure 6.2: Different Agricultural categories and their contribution

(Source: Moonmoon, D.dhiman, 2014)

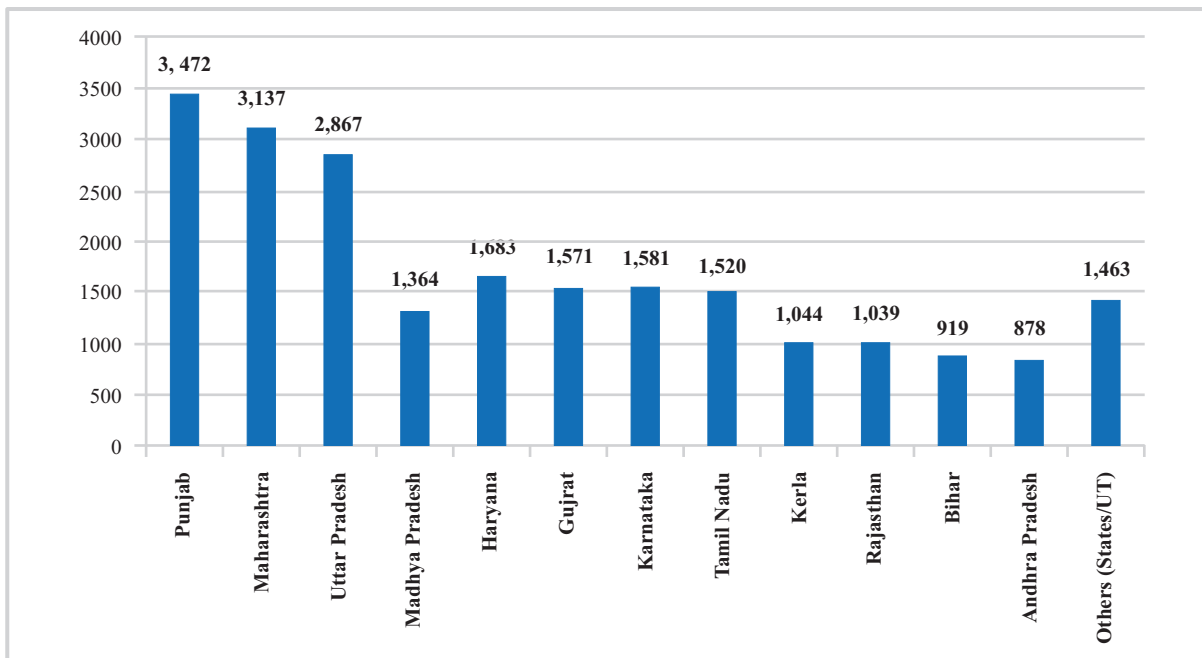
6.2.1. State-Wise bioenergy Estimated Potential

The Table 6.1 shows the State wise estimated potential of bio energy in India. Punjab is leading states with its biomass power generating capacity is (3,172) MW i.e. 18% of the total capacity and its cogeneration bagasse power generating capacity is up to (300) MW i.e. 6% of the total Cogeneration bagasse capacity. Rest of the states/UTs combined to form the other (states/UTs) as there potential is very small hence they club together. All these states contribute to 1463MW i.e. (8.3%) of the total Biomass. From the Figure 6.3 its clear that Punjab has a huge surplus bio mass potential (3472) MW, followed by Maharashtra (3137) MW and Uttar pradesh (2867) MW, while Haryana, Gujarat, Karnataka and Tamil nadu has almost same potential. Main reason of these variation is climatic varations and land fertility, As punjab has very fertile land the climatic condition is very favourable for cultivation hence its has huge biomass potential while the Maharashtra and Uttar Pradesh has huge (Cogeneration-bagasse) Potential. Both of them can produced (50%) of the total (Cogeneration-bagasse) potential. with this huge Cogeneration-bagasse potential ,they acquired the second and third place after Punjab, rest of the states have very similar structure with slight varaitions in their potentials.

