GREEN SOLUTIONS FOR ENERGY SELF-RELIANCE: THE CASE OF GUDUR MUNICIPALITY, INDIA

By

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DECLARATION

I, hereby declare that, the contents of this work are results of my own research, and that every source of information utilized in this report has been acknowledged and referenced. I accept the full responsibility for contents of this work.

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15th July, 2014

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EXECUTIVE SUMMARY

The purpose of the research paper is to demonstrate the economic, ecological and social importance of implementing de-centralized power systems based on locally available renewable energy sources in Indian municipalities by using a case study on the Gudur municipality in the state of Andhra Pradesh. Methodologically the paper starts with a material flow analysis (MFA) evaluating the current status quo as well as assessing the locally available potential. In terms of renewable energy conversion technology, the focus will be placed on photovoltaic and biomass to energy technologies. After predication of the renewable energy coverage, the regional added value potentials are determined and current challenges and barriers analyzed. The research paper ends with a conclusion and policy recommendation towards the necessary legal and economic framework condition.

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ACRONYMS

CDM	Clean Development Mechanism
CDM PoA	CDM Programme of Activities
CEA	Central Electricity Authority
CEP	Community based Energy Planning
CH_4	Methane
CHP	Combined Heat & Power
CPA	CDM Project Activity
CSP	Concentrating Solar Power
GC	Grid Connected
GHG	Green House Gas
GOI	Government of India
GWP	Global Warming Potential
IEA	International Energy Agency
IREDA	Indian Renewable Energy Development Agency
HHV	Higher Heating Value
MDG	Millennium Development Goals
MFA	Material Flow Analysis
MFM	Material Flow Management

MNRE	Ministry of New and Renewable Energy
MSW	Municipal Solid Waste
PV	Photo Voltaic
RAV	Regional Added Value
RD&D	Research Development & Demonstration
REC	Renewable Energy Certificates
REN21	Renewable Energy policy Network for 21st century
RET	Renewable Energy Technology
SA	Stand Alone
SME	Small and Medium Enterprises
SWDS	Solid Waste Disposal Site
tCO_2	Tons of Carbon dioxide
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change

Chapter 1: INTRODUCTION

1.1 TITLE

GREEN SOLUTIONS FOR ENERGY SELF-RELIANCE: The Case of Gudur Municipality, India

1.2 BACKGROUND

The advancement of human civilization since the past century can be linked with the unprecedented rise in energy demand in general, and in hydrocarbon and electricity consumption in particular. Around half a billion people, who include 47.5% of rural population, live with no electricity supply in India (MNRE 2012). This population size is more than the entire population of United States of America. There are number of villages which are either un-electrified or partially electrified in India (EngineeringReview 2012). Transmission losses in India stood at 19.88 % during 2009-10.

"We are energy secure when we can supply lifeline energy to all our citizens irrespective of their ability to pay for it, as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times and with a prescribed confidence level considering shocks and disruptions that can be reasonably expected" - Integrated Energy Policy (2006). Energy is a prerequisite to economic development and it plays an important role in overall human development. Energy alone is not sufficient for creating conditions for economic development but is certainly necessary (IEA 2004). Virtually all physical processes in the economy require energy (Loschel et al. 2010).

India's primary energy demand is fulfilled by fossil fuels. India is a net importer of oil, importing more than 3/4th of its total annual consumption. Last few years have seen high increase in petroleum consumption in the country, which accounted to annual growth rate of 4%. Industry predicts that, India has to import 90% of its total oil requirement by 2030 (IREDA 2012). As spoken in material flow management language, tremendous amount of money is leaving out of the region adding no value.

During the last five year planning period which ended in March 2012, Indian power sector constantly failed to meet the peak demand in spite of increasing its installed capacity at an annual rate of 7.6% (IREDA 2012). To be specific the power sector has encountered a power deficit of 9% of the peak demand and energy supply deficit of 8.7% in the year 2012-2013 (CEA-India 2013). Annual Per capita electricity consumption in the country as of March 2012 is 879 kWh, which is approximately one-quarter of the world's average. Total renewable energy potential (excluding solar energy) in India as of March 2012 is estimated to be 89,774 MW, distributed across the nation (CSO-India 2013). After a high level analysis of the Indian power sector, the following paragraph describes the situation of the state of Andhra Pradesh.

