Chapter 1

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1.1 General Introduction

Rapid urbanization of India has led to several challenges like rising consumption and demand for energy, increased pollution, increasing levels of greenhouse gas emissions, and constraints on natural resources. It is high time that our country finds a better way to make energy sustainable and simultaneously does not hamper the future social and economic development goals. As per estimation, the coming two decades will result in an increase of around two-thirds of the present day global energy consumption. India, witnessing a very fast development along with a mushrooming population, has experienced both economic boom and huge energy shortage in the recent thirty years [1 - 4]. The need for a greater energy demand and simultaneously minimizing the environmental impact has led to the consequence of increasing the role of new and renewable energy sources in the past decade. The Renewable Energy Sources (RES) are cleaner, safer, easier to maintain and are a sustainable method of generating power, as compared to the non-renewable sources of energy.

The rural India constitutes 68.84% of the total population of India. The rest 31.16% consists of urban and migration population of the country; where 24% people live in urban India whereas the rest of the population keeps migrating as per their needs, according to the data of Census of India – 2011. With a low percentage of people residing in the urban areas, still at present, India faces a serious crisis of urban growth. A great pressure is automatically being created upon the public utilities like housing, sanitation, transport, water, electricity, health, education and so on, owing to the present day rapid growth in urbanization. The prime focus lies
on watershed development, agricultural waste management and optimization of agro resources, access to basic amenities and public health and energy consumption.

1.2 Watershed development

From ancient times, the settlement sites for people have always been chosen keeping in view the availability of water to the inhabitants of the settlement. Hence, water has always been a priority and is one of the very essential elements of nature, which is required to sustain life. Nevertheless, the mushrooming population and increasing infrastructure led to insufficient supply of water as compared to its demand. As a consequence of this, at the present day, none of the state of our country has adequate amount of water to meet the needs of its own dwellers. Striking examples are those cities which provide water for less than half an hour every alternate day from the municipal sources, and the situation for these cities worsens during the dry summer seasons. Hence, in order to provide water to towns with population of less than 20,000, a scheme called Accelerated Urban Water Supply Programme (AUWSP) was launched.

As evident from the discussion above, there is a remarkable increase in the water demand among the urban population. For this reason, the Central Public Health and Environmental Engineering Organisation (CPHEEO) has fixed a certain amount of water supply for a particular range of population for example, supply of 125-200 litres of water per head per day for the cities having a population of greater than 50,000, water supply of 100-125 litres for population between 10,000 and 50,000 and a water supply of 70-100 litres for towns with a population below 10,000. Moreover, the Zakaria Committee decided the water supply of 272 litres per head per day for cities with population more than 2 million and 204 liters for cities with population between 5 lakh and 2 million. This water supply was intended to be used for all purposes like drinking, bathing, kitchen, floor cleaning, washing cloth, and vehicle washing and also for
gardening. Unfortunately, this recommended amount of water is also not received by most of the people. There is a remarkable gap in the demand and supply of water in the four metro cities of our country and accounts for nearly 10 to 20 percent shortage. This gap worsens in smaller cities and towns. Many Indian cities are tapping external water supply sources in order to meet their respective growing water demand. Neighboring areas of Western Ghats which are around 120 kms away from Mumbai are the water source for this city. In order to meet the growing water demand, the water express trains are used in Chennai. Cauvery River is at a distance of 100 kms from Bangalore and is a potential source of water for the plateau dwellers, where lifting pumps have to lift the water for about 700 meters prior to being used by the users of Bangalore. Nagarjuna Sagar is located around 135 kms away from Hyderabad and is a reliable source of water supply for the people of Hyderabad. Delhi meets its water requirements from Tajiwala (in Haryana), Ramganga (as far as 180 kms away), and in near future Delhi shall draw its water from Renuka, Tehri and Kishau barrages [2, 3].

1.3 Agricultural waste management and optimization of agro resources

Inefficient and insufficient sewage facilities are found to be plaguing behind the urban areas of India. Hence, not single city is found to be totally sewered in India. As par the latest estimates, only around one-thirds of the urban dwellers have the option of sewage system. Maximum numbers of cities are witnessed to be having very old sewerage lines which are not taken care of properly. In majority of these cases, either the sewerage lines have broke down or they are seen overflowing. Also, the sewerage waste are not properly treated and are often drained into a nearly river (that in Delhi) or in sea (as that in Mumbai, Chennai and Kolkata), thereby polluting the major water bodies. Another loophole found in the water supply of most of the Indian cities is that – the water pipes usually run in proximity to the sewer lines. Owing to
this, if there is any leakage in the pipes then it will directly lead to contaminating the unused water and finally results in the spread of many water borne diseases [8, 9].

1.4 Access to basic amenities and public health

All the Indian cities have grown in their number and size leading to creating another big concern for their urban areas - The trash disposal, which is creating alarming proportions. A serious health problem is posed by the large amount of garbage that is produced by the Indian cities. The cities having an improper arrangement for garbage disposal often witnesses full existing landfills. These particular landfills and the wastes putrefying in the open become a prime source of diseases and also result in innumerable poisons leaking into their own surroundings, which also leaks out from below and contaminates the ground water [1, 2]. People living near these rotting garbage and the raw sewage often fall easy victims to many diseases e.g. malaria, dysentery, jaundice, plague, typhoid, diarrhea etc.

There has been a rapid growth of economy in past decade, however, basic facilities like access to drinking water and sanitation continues to be a major challenge in our country. With the economic growth, a remarkable improvement in medical strategies has been witnessed still sufficient public health facilities under appropriate authorities are not available to the citizens. The rate of death in case of children under the age of 5 still remains to continue in India and this is primarily noticed in the rural areas. India spends nearly one percent of Gross Domestic Product (GDP) on healthcare (combined health expenditure by both Centre and state). This is equal to 25% of the total health expenditure of our country. This implies to the fact that private spending on healthcare is nearly 3% of GDP i.e. 75 percent of private expenditures on healthcare as per Planning Commission data, mentioned in Planning Commission 2013b. This leads to a situation where households have to bear the major share of private health expenditure. The
inadequate and poor quality of healthcare infrastructure in India is a result of the low public spending on healthcare over the decades. There are inadequate numbers of sub-centres, community health centres (CHCs) and the primary health centres (PHCs) as shown in Table 1.

Table 1.1: Healthcare infrastructure in India

<table>
<thead>
<tr>
<th>Year</th>
<th>Status</th>
<th>Healthcare facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sub centres</td>
</tr>
<tr>
<td>2005</td>
<td>Required</td>
<td>158,792</td>
</tr>
<tr>
<td></td>
<td>Shortfall</td>
<td>19,269</td>
</tr>
<tr>
<td>2014</td>
<td>Required</td>
<td>179,240</td>
</tr>
<tr>
<td></td>
<td>Shortfall</td>
<td>36,346</td>
</tr>
</tbody>
</table>

This wide shortfall has to be managed in the rural areas so as to provide better life to the villagers.

1.5 Energy consumption

Energy is the product of time and power and is converted from energy resources available in the form of conventional resources and renewable resources. The conventional resources are mainly composed of Carbon and Hydrogen. The number of Hydrogen combined with the number of Carbon indicates the energy density in the conventional fuel [12, 16, 21, 22, 26]. As an example, wood is the primitive energy resource which contains more than 10 Carbon with 1 Hydrogen. In coal, the number of Carbon reduced per Hydrogen. In gas, there are less Carbon and more Hydrogen e.g. CH₄. Similarly, in case of oil, density of Carbon is less than that of Hydrogen. Thus, it has been inferred that calorific value of the fuel is depending upon the concentration of Hydrogen as evident from the discussion above, where it comes that the calorific value of wood is less than that of coal and the calorific value of coal is less than that of
gases for the same amount of masses. Thus, Hydrogen is playing a major role in the energy content of conventional fuels [3, 4]. To have the energy security, there is a search for locally available resources those can be utilized to convert into fuels. In the developing world, especially in SAARC countries, most of the rural areas are depending upon the available resources e.g. biomass, animal wastes etc.