Table 6.1: State-Wise Bioenergy Estimated Potential

S. No.	States	Biomass Power (MW) (A)	Percentage	Cogeneration -bagasse (MW) (B)	Percentage	Total Bio-waste potential (A+B)
1	Punjab	3,172	18%	300	6%	3,472
2	Maharashtra	1887	10%	1250	25%	3,137
3	Uttar Pradesh	1617	9%	1250	25%	2,867
4	Madhya Pradesh	1364	7.7%	0	0	1,364
5	Haryana	1333	7.6%	350	7%	1,683
6	Gujarat	1221	6.9%	350	7%	1,571
7	Karnataka	1131	6.4%	450	9%	1,581
8	Tamil Nadu	1070	6.1%	450	9%	1,520
9	Kerala	1044	5.95%	0	0	1,044
10	Rajasthan	1039	5.92%	0	0	1,039
11	Bihar	619	3.5%	300	6%	919
12	Andhra Pradesh	578	3.2%	300	6%	878
13	Others (States/UT)	1463	8.3%	0	0	1,463

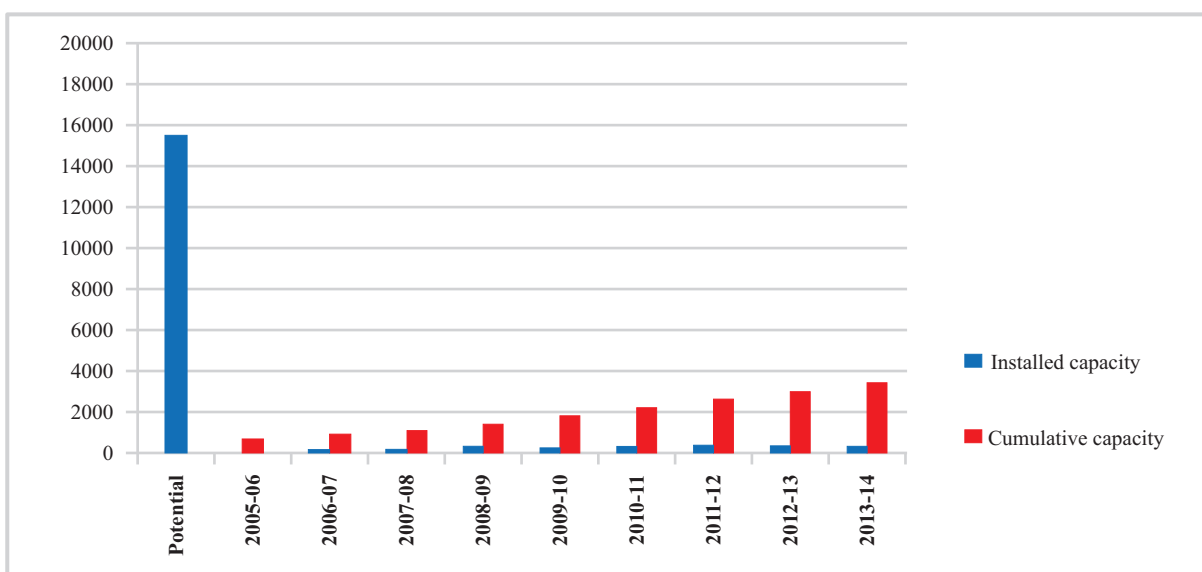
(Source: mospi.nic.in/mospi_new/upload/Energy_stats_2014.pdf)

Figure 6.3: State wise total Bio Energy Potential (MW) in India

(Source: http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2014_28mar.pdf)

6.2.2. State wise achievement in capacity addition year wise and total capacity achieved

In India till date approximately 2663MW grid connected energy has been produced from biomass which is approximately 10% of estimated biomass potential. Still 90% potential is untapped. Year wise there is small amount of addition is observed since 2005-2006 to 2013-2014.