Andhra Pradesh is one of the 29 states of India, located in the Southern part of the country with a coast line of 972 km, which is longest in the country. The population is 49.38 million as of May 2014 and the capital city is Hyderabad. The coastal belt is fertile and depends mostly on agriculture. The state is endowed with a variety of physiographic features ranging from high hills, undulating plains to a coastal deltaic environment (Government of Andhra Pradesh 2014). The sources of energy production in the state of Andhra Pradesh are: majorly thermal (68%), followed by hydro[1] (25%), renewable (5%) and nuclear (2%). State has seen an average energy deficit of 12% in 2011-2012 (Confederation of Indian Industry 2012), leaving no electricity supply for 2 hours in cities, 4 hours in district head-quarters and municipalities, 6 hours in villages per day. The current mix of energy production implies, there is high impact on environment and lack of diversification in the supply sources making the energy systems vulnerable to factors such as coal price hikes, monsoons etc,. Hence there is a need to introduce renewable, decentralized, locally available and flexible energy sources into power production.

The promotion of de-centralized power systems, not only makes the region energy self-reliant but also provide new job and investment opportunities for local residents. The other main aspect of de-centralized power systems is reduction in the transmission loses, which accounted for 18.04% in 2009-2010 (Confederation of Indian Industry 2012). The transmission and distribution structure in the State of Andhra Pradesh is presented in the Figure-1 below. This shows that the power sector

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[1] Ministry of New & Renewable Energy, India classified Hydro power plants upto 25 MW capacity as small-hydro and listed under Renewable projects.

is centralized and hence the above mentioned energy source mix is applicable to any region within the state.

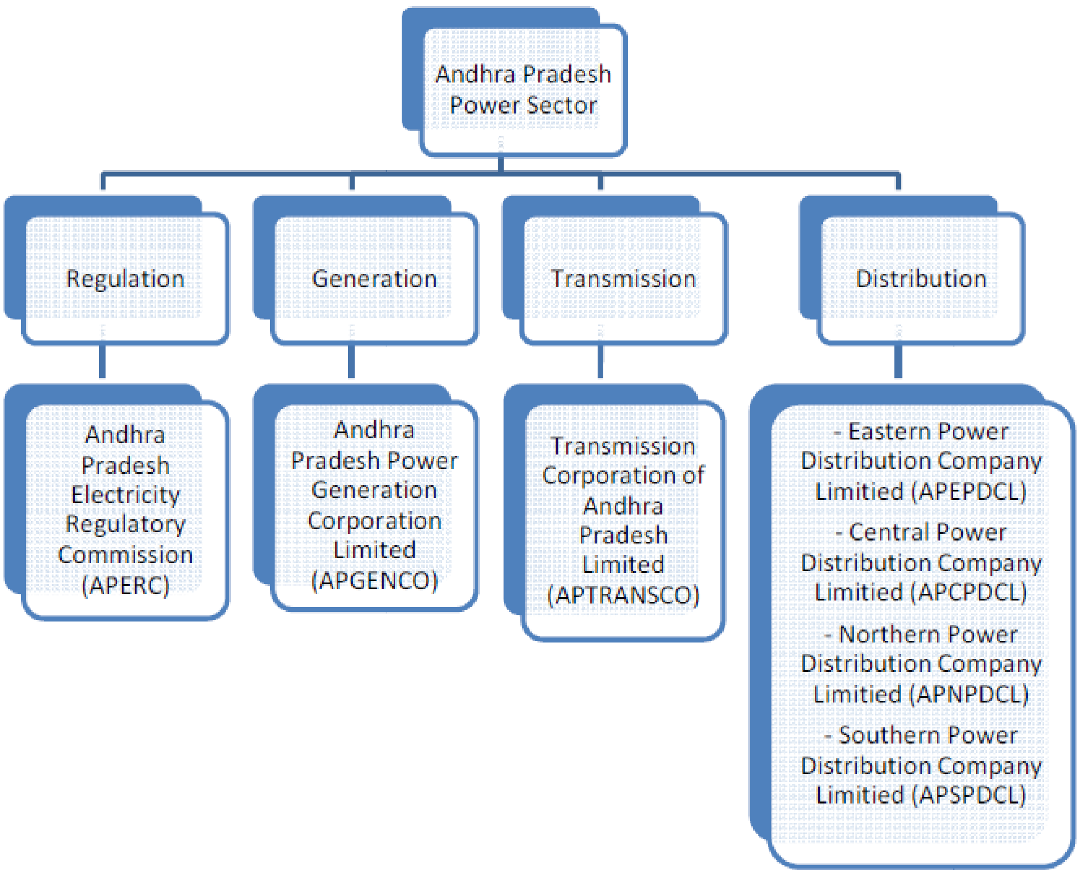

FIGURE 1: INSTITUTIONAL STRUCTURE OF POWER SECTOR IN STATE OF ANDHRA PRADESH

(Source: (Confederation of Indian Industry 2012))

Figures-2&3 depict the electricity sector scenario in the state of Andhra Pradesh. As the grid is centralized, the similar situation can be interpolated to the municipality of Gudur.