Conversion of conventional coal-based resources is generally done in furnaces whose efficiency is much lower i.e. around 8-12%. On the other hand, during the conversion process, the fuel emits lots of toxic gases and particulates those are inhaled by the operator of the oven. Normally, burning of biomass emits toxic gases like NO\textsubscript{x}, SO\textsubscript{x}, phenolic acid or tar. Inhaling of these toxic items cause health hazards and based on a study carried in a rural area, the women are the prime victims, who are affected by early cataract, lung problem, anemia and sometimes the case worsens and the village women give birth to disabled children. Thus the bad effect of energy resources and its successful utilization has not been properly explored. Hence, the focus should be to explore clean and safe energy resources to bring both health and energy benefits.

It has been discussed in the previous sections that energy is the central parameter in the context of development and it is developing a correlation between ecology, economy and empowerment. To integrate these, a study was conducted on the aspects of onsite generation where the resources are available on the site itself. The developing countries, particularly in the SAARC region, two resources are most accessible to the people, particularly to the people living in the rural areas. The resources are solar energy and bio-energy. But suitable technology is required to develop and to use these resources for meeting the demand. In this reference, study is conducted in the eastern India that the potential for these two resources for meeting the energy demand for bringing energy security of these places in developing countries of SAARC [5].
Agriculture is the backbone of economy in the rural India and agricultural waste is a form of biomass that is used today in inefficient ovens. This causes health problem, environmental as well as in the energy generation issues. However, the successful use of these resources can build up with the pillar on three items. In this respect, a technology has been developed and studied at depth to extract bio-oil resources for developing bio based technology. Details of this work will be available in subsequent chapters. The bio-oil can meet the demand by blending it with conventional oil to run agro-irrigation pump where only conventional diesel oil is used. Similarly, the solar power can also be utilized for meeting the energy demand in lighting. Integration of these two aspects is the major theme of the present thesis work. The studies are presented in the present work. The analysis of the entire work can be categorized with the following four salient features: Existence of rationalization of the problem, Justification for a proper solution, Originality and novelty of the solution, Methodology adopted for solving the problem.

1.6 Literature Review

It has been observed that for rapid urbanization, migration from rural to urban area increases because the opportunity of availability of job is higher in urban areas than in rural areas. Moreover, in the rural area of India, there is a lack in infrastructure. As a result, the opportunities in rural areas are less than that of the urban areas. Thus, the people of the rural areas are paying a lot of opportunity cost to achieve the amenities of the urban areas. Thus, access to energy is essential for all activities including cooking, illumination, comfort and other activities. In the rural areas, there is electricity but the people have a limited and meager affordability to get the power. Moreover, the availability of electricity is fluctuating and the area sometimes submerges in load shedding. Thus, although electricity has reached the rural areas,
still it is very unreliable. Therefore, the local industries have their own power generation systems. These power generation systems are run by consumption of diesel fuel where the price of the power from the diesel generator is a function of the market price of the diesel. As a result, it is difficult by the local industries to continue the use of diesel generating power. To overcome this, the rural industries take a major step for diesel conservation by using synthetic fuel gas. The synthetic fuel gas is a mixture of Carbon monoxide, Hydrogen and Methane. The fuel value of the gas is moderate in nature nearly 3100 Kcal/m$^3$ or 13 MJ/m$^3$. The synthetic fuel gas is prepared through a gasification technique and a thermo-chemical reaction by means of which the biomass goes through 4 stages of reaction – drying, pyrolysis, oxidation and reduction. The gasification was conducted in a metallic vessel and the syngas was produced. But the production of the syngas results in a lot of dirty particles like phenolic acid commonly known as tar, carbon particulates or soot, and other particulate matter (PM) whose dimension varies from 2.5micron to 10micron. Inhaling of these particles causes serious effect on health and hygienic system of human and also on the electricity generating system. But the major advantage of the pyrolytic compound is that some oil can also be extracted from that system. Thus, if the pyrolytic content can be extracted and processed, then the fuel grade oil can also be extracted. So, a detail study is essential on how to condense the pyrolytic extract and to analyse them to have quality oil, which can be used to blend in the conventional oil. To have this in the present thesis, a step has been developed to adopt a device by means of which biomass can be pyrolysed under thermal treatment and the extract can be collected to check its quality from various feedstock. The device is versatile in nature as for extraction of bio-oil and no mechanical pressure was given. So, this type of device can also be used to extract bio-oil from different feedstock e.g. jatropha, mustard seeds and other oil seeds. The detail of extraction is given in the chapters of the thesis and the
conducted study has been presented. The work of some of the authors on energy security and renewable hybrid standalone systems [15, 17, 18, 20, 24, 27, 30] have been discussed below.

According to the author B. Sinha [36], it is apparent from the foregoing deliberations that access to sufficient clean energy is essential to empower individuals for maintaining sustained economic growth. But there is a stark difference between the energy requirements of rural and urban areas. It is also evident that even after a handful of initiatives from the government side; there is still a gloomy scenario of energy sufficiency in the rural areas. To cover up the gaps of energy requirements of all the rural sectors like domestic consumption, agriculture, small scale industries (MSMEs) etc., and demand-driven S&T interventions are essential to provide sufficient and clean energy to the rural people. Nevertheless, all the initiatives should involve full community participation to ensure the success of the endeavors. To ensure energy security in rural areas, B. Sinha [36] suggested a decentralized strategy to be emphasized on the following: Technological empowerment of the rural communities and institutions to deal with maintenance, management and distribution functions, Location specific choice of technologies depending on the sources available e.g. micro-hydel, biomass gasifier, solar and a combination/mix of these, need to draw lessons from field experience. There is no system in place for this important function – the need for energy audit – and this is a main reason for slow progress in Renewable Energy, R&D must be an on-going activity for appropriate choice of technologies and should not be influenced by failures. For example, Gobar consigns mainly of bacteria and little energy. The case of failure of gobar Gas plants due to practical problems needs proper appreciation followed by consistent effort towards success of the project: Bio-fuels, bio-diesel must be a plank of rural energy security as GOI has allowed 100% use of bio-diesel to run state facilities like pump sets.
Growing economy of India, coupled with its ever increasing appetite for energy has become an increasing concern for many across the spectrum, both domestically as well as internationally. N. Chakravarty [56] adds that in its rise through what India calls as “enlightened self-interest”, the country needs to secure its energy needs for obvious and numerous reasons. India’s limited self-sufficiency in energy resources, coupled with an increasing reliance on fossil fuels (primarily coal and oil), pose serious questions for policy makers regarding the future availability of these sources, keeping in mind its depletion globally, and its steady and affordable supply - as India continues to depend on the areas which are socio-politically unstable. The dissertation examines existing scenarios and policies and tries to underscore and suggest possible solutions for India’s planning and policymaking which is integral towards securing its energy needs. The study conducted by S. Chakrabarty [72] reveals how India as a net importer of energy can find reliable and affordable solutions towards meeting its future energy concerns that would not only be economically sound, but would promote overall sustainable development.

According to Jiri Matusik [104], during the past century the intensity of energy security conceptualizing, and the significance of the energy security agenda, has resembled a ‘sinusoid curve’. It has had its ups (the intensity of conceptualizing and the agenda increased), especially after the 1973-1974 and 1979 oil crises, and downs (the significance dropped), during times of stable oil markets. However, the paper argues that the contemporary trend reflects a qualitatively different trajectory. The path seems to be approaching a peak of a ‘sinusoid curve’ and yet the drop is not likely to follow in the foreseeable future. Instead, it now appears to project the qualities of an ‘exponential curve’. In order to conceptualize and understand the meaning prescribed to energy security, the paper by Jiri Matusik [104] shifts the argument one stratum higher and examines the bigger picture – the security concept as such. The paper brings in the
family resemblance concept and argues that energy security is embedded in a greater whole and, hence, is a part of a broader security discourse. The paper then adds that the meaning of security has changed. This allows scope for the argument that energy security does not represent ‘survival’ as such; it goes beyond this category. It reflects the concern with socio-economic development which is a manifestation of the contemporary IR battlefield.