Figure 6.4: Biomass Power Generating capacity in India

(Source: MNRE)¹¹³

¹¹³http://mnre.gov.in/file-manager/UserFiles/strategic_plan_mnre_2011_17.pdf
<http://www.mnre.gov.in/schemes/grid-connected/biomass-powercogen>

Statewise up to 2013, Uttar Pradesh has achieved the highest capacity addition followed by Tamilnadu and Maharastra. In gujarat and Maharastra energy from biomass is in very nacent stage.

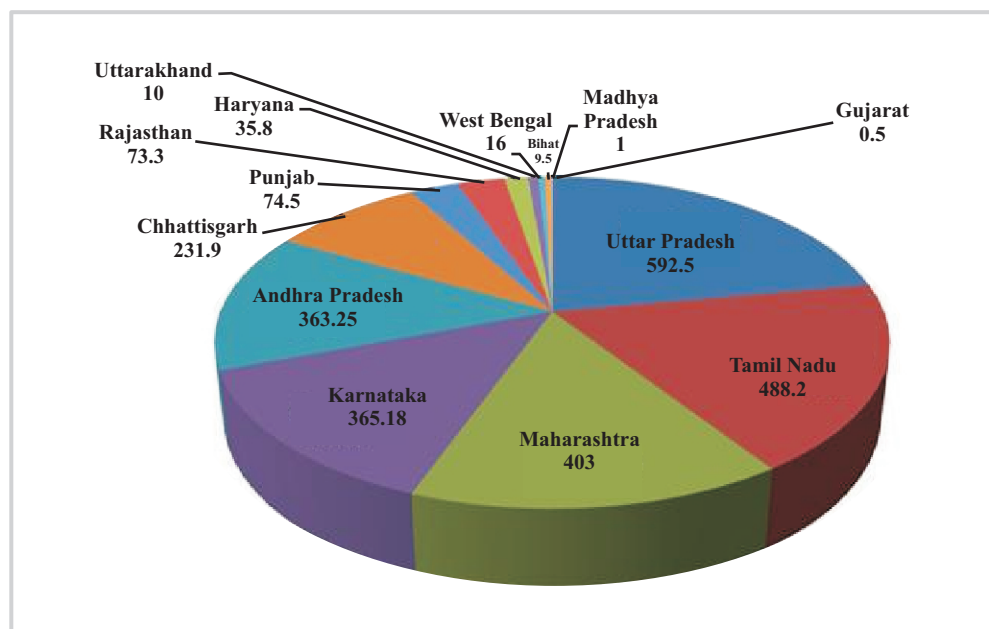
Table 6.2: State-wise biomass power Generating capacity addition and total achievement¹¹⁴

State	Up to 31.3.2013	2003- 2004	2004- 2005	2005- 2006	2006- 2007	2007- 2008	2008- 2009	2009- 2010	2010- 2011	Total (MW)
Uttar Pradesh	46.5	12.5	14	48.5	--	79	172	194.5	25.5	592.5
Tamil Nadu	106	44.5	22.5	--	42.5	75	43.2	62	92.5	488.2
Maharashtra	24.5	--	11.5	--	40	38	71.5	33	184.5	403
Karnataka	109.38	26	16.6	72.5	29.8	8	31.9	42	29	365.18
Andhra Pradesh	160.05	37.7	69.5	12	22	33	9	20	--	363.25
Chhattisgarh	11	--	--	16.5	85.8	33	9.8	43.8	32	231.9
Punjab	22	--	--	6	--	--	--	34.5	12	74.5
Rajasthan	--	7.8	--	7.5	8	--	8	--	42	73.3
Haryana	4	--	2	--	--	--	--	1.8	28	35.8
West Bengal	--	--	--	--	--	--	--	16	--	16
Uttarakhand	--	--	--	--	--	--	--	--	10	10
Bihar	--	--	--	--	--	--	--	--	9.5	9.5
Madhya Pradesh	--	1	--	--	--	--	--	--	--	1
Gujarat	0.5	--	--	--	--	--	--	--	--	0.5
Total	483.93	129.5	136.1	163	228.1	266	345.4	447.6	465	2664.63

(Source: <http://mnre.gov.in/schemes/grid-connected/biomass-powercogen/>)