Moving one stratum lower, the paper examines the changing energy security concept. It argues that the theoretical or methodological approaches captured in recent works fail to address the complexity of the issue at hand. Energy security cannot be conceptualized in the light of consumer-supplier dichotomies anymore since there are ‘new’ variables to be considered. Energy security has to be conceptualized in tandem with environmental security, particularly concerning climate change. The paper states that the energy/environmental security nexus then substantially affects the consequences stemming from the implementation of the energy security concept.

Jamie P. Rubbi-Clarke [105] focuses on the highly important and crucial issue of the energy security within the European Union framework. The author very precisely identifies the main problematic points, which have emerged not only on the practical level (in relation energy consumers – producers), but also in the broader debate on energy security in the post 9/11 era. The author shows the ability to conduct independent analysis and the final conclusions have credible value. J. P. Rubbi-Clarke [105] evaluates energy security in the security complex with special attention to the common approach of all the EU member states. He stresses the various ways in which current energy demands and prospect supplies are managed. In that context, not only energy consumers and producers are taken into account, but transit countries are also involved into debate. The question of energy security is strongly connected to the security situation in oil and gas-rich countries and regions. The text presented also pays attention to the
geopolitical consequences of oil, gas reserves and the next development of production. It is clear that there is direct link between the amount of proven reserves and prospect production capacity.

The major objective of the study by G. Gautam [106] was to understand the effect of various parameters on the syngas composition from a stratified downdraft gasifier in a better way. The study was primarily experimental but supplemented by the mathematical modeling that explains various steps in terms of existing scientific principles.

The research paper by K. Song Lin [69] of International importance focuses on the gasification technique used by the authors in the year 1998, having the prime objective to develop a rice husk gasification process. They used the diffuse reflectance infrared spectra which revealed that the partial oxidation of rice husk at reaction temperatures below 1000 K would allow recover valuable of amorphous silica materials. In their laboratory-scale fixed-bed and bench-scale downdraft experimental approaches, the process of gasification of rice husk was accompanied by a substantial production of syngas at the temperatures of 760–900 K. Their calculation led to the need of approximately 28 kg per hour of rice husk in order to generate an electric power of 10 kW, whereas the gasification technique used by the field study of this dissertation shows the use of 250kg/hr of rice husk to be fed to a dual fuel generator of 250KVA rating. The process of author Kuen Song Lin [69] included the use of a rice husk feed system, a downdraft type gasifier, an ash discharge system, a tar adsorbent, and an internal combustion engine for power generation. The technical and economic viability of the rice husk gasification process concept were yet to be analysed.

The biomass is combusted in small scale facilities using steam cycle in order to produce power. The electrical efficiencies for such facilities are relatively low. By gasifying the solid biomass to syngas, it was used for running a gas turbine. This mechanism laid by Emil
Bjäreborn, Fredrik Åkerman [107] has been used in this work using which the agricultural residue rice husk has been used to produce synthetic gas which runs the dual fuel generator. According to the authors Emil Bjäreborn and Fredrik Åkerman [107], the gas turbine was then combined with a steam cycle which increased the electrical efficiency. The purpose of this master thesis was to investigate the electrical efficiency of biomass integrated gasification combined cycle and compares this to the facilities using the Rankine-cycle and to model an integrated gasification combined cycle plant. The models and simulations were made with the software IPSEpro, which is a simulation environment for energy engineering. The results for the electrical efficiencies were in the region of 45-50%, which is higher than for conventional power plants using biofuel. An integration of a gasification unit was planned to be incorporated which was expected to create a very advanced system. Finally, the gasifier model was adjusted for atmospheric operation, which resulted in lowered electrical efficiencies compared to those of the pressurized configuration.

Based on the electricity tariffs, A.H. Mirzahosseini and T. Taheri [108] have developed three scenarios with The RETScreen International Photovoltaic Project Model, according to the targeting of energy subsidies in Iran. They have also dedicated one of these scenarios to the reduction of greenhouse gases. In the first case, the electricity price was set to 3.75 Cents/kWh (450 Rial/kWh) and no credit was assigned to the reduction of greenhouse gases (GHG), therefore equity payback (Return positive cash flow) has been 12.1 year. In the second case, the electricity price was set to 17.5 Cents/kWh; therefore, equity payback (return positive cash flow) was 8 years. Finally, in the last scenario by considering a credit to the reduction of greenhouse gasses and electricity price being 175 Cents/kWh and applying solar panels with high efficiency and suitable batteries (DOD = 60%), equity payback (return positive cash flow) reached within 6
years. As compared to the paper by A.H. Mirzahosseini and T. Taheri, in this present dissertation, the economic evaluation of the solar PV was done in a rural area near Bhubaneswar, India, where the payback period of the project was 8 years.

The authors T. Som and N. Chakraborty [56] have made an economic evaluation of a network of distributed energy resources (DERs) forming an autonomous power delivery system in an Indian scenario. The mathematical analysis is based on the application of a real valued cultural algorithm (RVCA) [27]. The RVCA-evaluated total annual costs for the autonomous microgrid system utilizing both solar module and fuel cells as DERs, and solar module and biomass gasifier unit as DERs have been compared. The optimal power generation conditions have been obtained pertaining to minimum cost of microgrid system. The results for different loading scenarios, using hybrid solar—biomass gasifier unit are found to be more cost competitive [37, 38, 52, 54, 56, 57]. A reduction of 8.1% in the annual cost is obtained using solar module-biomass gasifier unit to that using solar module-fuel cell for the same load demand in microgrid operation [60, 61, 64, 66, 68, 70].

1.6.1 Indian energy trends and Characteristics: An overview

Supply of energy is a crucial parameter for the development. When the grid power is disrupted, it creates problem in having the security for smooth supply. Thus, energy security is an integral part of the National security as mentioned in Trade, the WTO and Energy Security: Mapping the linkages for India, written by Sajal Mathur. The possible reason behind this statement can be that all sectors depend highly on the energy, helping the latter to run the country’s economy [32-36]. Managing the available energy resources is a very important step towards making the use of those resources sustainable, where the present can use these resources without ending the option for the future generations to use the remaining resources.
The energy starvation duration of our country calculated per capita has been found to be exceeding 70%, for which there will be a heavy demand for the different energy resources in the coming years, since the living standards of a developing country like ours, will take no time to equal the standards of that of the developed countries [41, 43]. This energy starvation is a condition where the people do not experience a natural ambient temperature of the range of 20˚-30˚C. The prime consequence of this condition is that the people will undergo a hunger for the use of more energy resources.

Even though, the issues of energy security, energy starvation and all are being faced, there remain numerous short and long term energy policies to be made to meet these issues and overcome them without compromising the energy needs of the future generations. It has been noticed that energy resources except natural gas and petroleum products, are mostly used for the purpose of generation of electricity.

There is possibility to implement the following options in India:

(a) In spite of the generation of liquid fuels in India, there is a predominantly large quantity of its import, which no doubt adds more burden to the Indian economy. This burden can be minimized by limiting the consumption of these fuels to only the unavoidable transport system e.g. marine transport, military vehicles and the air transport. For rest of transport sectors, bio-diesel, LPG and/or CNG may be used.

(b) The heating and catering requirements of the commercial and the domestic sectors may be met with piped natural gas, which may be supplied through the city gas distribution piping networks and the cross country natural gas pipe line networks.
(c) The energy resources except natural gas and petroleum products are to be mostly used for the purpose of generation of electricity. And the decision on the means of the generation of electricity can be done based on the cost of delivery of the electricity at the end user where the costs of generation and transmission can be taken into account.

(d) Coal can be transported to long distance power stations using the cross country coal slurry pipe lines. These may increase the initial investment, but no doubt, shall help in the reduction of the coal transport cost.

(e) The option for underground coal gasification technology in commercial scale should be considered which can convert coal into gaseous fuel for the generation of electricity as well as for other energy requirements.

(f) Policies should be more implemented in order to commercialize the production and the usage of bio-diesel from agricultural residues, algae and jatropha cultivation, be it B100 or blended biodiesel.

(g) Extensive efforts should be made in order to popularize the biomass gasification and biomass pyrolysis mechanisms. Until the latest technologies for using the solar energy, biomass and nuclear fuel are commercially proven, these preferred fuels and methods discussed above may be capable enough in building a self-dependent energy sector [29].

1.6.2 Energy Resources in India

There is a major role of energy in this present era. Its uses include motive power in automobiles, lighting/illumination, heating ships & airplanes, refrigeration and air conditioning, water pumping, cooking, electronic data storage, motive power of various machinery/appliances etc in the sectors like industrial, agriculture, domestic and commercial sectors. There is a high
production rate of energy in our country. Moreover, India also imports fossil fuels in large quantities, thereby, spending a major part of its economy. The exhaustible sources of energy which once used cannot be generated after their exploitation is called conventional sources of energy. These include petroleum, coal, natural gas, hydro power etc. Even though hydro power is a conventional source of energy as it has been in proper use since time immemorial, the hydro power is discussed in the next section of renewable sources of energy because of its nature of not getting replenished in the future [46-49].

Petroleum product is an inflammable liquid which in its crude form consists of hydrocarbons, be it solid, liquid and/or gas. Petroleum has compounds which belong to the paraffin series, some unsaturated hydrocarbons and the benzene group. Mainly used in motive power, it is compact and can be transported to the consuming areas by tankers or by pipelines and is easily stored. Petroleum emits much lesser smoke; no ash is left behind, has its cent percent utilization and is a very excellent lubricating agent. Although the production of petroleum oil in 2013 was 772.08 thousand barrels per day, its consumption was noticed to be 3509 thousand barrels per day, resulting in an import of 80% of its requirements. In the absence or limited availability of other fuels, petroleum products can also potentially be used for the generation of electricity, lighting and heating purposes. All these advantages necessitate the wide use of petroleum products so as to power almost all mobile vehicles.

Coal is a combustible black or brownish-black sedimentary rock which is burnt for producing electricity and/or heat, and for industrial purposes like refining metals. The formation of coal is through physical, biological and chemical processes, governed by temperature and pressure, and deposited in ancient shallow swamps over millions of years on the remains of plants [34]. Coal is witnessed as the largest global energy resource for generating electricity.
This energy resource usually occurs in the rock strata in layers known as the coal beds. Coal is composed predominantly of carbon and elements like hydrogen, oxygen, nitrogen and sulphur. If the present consumption rate of coal is maintained, then with a 200 billion ton coal reserves, the coal of India will last for another 400 years. Again assuming the consumption rate of coal to increase by 10 times, the coal reserves is estimated to last for another 40 years. As per the present technologies, the coal mining can be done only till 600 meters deep. Emerging technologies are being proposed so as to convert coal into clean gaseous fuel e.g. serpentine/inseam drilling, bunching of wells, guided drilling etc. as in case of the oil & gas wells drilling. Such possibilities give a ray of hope towards a reliable and commercial proposition of coal gasification technology. Imports alone cannot meet the high consumption demand of a huge country like India. Moreover, there is a high CO\textsubscript{2} emission from coal [67]. These demerits demand an alternative cleaner, cost effective and more efficient energy fuel for generating electricity.

Natural gas is the gaseous fuel which is comparatively a less polluting fuel but can be transported only by pipeline network; and for maritime transport the gaseous fuel has to be refrigerated into a temperature of minus 160°C. This is the Liquefied Natural Gas (LNG) which incurs heavy investments in its process of liquefaction, transport and re-gasification processes. In order to control the cities’ air pollution, for the purpose of intra city transport vehicles, CNG or better known as the Compressed Natural Gas, has been noticed to be in an increased use in place of diesel/petrol fuels. The primary uses of Natural gas are at present confined to the manufacture of fertilizers and the power generation [72].

The proven reserve of natural gas is 1,075,000 million cu m [6]. Burning the natural gas is much cleaner than burning coal or petroleum. However, the prime concern is the drilling for natural gas. The companies have recently ramped up the use of fracking or hydraulic fracturing
in order to obtain the shale gas. Plumbing natural gas deposits that are trapped in shale with the help of conventional methods is a very expensive mechanism. Alternatively, very high pressure is used to pump high volumes of mixture of water, chemicals and sand into deep wells. These induce fissures in the underground rock, releasing the trapped gas and then collecting it. This collecting procedure, “fracking”, allows the companies to inexpensively access more gas as the companies do not have to compulsively drill to each and every locations of the gas as compared to that of the conventional gas drilling mechanism which forces a company to drill to the exact location of the gas [5].

**Figure 1.1: Process of Hydraulic fracturing [107]**

Another contentious demerit of the process of fracking is the large quantity of water requirement. This water after being used needs to be treated. Moreover, any leaks herewith can significantly lead to the contamination of drinking water with many chemicals and also the
ground water. The industry is rapidly expanding even if the use of fracking has been seen as controversial in several states of the country. LPG, the abbreviated name for Liquefied Petroleum Gas, is a clean fuel made up of propane or butane and is a flammable gas mixture of hydrocarbons whose primary use includes as fuel in vehicles, heating appliances and cooking equipment. Its extraction is either from the natural gas or from production as a byproduct from crude oil refining. With 8 bar pressure and an ambient temperature, this particular gas can be easily compressed to liquid. LPG can be transported through pipe line transport and cylinders/tanks. The inadequacy of LPG to meet the country’s growing energy demand leads to the huge amount of import of this particular energy resource. Also, with the use of a small amount of radioactive substance, Uranium (U\textsuperscript{235}), lots of energy through the process of nuclear fission can be generated e.g. a ton of uranium is capable of providing energy higher than 3 million tons of coal or 12 million barrels of oil. The conventional nuclear fuels used for the generation of electricity are Uranium and Plutonium, which are not available in India, however, substantial amount of Thorium reserves are found which may be easily used for meeting the electricity needs. The associated issues with the Nuclear energy fuels are radiation leakages, nuclear reactor decommissioning at the end of their useful life, disposal of spent radioactive fuels and equipment etc. According to some critics, the parasitical electricity consumption of a nuclear power plant (in its establishment and operation) exceeds the electricity that can be generated by the power plant in its whole life time, in order for electricity generation and to meet the requirements of the military forces. The reason behind this opinion of the critics is the very high initial capital requirements of the nuclear power plants and their even higher decommissioning costs.
Out of the various forms of energy, electricity is the most desired form of energy. The reason behind this is that electricity is simple for conversion from its stage into other forms of energy. Moreover, this can be done at high conversion efficiency along with minimum negative environmental impacts. Another major merit associated with the electricity is its comparatively simpler and cleaner method of transmission with the help of cables/conductors. Pros and cons are the two sides of a coin. And this leads towards mentioning the demerits of electricity that is – its storage cannot be done in bulk to be later used in the transport/mobile applications owing to which transport sector preferably uses the liquid fuels. Even if there is lack of non energy minerals and human resources in any country, it is treated and believed to be a potentially rich country, if it has reserves of the unevenly distributed crude oil fuel. Capital intensive extraction and usage mechanism and emission of pollutants are the associated demerits of the crude oil. These fuels contain Hydrogen and Carbon which contributes to generate the heat energy when burnt or oxidized. This carbon then gets converted to gaseous form i.e. carbon dioxide. More is the use of these carbonaceous fuels, more is the increase in the amount of CO$_2$ in the earth atmosphere leading to global warming i.e. the issue of greenhouse phenomenon. So there is a discouragement towards the use and/or generation of the carbon derived energy. Coal is considered as main culprit in this scenario as there is an emission of 95% of heat energy from its carbon content when burnt or oxidized, as compared to 50% of other carbonaceous fuels. Hence, it is the need of the hour to highlight the already existing focus on renewable energy sources and to utilize the same at their optimized form. These renewable sources are discussed in the subsequent sections.