¹¹⁴<http://mnre.gov.in/schemes/grid-connected/biomass-powercogen/>

Figure 6.5: State wise commissioned Biomass Power/cogeneration projects¹¹⁵



(Source: <http://mnre.gov.in/schemes/grid-connected/biomass-powercogen>)

6.3. Policies Environment to promote Biomass Power Generation

6.3.1. National Biogas and Manure Management Program (NBMMP)

The program was launched in 1981 to promote the Biomass, it is started at very small level to promote the rural family for cooking, and water heating purposes at that time it's very costly at individual family level so the government has stepped forward to promote the program by providing capital subsidy, incentives (five year for saving conventional resources)

6.3.2. National Biomass Cook stoves Initiative (NBCI)

The program was launched in (2009) to step up in providing the clean and efficient energy to rural and energy deficient areas across the country by accelerating the deployment of improved cook stove. In this scheme the pilot project was also started named as "A new initiative for improved cook stove" it's a collaborative approach among SNA, university/research institute, and non-governmental organization

6.3.3. National Biomass Resource Assessment Program (NBRAP)

This program is joint venture of both the central and states government to promote the biomass and to acquire its potential.

Incentives Schemes

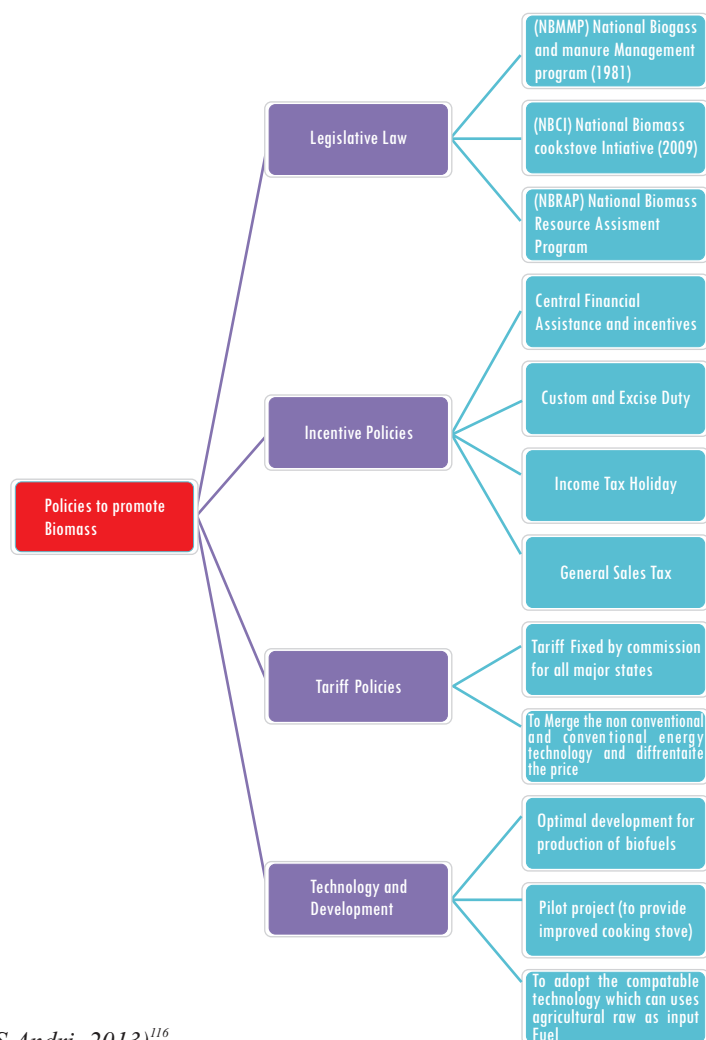
Government is providing following incentives to promote energy generation by biomass

¹¹⁵<http://mnre.gov.in/schemes/grid-connected/biomass-powercogen/>

Table 6.3: Incentives to promote Biomass

S. NO.	Policies	Description
1	Custom and Excise Duty	Concessional customs and excise duty exemption for machinery and components for initial setting up of Biomass power projects.
2	Income Tax Holiday	10 Year tax holiday
3	General Sales Tax	Exemption is available in certain States