When water flows from a higher altitude to a lower level, it can be harnessed in order to generate electricity. This is called the hydro power which is a very clean energy and has a
potential of approximately 85,000MW at 60% load factor. Associated issues of installing hydropower plants are vast land requirement, evacuation of those areas, and other environmental and social problems like displacement of population, submergence of forests etc. The North Eastern Indian states own most of the untapped hydro power, whereas on the both sides of India-China border, 1,00,000 MW at 60% load factor of untapped hydro power is available which may be jointly harnessed. Electricity generation is done using wind turbines [45, 53] from the wind speeds above 15Km per hour. The movement of air primarily occurs owing to the temperature difference at the Earth’s surface caused by the solar energy, and owing to the rotation of the earth. Wind power is also clean fuel with barely any control on the generation of electricity from these units as the generation of power depends predominantly on the erratic availability of wind. India has nearly 10,000MW wind energy potential at 60% load factor. As per available data, nearly 20,000 MW of electricity generation can be done using wind. The generation capacity of the wind farms set up in Puri is 550 kW of electricity. This energy is the primary energy source and is used for generation of electricity during the day time. Being near the equator, India is endowed with substantial opportunities for solar power generations. As per the data collected from the government website, the state of Odisha (India) receives an average of 5.5 kWh/m² area of solar radiation for around 300 clear sunny days per year. There is a rough estimate of 8000 MW from the Solar Photovoltaic power generation and the power generation from Solar thermal is nearly 2000 MW. However, vast water bodies, large unused area by farm lands and the forests with abundant sunlight are needed for the generation of power. Commercial large scale solar power generation has not yet been proven.

Sun is the cause of generation of wind power and wind is the cause of generation of wave power [23, 25, 29]. Some of the wind energy gets transmitted to water at the time of wind blow
on the mentioned water bodies. This creates the wave energy. Harness of electricity generation from wave energy has not been done on major scale till date. Nevertheless, possibilities of harnessing wave energy and wind energy already existing on the oceans are there which can potentially lead in augmenting the fresh water availability and the generation of hydro-electricity. In some parts of India like the Eastern states, agro wastes such as rice husk, bagasse, crop waste, inedible plants and leaves, wood from old plantations etc. are available. Being waste, these usually end up getting thrown away or being used by the rural masses for their cooking requirements. However, when the quantity of these residues increases, they are a potential source of electricity generation and can also be used in the process industries. Gasification of biomass can lead in producing syngas or producer gas, or can be liquefied by the mechanism of fast pyrolysis so as to produce bio-oil and/or can also be carbonized by the process of slow pyrolysis for charcoal production [79, 80, 82, 83].

Varying percentage of bio-char (charcoal), bio-oil and biogas are produced from these processes [5, 6]. In the absence of oxygen, the carbonization of biomass is done either at low temperature (upto 600°C) or at high temperature (upto 1200°C). After the completion of this process of biomass slow pyrolysis/carbonization, the remaining products are charcoal (25% by weight of biomass), organic liquid chemicals which is 30% by weight of the biomass and 850 Nm$^3$ of town gas per dry ton biomass. 45% by weight of Hydrogen is obtained having a gross calorific value of 3000 Kcal/Nm$^3$ from the town gas [96 - 98]. The latest fast pyrolysis technologies with a conversion efficiency of upto 70% can lead to the conversion of biomass into bio-oil/pyrolysis oil. The heating value of Bio-oil to that of crude oil is of the ratio of 0.5:1. This unstable liquid is rich in Oxygen content and is acidic in nature, unlike that of its crude oil counterpart [14, 19, 33, 50, 51]. Bio-oil can be potentially used for the stationary low and
medium speed diesel engines and also in the gas turbines with minor changes, however, researchers are determined to test and prove the suitability of bio-oil in the mobile vehicles. Bio-oil production cost is nearly Rs 10/kg of dry biomass having a cost of Rs 2.5/kg. Water soluble fraction of pyrolysis oil produces hydrogen. There is a high content of water and biomass in the garbage collected from the Indian cities and towns enabling its commercial conversion into Bio-oil/Bio-crude using the methodology of Hydro thermal upgrading (HTU) method. This HTU is a type of pyrolysis process [58, 62, 69, 71, 75]. Biomass gasification is performed in the presence of air and steam in order to produce the syngas/producer gas/synthetic gas. This converted syngas is rich in hydrogen which is nearly 15% by weight of the raw biomass and with a gross calorific value (GCV) of around 1500 kcal/Nm³. In the process of gasification, more numbers of hydrogen are produced by splitting water molecules for optimum hydrogen yield. This is performed by using the thermal energy available in the biomass. The by-product of this process is production of ash which is full of nutrients like nitrogen, phosphorous and potassium (already present in the biomass) and can be potentially used as a good fertilizer. The heating value of bio-char is found to be 7500 Kcal/kg. This has the capacity to replace all mined coals which are consumed by the thermal power stations. Pyrolysis produces biogas having around 5% hydrogen by its weight where this hydrogen has the potential to generate 50 million tons of Urea fertilizer, possibly enabling our country into urea exporter after it meets all its internal consumption [29, 31]. Biomass is found to be rich in starch/carbohydrates content from which the ethyl alcohol or ethanol is fermented. Ethanol can be blended in the diesel and gasoline fuels so as to use it in the transport sectors. Food grains and sugarcane are the primary source of production of ethanol. These sources are costly and are also used as food source, which raises questions on economic feasibility and food security respectively. The questions, mentioned above, raised on the
economy and food security is faced and overcome by the use of inedible oil seeds produced to be used in mobile vehicles in order to replace the expensive imported diesel and petrol (gasoline) fuels. These non-edible vegetable oils are usually extracted from Karanja oil (Odia) (*Pongamia pinnata*), *Jatropha curcas* (Castor oil), algae (*Chlorella, Azolla sp.* etc.) etc and can be used by blending 20% of this oil in the conventional diesel fuel i.e. B20. These may also be converted into bio-diesel by the process of esterification of vegetable oils and by adding methanol or ethanol to the vegetable oils, which has the potential of replacing diesel and petrol fuels as a whole.

1.6.3 **Implications of Energy on Society**

According to the Electricity Act 2003, the per capita electricity consumption has increased substantially. A village is said to be electrified (Feb 2004 report amendment) if:

(a) Basic infrastructure such as distribution transformer and distribution lines are provided in the inhabited locality, as well as in the urban slums/hamlet, where it exists (for electrification through renewable energy sources, a distribution transformer may not be necessary).

(b) The number of households electrified is at least 10% of the total number of households in the village.

(c) Electricity is provided to public places like schools, panchayat office, health centres, dispensaries, and community centres.

The physical growth is witnessed more in the cities, unlike in the villages. This growth is dense, centralized and is expanding outwards from the specified urban demarcation as discovered by the eminent geographers and planners [10, 11]. The reason behind this growth pattern might be due to social and environmental consequences. The most important link existing
between the patterns of uncoordinated growth is the leapfrog developments taking place in Asia, especially in Indian cities. These social and environmental factors lead to the act of community or human group towards the use of resources for survival, needs, comfort and enjoyment and is called consumption pattern [74]. Consumption is the aggregate of all economic activity that does not entail the design, production and marketing of goods and services (e.g. the selection, adoption, use, disposal and recycling of goods and services) [85]. When income increases, agriculture sector and industrial sector get mechanized which leads to increase in population and hence the consumption of electrification increases in both rural and urban areas. The electricity consumption increase is owing to the Indian economy which is growing very fast owing to modernization, globalization and liberalization [88]. There is a close relation between electricity consumption and economic growth. Countries having higher income level consume more electricity [93, 94, 100]. With the improvement of the condition of a country, it was seen that their level of electricity consumption also increases. India is a developing country and recently India’s economic growth has started increasing day by day. Around 77 percent Indian economy growth occurred during 2000 and 2007 and around 60 percent increase in electricity consumption. Electricity is highly essential for economic development of a country. The disparity between income and energy consumption, found in rural India is an important issue in this present context. This includes use of modern energy i.e. mainly the use of electricity. It has been studied that in India, 57 percent of electrification is found in rural India and 95 percent of electrification is found in urban areas. In rural areas, people mainly use kerosene for lighting lamps and use charcoal and wood for preparation of food. These are inferior types of energy consumption. And in urban areas, people use modern energy like electricity for lighting and cooking food and also use LPG for cooking.
The basis of life is energy, whose lack or insufficiency can easily bring forward an economic stagnation stage by lowering the optimum productivity. Access to steady supply of enough and clean energy is quite a critical parameter in determining the all round development of the people, irrespective of their geographic location, social and/or economic status. Energy dynamics for rural and urban areas are more or less different from each other. The importance of energy security is more for the rural people as they are witnessed to be marginalized, more vulnerable and they also seem to be lacking a proper access to most of the basic resources. Traditional fuels like fuel wood are used by most of the rural people in order to meet most of their energy requirements. Small quantities of kerosene and the unreliable electricity are also used for the lighting purposes. The primary sectors consuming power in rural areas are domestic sector (for cooking, and for lighting), agricultural sector (energy consumption for farming) and commercial sector (for Micro Small and Medium Enterprises). Agriculture is the backbone of India and hence, a variety of biomass with sufficient quantity is available round the year. Agro-waste is the prime by-product of agriculture. Whether it is animal wastes, or the discarded plant stalks thrown away after the harvesting and milling of rice, grains or maize etc. if properly utilized then these agricultural wastes can be a potential source of electricity and cooking gas, and hence can lead in the reduction of the burden of energy requirement in rural India.

The Government of India through the Ministry of New and Renewable Energy Sources is implementing many schemes to facilitate the exploitation of the potential of various renewable energy sources. These achievements under the off-grid/distributed renewable, remote village electrification and decentralization of energy systems are of great relevance to solving the rural energy security issue.
1.6.4 Impact of social scenario on adaptability

The societal scenario in parts of the world shares the need of renewable but the awareness, concerns differ. For example, the issue of privacy can be a concern for Germany whereas for rural parts of India, the focus might be on the issue of understanding. Focusing in the rural India societal scenario raising the awareness and information sharing is primary focus. Educating the mass on the possibility to utilize the locally available resource to generate the necessary electricity will make a difference. Further, adaptation to the new technology demands easier availability of the information, economical freedom. In the 21st century the internet is constantly revolutionizing the information sharing process which intern is also spreading across rural places in India too. From a historical prospective, the rural India is well adept of utilizing the waste of animals in multiple purposes; in view of aforementioned fact, it makes logical directives that the society is not too far from the core concept of renewable sources. The only purpose of the Indian rural electrification schemes in the initial years of its implementation was linked to the development of rural areas by solely promoting irrigation, as a result of which enhanced agricultural productivity can be achieved. However, this purpose, in the recent electrification schemes like Kutir Jyoti programme, got modified and aimed at electrifying villages with the prime emphasis on the BPL households i.e. the ones which are below poverty line [36]. As per the target plan of the government, complete village electrification by 2010 was targeted under the Rajiv Gandhi Grameen Vidhyutikaran Yojana scheme. The delay in the success of meeting this target occurred and even more delay is expected as there are 71.7 million households still non-electrified, as per the data of 2005 (IEA, 2007). The term electrification is interpreted in many different ways in our country, India. Recently, it was interpreted as the means to be used for any purpose within a village whereas now, it is interpreted that at least 10%
of all households in the village must have a good access to electricity. Electrification of the remote households is a big hurdle in achieving the target set by the rural electrification scheme. These remote households are found to be established in an inaccessible terrain. Moreover, the cost of grid electrification raises upto 10 times more in the hilly terrain as compared to the plain areas. This is the prime cause of the promotion of renewable energy in the remote households by the Indian government which, on the other hand, offers high capital investments for these projects.

1.6.5 Impact of economic scenario on affordability

Economic freedom enables the access to the technology. Renewables, be it PV or Biomass gasifier is indeed a newer construct to the decade old fan or light. Thus, an energy efficient light bulb will be much easier to accept than that of PV panels. Though subsidized products such as LED lights, PV panels are already available in the market to boost the economic access to the technology, the purchase capacity in rural areas is seems to be limited, and highly dependent on local markets. Meaning the product transportation cost is added to the process. On an average, energy needed by the rural people is primarily for meeting the cooking and heating water demands, accounting for 80-90% of the total energy usages and the remaining energy is used for lighting and for using the basic appliances such as radios and fans. The total primary energy use in the households of the non-electrified rural Indian in the year of 2005 was recorded to be roughly 73% traditional biofuel, 19% oil products, 7% solar energy and 1% coal which is primarily charcoal. Therefore, the avid challenge is to make the renewables more economically viable for long term investment and interest in contrast with the current practises in the form of coal or oil which is also highly subsidized in on-going governmental policies.
1.6.6 Impact of geographical location and accessibility

Indian being diverse and a seventh biggest country in terms of landmass, it has geographical variations. For example, a location near sea or in deep forest region may vary significantly based on the natural resources. Road connectivity and population density are other prominent geographical markers those have a significant impact on the accessibility. Though, the fast increasing connectivity via road, railways is chaining to meet the seemingly rising constraint- accessibility but there still remains a gap to cover. Energy starvation or energy poverty is seen primarily in the rural areas, which clarifies the imbalance existing in the socio-economic development between the urban and the rural areas. The absolute monthly expenditure for fuel and lighting as indicated in the India National Sample Survey (NSS 66th) was found to be much higher for an urban resident than that of their rural counterpart in 2009-10.

It has often been marked that the geographical attributes like hot climate, less fertile land, scarcity of water etc. are seen in the developing and poor countries, and not in the developed ones. The geographical parameters highly impact in the growth of a country’s economy and development. Some places are highly endowed with natural resources whereas the others who are financially stable have to import the same from the former. Even there are some places which are remotely located, do not possess any natural resources and lack on monetary ground, have to suffer the most. A kind of natural disadvantage appears to on their part. Owing to their location, the inhabitants do not receive grid connected electricity. And owing to a lack in economic stability and significant resources, the people cannot afford to buy the power. Hence, the option left out with them is the inefficient methodology to use the existing biomass.
1.6.7 Energy Demand, Supply and Insecurity Issues in India

Energy is considered as the principal component influencing the economic growth and the human development, and establishing a two-way relationship between energy consumption and economic development. Regarding the energy demand of domestic sector, India consumes only 6% of the world energy while home to 18% of the world population [World Energy Outlook, 2015]. The energy commodity has witnessed a sharp growth since 2000 in India, especially in the domestic sector. Being the 5th largest economy it has a big impact in the world energy scenario. The population growth and economic development are prime causes behind the fast rise in the energy consumption of our country. Although a 6% rate of primary commercial energy demand has taken place in 1981-2001, as per the Planning Commission 2002, still a very low overall increase in energy demand has been noticed.

Apart from the rapid changes in the technical devices, energy ratings system and agenda of government to lean more towards the low-carbon framework are fast forwarding the ever growing energy demand in India. In order to ensure ‘24×7 energy supply’ in the amid transmission losses reaching to 30%, it is appropriate to turn to renewable resources. The traces of demand increment and renewable adoption to mitigate this problem can be noted in form of the roof-top PV installations across India. Following the wind generation and biomass in particular has picked up attention, due to the capacity to provide better control like intermitted resources such as wind. As discussed in the National Energy Map for India: Technology Vision 2030 by The Energy and Resources Institute with reference from Deen Dayal Upadhaya Gramin Jyoti Yojana (DDUGJY), the following steps are recommended which can help in establishing a better domestic sector [37, 38]:

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(a) The primary consumption of electricity in the domestic sector is owing to the lighting, where replacing the light bulbs with tube lights and CFLs can be very beneficial in saving a huge amount of energy.

(b) It is highly recommended to promote large-scale manufacturing of CFLs, thereby reducing the cost of CFLs, so that the use of CFLs can be facilitated.

(c) Motors should be made more efficient as against the local makes, and incentives to be provided in the government certified outlets. This can be a good step in creating awareness among consumers to opt for efficient appliances.

(d) More awareness should be created for the cleaner fuels so as to replace the use of traditional fuels which usually have low efficiencies, high polluting nature, and other social and environmental aspects. The population which has not shifted their energy use to cleaner options, there should be programmed in order to help them buy and use improved cook-stoves.