(Source: <http://mnre.gov.in/schemes/grid-connected/biomass-powercogen/>)

Figure 6.6: policies and outlay to promote Biomass in India

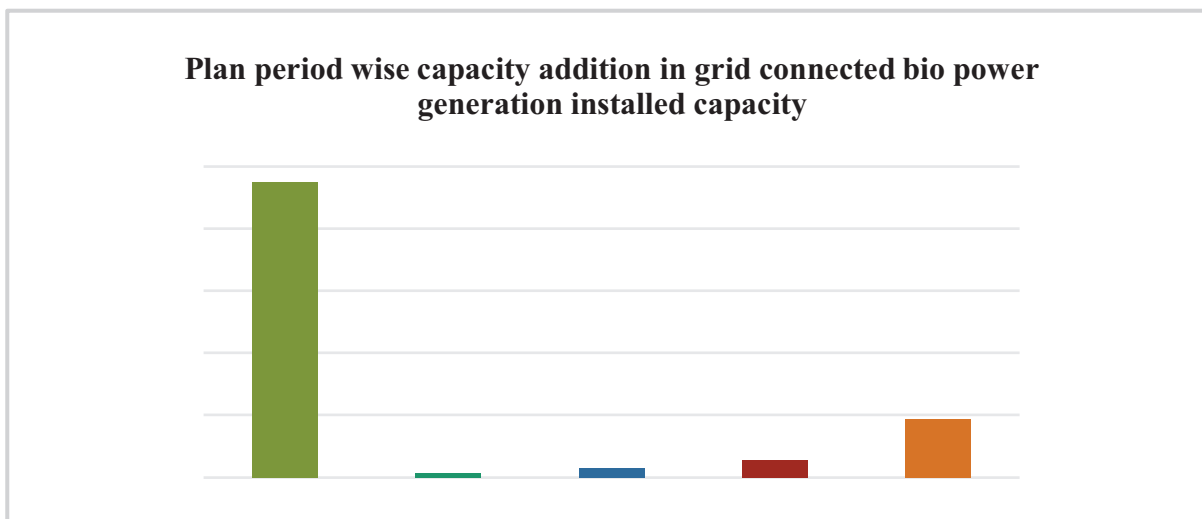
(Source: S.Rajbeer, D.S.Andri, 2013)¹¹⁶

¹¹⁶S.Rajbeer, D.S.Andri(2013). Biomass energy policies and strategies: Harvesting potential in India and Indonesia. *Renewable and Sustainable Energy Reviews*, 22,332-345

6.4. Challenges and Recommendations

6.4.1. *Lagging behind to achieve the desire target*

Figure 6.7: Plan period wise addition capacity in grid connected biomass power



(Source: <http://www.mnre.gov.in/information/policies-2/>)

The Indian biomass potential is 23,700 MW which comes from biomass (agricultural waste + bagasse cogen). From the above graph, we conclude that during the ninth year plan, we can only connect 1.6% of the biomass potential to the grid. During the 10th year plan, this percentage reached 3.3%, but still low. During the 11th year plan, this percentage reached 6.02%, and the target for the 12th year plan (2011-17) is to gain up to 20% of the potential. This rate has to increase if India has to become self-sufficient and self-dependent in energy.

Recommendations

India needs to implement policy which can help speed up the capacity addition from bioenergy by providing long-term financial assurance to biomass utilities as well as biomass producers. Government should also need to create a risk fund so that producers should not suffer due to natural disasters. This kind of policy will encourage local communities to plant energy crops, hence will increase biomass production which further increases bioenergy.