As for the energy demand in industrial sector, India has recently received a boost from the ongoing ‘make in India’ initiative. This is not only increasing the existing industries but also attracted MNC (Multi-National Corporations). Thus the demand in industrial sector for energy is going to be more power hungry. Though it is also important to notice the kind of industry and the operational procedure as some provide flexibility in operation and some has to be completed back-to-back. On top of that, modernization of infrastructures is brining rapid growth in the energy demand in industrial sector than ever before.
In figure 1.2 and 1.3, the share of coal is evidently the highest share and also constantly rising, mainly due to the availability and controlling possibilities. In order for the renewables like PV to make a fair share in the chart, the policy and technological support is essential.
As discussed in the National Energy Map for India: Technology Vision 2030 by The Energy and Resources Institute, the following steps are recommended which can help in establishing a better industrial sector:

(a) Import of the second-hand machineries should be banned.
(b) Cleaner fuels must be used.
(c) There should be a shift towards cogeneration and tapping waste heat for process heat.
(d) The large, medium and small-scale industries should be supported.
(e) The following sub-sectoral technologies are estimated to lead to energy savings in a large-scale: Introduction of blast furnace with top recovery turbine in the BOF (basic oxygen furnace) for steel making, integrated steel plants and the continuous casting for finished steel; COREX process is recorded to be helpful in the reduction of carbon dioxide emissions and also helps in energy savings. So, this procedure should preferably be adopted in the integrated steel plants; Six-stage preheating and the blending materials like slag and fly ash are to be used in the upcoming cement plants; and by adopting efficient pre-baked electrodes in aluminum manufacturing process.

1.6.8 Energy supply mode and flow pattern

The lack of a common market control for energy in India makes the process of energy flow more difficult than ever. The current pattern of energy flow manages to unite some part of India as in the North-India. The CERC (Central Electricity Regulatory Commission) along with the RLDC (Regional Load Dispatch Centre) and SLDC (State Load Dispatch Centres) are the existing mechanisms to control the energy prices and therefore the flow of power. Upcoming distributed generation and renewable energy penetration to the grid is making it increasingly challenging and demand the attention of common nationwide control structure for the optimal
regulation which ensures the supply and flow of power. As mentioned in the ‘Understanding Energy Challenges in India: Policies, Players and Issues (International Energy Agency)’, there was a high rise from 291 Mtoe to 502 Mtoe in between 1990 and 2009 at a compound annual growth rate (CAGR) of 2.9% in India’s domestic energy production, whereas there was a much higher rise in the demand growth of our country i.e. at a CAGR of 4%. On a further more discussion on individual resources, it is noticed that the share in the production of biomass reduced from 46% to 33% in the above mentioned time period. However, the coal production increased from 104 Mtoe to 244 Mtoe at a CAGR 4.6%. And the fastest growth was marked in that of natural gas i.e. from 10 Mtoe to 38 Mtoe at a CAGR of 7.0%.

1.6.9 Energy insecurity problem in rural India

The association between national security and the availability of natural resources for the consumption of energy is called Energy security. The definition of energy security as per the IEA is “the uninterrupted availability of energy sources at an affordable price”. The energy security in India can be achieved when our country will be capable of minimizing the vulnerability towards the disruptions in resource supply, having a reliable access to energy use at a reasonable price, and can enable the resource consumption that least damage the environment and/or promote sustainable development [12, 72]. Focusing on the basics of energy, the increase in the gradual use of some particular energy resources over the passage of time has to be well-understood. As discussed in previously, calorific value of the fuel depends primarily upon the concentration of Hydrogen e.g. the calorific value of wood (having more Carbon per Hydrogen) is less than that of coal (which has lesser Carbon per Hydrogen) and the calorific value of coal is less than that of gases (e.g. Methane, having 4 Hydrogen per Carbon) for the same amount of masses. Thus,
Hydrogen is playing a major role in the energy content of fuels [43]. And hence, it gives rise to more calorific value (CV) for which some fuels having more CV are mostly preferred than their counterparts. So, the fuels having more heat content or calorific value and are locally available can be utilized to convert these into fuels, in order to establish the energy security.

1.6.10 Energy conservation methodology using local resources – solar and biomass

In the developing world, especially in SAARC countries, most of the rural areas are depending upon the available resources e.g. bioenergy, solar energy etc. International Energy Agency (IEA) has predicted an increase in the factor of three in the energy production of biomass, which in the present-day-scenario provides around 10% of the world’s total primary energy. This contribution as compared to its use in 1990 further had grown to 41% from 1990 to 2010 as par the record of IEA. There are different kinds of biomass and various methodologies to extract energy from biomass resources. Presently 60% of the total biomass used is the ‘traditional biomass’, nevertheless, other types are also present, whose use is increasing rapidly. The use of bioenergy ensures low carbon footprint of whole life cycle of biomass and also avoids associated negative impacts on food production and on the ecosystem services [45, 46]. Along with these concerns, the energy production from biomass should also aim for more efficiency and sustainability.

Carbon neutrality is a major concern in today’s world and this is the prime attraction of biomass energy. The energy generated from biomass also has the potential to be carbon negative. Along with the mentioned point, other advantages are that it can be converted into high-energy solid, liquid or gaseous forms and also it can be produced in various regions [45]. Specifically, energy conservation is more of a behavior of usage than a control. Awareness of efficient usage
terms triggers the prolific utilization of energy. PV in Rural India is playing a pivotal role on this aspect, mainly because of the availability of the sun, in average 6 hours/day. In rural areas the PV charging lamp, water heater and induction cookers are the most used appliances, which needs to be charged during the day time and conservatively used during the night time [44, 59, 73, 81]. Biomass on the other hand, work as the small scale base generation capacity in many areas for proving the cooking and electricity [50, 51, 58].

1.6.11 Energy security issues pertaining to rural energy trends

As discussed above, the current capacity of the energy resources of India are 47 trillion cubic feet of proven natural gas reserves, 5.7 billion barrels of proven oil reserves and 60,600 million tons of proven reserves of coal [8, 9]. In terms of the primary energy consumption, the dependence of our country on natural gas, oil and coal accounts for 10.6%, 29.6% and 52.9% respectively. Since there is a very high dependence on coal and also the coal industry is mired in many technical, regulatory and distribution challenges, hence it becomes a mandatory step to import coal despite its quite high price. As already discussed in the previous section, India occupies the third position in global scenario in terms of producing coal. However, the consumption rate of the electricity generation sector is much higher than the production rate of coal [8]. Nevertheless, a ray of hope arises when this fact comes to picture. Out of the total installed power capacity of India, hydroelectric produces 16% and occupies seventh position in hydroelectric power production, as per the data recorded in 2012. 2% of power is generated from nuclear energy. There is a substantial use of biomass resources in the rural areas. India’s energy policy as defined by the Integrated Energy Policy of India has three cornerstones and they are: energy access, energy security and climate change. For a fast developing country like India, if there is a lack of access to electricity by majority of population, then it proves itself to be a great
hindrance to the economic growth of the country. A major part of the energy poverty faced by the rural people can be easily met with the rural electrification project instituted through the policy. Adding to this is the depletion of India’s foreign exchange reserves by the import of oil. As the consequence of which high inflation comes to the picture necessitating subsidies and all from the government, hence increasing fiscal deficit even more. In terms of climate change, even though the per capita emissions of carbon dioxide of India are just nearly one-third of the world average, no significant steps are being taken in adopting the green technologies [8, 11]. Since the global geo-political environment and the national energy sector are interlinked to each other and also there is a high import dependence of India which most likely can rise in the near future, hence, our country needs to secure its own supplies through various energy diplomacies. There are many opportunities that can be explored by India towards building energy sovereignty. These are:

(a) Alternative Resource Development: There is a high scope for biomass, wind and solar to become an important part of India’s energy mix. However, there are problems associated with the storage and transmission of wind and solar sources which are to be dealt with, prior to believing these renewable energy sources as the potential alternatives. This issue can be sorted out by meeting the high cost and low efficiency of PV panels and also by capturing the energy exactly when wind is blowing then storing it, and then using it when there is a need of power.

(b) Technology partnerships: as discussed earlier, energy diplomacy is required to secure own energy supplies. And it can also help in forging technology partnerships with other countries. The Japan-India partnership can help in strengthening the renewable energy front of each country and in moving towards energy efficiency and also in the
conservation of technologies. Some other initiatives like Green Corridor, Waste to Energy and smart grid development are beneficial as Japan has competitive advantage through its projects like Sunshine and Moonlight.

So as to achieving economic sovereignty in terms of energy security, formulation of energy doctrine needs to be done urgently which must be aligned to its foreign policy so that it can secure the state’s energy needs in the present and the future. The imports have to be minimized whereas the more national energy options have to be generated through the exploration of low-carbon hydrocarbons or through the promotion of alternative energy sources. Options for technology partnerships e.g. Japan-India partnership, need to be more actively created in order to accelerate the efficient utilization of domestic resources. This will also lead to extracting resources in more efficient processes and better infrastructure. Another step towards achieving economic sovereignty is to encourage more private investments which will lead to harnessing of the new energy reserves and hence, will further help in the national growth and development [8].

1.6.12 Renewable bioenergy

International Energy Agency (IEA) has predicted an increase in the factor of three in the energy production of biomass, which in the present-day-scenario provides around 10% of the world’s total primary energy. This contribution as compared to its use in 1990 further had grown to 41% from 1990 to 2010 as par the record of IEA. There are different kinds of biomass and various methodologies to extract energy from biomass resources. Presently 60% of the total biomass used is the ‘traditional biomass’, nevertheless, other types are also present, whose use is increasing rapidly. The use of bioenergy should ensure low carbon footprint of whole life cycle of biomass and should also avoid any associated negative impacts on food production or on the
ecosystem services. Along with these concerns, the energy production from biomass should also aim for more efficiency and sustainability.

In the present scenario, the solution to most of today’s environmental issues is the carbon neutrality which can be achieved by biomass energy, which also has the potential to be carbon negative. Moreover, biomass can be produced or grown in almost all geographical regions and can also be converted into high-energy solid, liquid or gaseous forms. Another striking merit of bioenergy is that the underutilized crop waste and crop biomass have the potential to deliver greenhouse gas savings of the order of 1 billion tonnes per annum globally. These can be used to make biogas, and hence renewable electricity. If the cost of agricultural wastes to electricity conversion is lowered, then the technology can be made much more economic at smaller scales as compared to the present day scenario. Research is going on to overcome this challenge and is a good success till date. One such research has been demonstrated in the Chapter-4 of this dissertation. Even though the use of biomass is growing globally, at the national level, traditional uses of bioenergy is primarily noticed. Rigorous research experiments and advancements in producing bioenergy has provided the users or consumers with options for modern technologies and many possibilities for the conversion of biomass into corresponding synthetic gas (syngas) or liquid fuels (like ethanol and methanol) and also electricity. The hindrance created in the penetration of modern biomass technologies into the system is owing to the lack of biomass energy market. Hence, a proper technology push policy strategy needs to get augmented by the market pull policies. A primary policy lacuna which hampers this growth of modern bioenergy options is the subsidy allowed to fossil fuels. Nevertheless, the modern biomass has a great potential to penetrate in the following four segments. They are Cooking energy in domestic and
commercial sectors (through charcoal and briquettes), process heat applications in industries generating biomass waste, transportation sector with liquid fuels, electricity generation.

The present economic reforms have helped in facilitating a good number of competitions in the energy and the electricity sectors in our country. The modern technologies are going to determine the future of biomass energy. Using Indian-MARKAL model [12], an analysis has been done which has suggested the potential of bioenergy to penetrate into the Indian energy market under the strong global greenhouse gas mitigation scenarios in the future. Competition on a fair market shall provide reliable energy services from biomass at a competitive cost and the consequence of this will lead to the increased use of bioenergy in the Indian market. Here, the most feasible and economical option is by utilizing the waste materials to generate energy. In India, a high quantity of 10,000 MW power can be generated from the agro residues and wood processing wastes. Major concerns associated with the biomass are requirement of land, enhanced biomass productivity; logistics infrastructure and economic operations of plantations. For a transition from present-day fossil fuel dependence to biomass based energy dependence in India, the following policies should be considered [46]:

Short-term Policies (1 to 5 years) include: Information dissemination, enhanced utilization of crop residues and wood waste, technology transfer (e.g. high pressure boiler), niche applications (e.g. remote and biomass rich locations), co-ordination among institutions, participation of private sector, community and NGOs, demonstration projects, subsidy to biomass technologies to balance the implicit subsidies to fossil fuels, waste land development.

Medium Term Policies (5 to 20 years) include: R&D of conversion technologies, species research to match agro-climatic conditions, biomass plantations, scale economy based technologies, removal of distortions in fossil energy tariffs, local institutional developments.
Long term policies (over 20 years) include: Multiple biomass energy products (e.g. gas, liquid, electricity), infrastructure (logistics, T&D), land supply for biomass generation, institutions and policies for competitive biomass energy service market.

There is a significant growth in the modern biomass plantations operation and the energy conversion technologies. The reliability and the efficiency of biomass production systems and conversion technologies are improving owing to the learning effects and the shared knowledge from innovations used in the conventional technologies. Many developing countries can make an easy transition from the inefficient biomass energy use to a commercial, competitive and an efficient biomass energy use through a proper realization of biomass potential [15, 17]. This can lead to the reduction in national energy import and help in the conservation of the finances saved for the national development. Nevertheless, there are a significant number of environmental and social merits that help in making biomass a deserving alternative to accomplish the sustainable development of the country and hence, they provide feasible options for the most-waited energy transformation [18, 20, 24].

1.7 Motivation of present work

Keeping in view to develop of indigenous sources for better national economy, to decrease the Greenhouse effect by substituting the fossil fuels with a sustainable and a renewable energy source and to achieve energy security, it has been thought to do research work based on the aforesaid issues. Solar PV is also to be utilized for meeting the energy demand in domestic and commercial lighting. Integration of these two aspects is the major theme of the present thesis work. With this approach, the scope of the present work leads to the establishment of energy security of the rural India with the help of agricultural wastes and sunlight. So, a detailed study is
essential on how to condense the pyrolytic extract and to analyse the same to have quality bio-oil, which can be used to blend in the conventional oil.

1.8 Objectives of Present Research Work and Organization of Thesis

In order to achieve a better environment with minimized greenhouse gases emissions and their adverse effects, biomass energy has been opted as the field of research work.

The prime aim of this work is the efficient gasification of the rice husk into syngas which can be fed to dual fuel generator. The process byproduct tar is studied and its conversion to bio-oil and other valuable products has been shown. The economical aspect of solar energy is simulated and payback period is obtained. This will not only bring a new era of renewable energy but also enhance the economic standard of our country. Bioenergy and solar PV have been utilized to achieve the energy security of Agadiapali village in the district of Khordha, Odisha.

Specific objectives of the present research work are as follows:

1. To visit the Biomass gasification plant in the state of West Bengal, India: A field study.
2. To evaluate the economic aspects of rice husk based gasifier.
3. To evaluate the economic aspects of a standalone Solar PV system.
4. To study the Solar-Biomass-BESS model using MATLAB software.

1.9 Conclusion

The study was conducted at lab scale with the rice husk. Other feedstock like mustard seeds and other seeds have also been a part of the experimentation. During the experiment, it has been observed that the oil component in the biomass can be extracted by the pyrolysis phenomenon. The pyrolytic component can be processed and valuable compound can be
extracted. In the present thesis, detail study was conducted on the pyrolytic compound extracted from rice husk, but the aromatic property of the extract, pharmaceutical and chemical nature of the extract also needs to be studied. Here, only the synthetic fuel compound and the chemical compound generated during pyrolysis has been studied owing to lack of time. This biomass gasification model [101, 102] of the field study was simulated using System Advisor Model [31]. Along with this, the feasibility of solar energy implementation [44, 59, 73, 81, 86, 89, 99, 103] was studied using RETScreen software [28, 39, 63]. And a microgrid model [76, 84, 87, 91, 95] with the previously mentioned biomass-solar-battery was designed using MATLAB Simulink 2015b. A battery energy storage system (BESS) was added to this hybrid system [13, 42, 55, 64, 65, 77, 78, 90, 92, 99].

1.10 Scope for future work

Pharmaceutical and other synthesis of pyrolytic compound for various applications in the streams of Science and Technology can be illuminated further. The device made in the present study can open up avenues for technologies e.g. extract of chemicals for biological applications, pharmaceutical applications, paint and anti-corrosive applications, apart from oil extraction. The future work on this subject can fill up the gap that has been generated owing to the lack of time, infrastructure and owing to the problem for access to other resources.