6.4.2. **Absence of Clear Policy to promote Biomass Commercialization**

India has a strong potential to produce bioenergy. It is estimated that approximately 231 Mt of surplus biomass is available to produce energy which has potential to produce 231 TWh electricity. Still, India is lacking a large-scale attempt to increase biomass production using high-yielding energy plantations due to technical barriers like low productivity, lack of financial support and poorly developed and unassured markets as well as socio-economic problems like land tenure problems, restriction on harvest, transportation and marketing of wood. Despite the considerable potential for generating bioelectricity, currently there are no large-scale attempts to grow energy plantations and generate electricity using biomass. It is necessary to consider the barriers to the spread of bioelectricity generation as well as biomass production for energy. These are land tenure barriers, restrictions on harvesting and transportation, the long gestation period, technical barriers such as low productivity, financial barriers, and poorly developed markets. Bioelectricity generation requires a long-term, sustained wood supply for

electricity utility from biomass producers. Land tenurial uncertainties prevent communities and farmers from committing land for sustainably producing biomass for energy.

Recommendations

Government should take initiatives and should mandatory changes in policy to produce energy from surplus biomass. It would create a demand for a large quantity of woody biomass as feedstock for electricity generation and will help to develop the market for wood from plantations. Besides that Research and development activity should emphasize to produce high yield energy crop and also encourage intensive plantations. Policies which can promote a long term contractual arrangement between bioenergy utilities and biomass producers will helpful to create a positive environment to produce energy from biomass.

6.4.3. Coupling of energy Policy and agricultural Policies issues

In India to produce energy from biomass .It is only emphasize in renewable energy policy separately. It is not linked with agricultural policies or environmental policies.

Recommendations

India need s coupling of energy and agricultural policies on promoting the productions of bioenergy from energy crops. To create a harmonious balance among agricultural production energy security and environmental protections. Ministry of Agricultural should take a step to encourage the plantation of local energy crops for energy production.

7. DISCUSSIONS AND CONCLUSIONS

India is a nation which is considered an “emerging economy”. India has remarkable energy needs and struggling in meeting those needs through conventional resources of power generation. India has 17% of world’s population but only 4% of primary energy consumption. Still it is struggling to fulfil this demand by traditional way of energy production. Expansion of electrical capacity using green technologies is need of hours. Yet, India is privileged with tremendous renewable energy in solar, wind, biomass and small hydro. This renewable or green technology helps in meeting the present energy requirement without compromising future energy needs. In fact, the technical potential of these renewable exceeds the present installed generation capacity. Unique in the world, India has the only ministry that is dedicated to the development of renewable energies: the Ministry of new and Renewable Energy. These bodies well for the acceleration of renewable development throughout the nation-both to meet the underserved needs of millions of rural residents and the growing demand of an energy hungry economy. The development and deployment of renewable energy, products, and services in India is driven by the need too.

Expanding electrical capacity is essential. Renewable energy remains a small fraction of installed capacity, yet India is blessed with over 150,000MW of exploitable renewable the overall potential is more than the current total energy consumption. It makes sense that all efforts and investment should consider accelerating these sustainable energy resources before committing to the same fossil fuel path as western nations. The fossil fuel strategy will surely bring price volatility from dwindling supplies and added pollution from carbon combustion. Tapping India’s Wind, solar, biomass, and hydro could bring high quality jobs from a domestic resource. Extending the electric grid between all states, and ultimately between neighbor nations will expand international trade and co-operation on the subcontinent. This report is meant only as an overview in hopes that it will encourage even more rapid and extensive development of the renewable energy resources on the Indian subcontinent.

India is generously endowed with renewable energy sources widely distributed across the country and the overall potential is more than the current total energy consumption [. In the context of the global warming and climate change problem, there is an urgent need for India to plan and expedite implementation of strategies for augmenting the renewable energy share in the energy mix for economic and environmental reasons; and India needs to shift to non-polluting renewable sources of energy to meet future demand for electricity justifying investment in this sector of renewable energy as the most attractive because it may provide long-term economic growth for India. Despite technological developments and economic viability for several applications, renewable energy has been used to a small fraction of its potential due to the existence of several types of barriers to adoption of renewable or green energy technologies varying across countries. Therefore, it calls for the need to identify major barriers to the adoption of renewable or sustainable energy technologies in the Indian context.