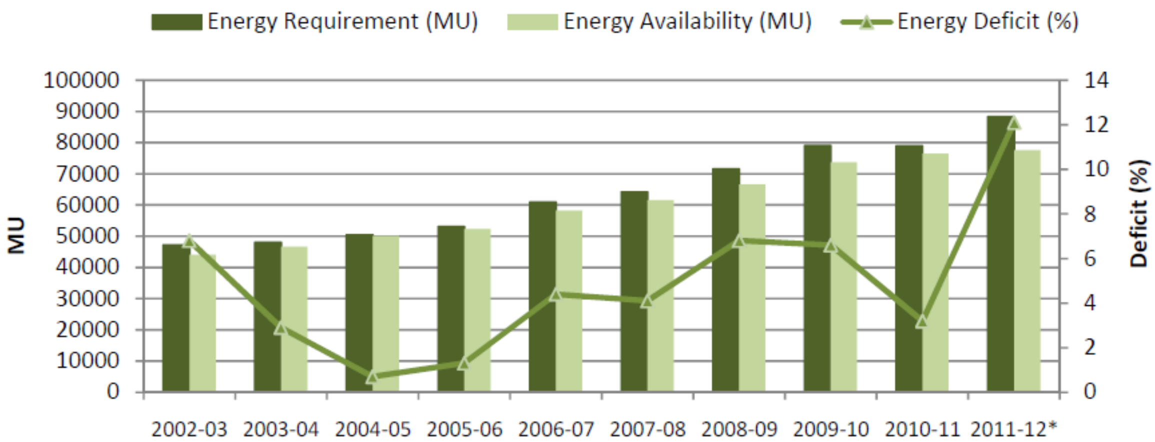

FIGURE 2: ENERGY REQUIREMENT VS. AVAILABILITY

(Source: (Confederation of Indian Industry 2012))

The deficit goes high in summer between months of April to June, due to the fact that there is no water available in reservoirs to generate the hydro power.

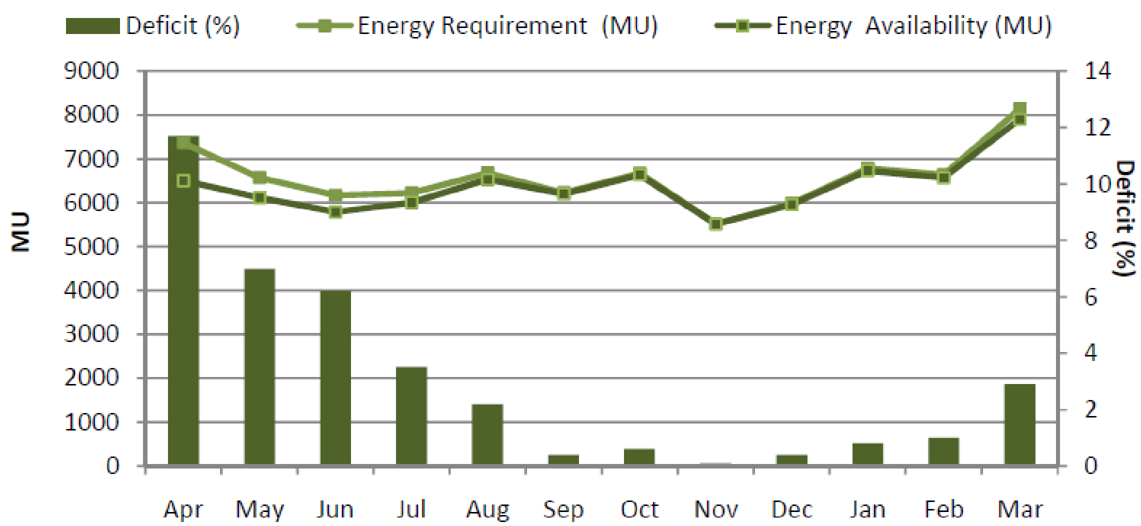

FIGURE 3 MONTH WISE ENERGY REQUIREMENT VS. AVAILABILITY 2010-2011

(Source: (Confederation of Indian Industry 2012))

Material Flow Management (MFM) is a tool that can be used to analyse regional potentials and activate the hidden flows. The aim of MFM is to create circular economy by maximising regional potentials and thereby achieving regional energy and material independence. Regional MFM starts with the potential analysis, key stakeholder analysis, developing sustainable projects based on potentials, aggregating the projects into a MFM master plan, setting up regional MFM company to implement the projects, developing financial mechanisms to fund the projects, capacity building by training local people and implementing identified projects. MFM techniques when applied on a region, creates Regional Added Value (RAV) by reducing the imports and keeping money flows within the region. The results of MFM are usually expressed in the language understandable to decision makers, targeted to influence them to invest in sustainable solutions. This method will be systematically applied to Gudur municipality and help in achieving energy security.

1.3 Research Theme and Plan

This paper argues the importance of implementing sustainable power systems in municipalities, using renewable resources of the region. Regional MFM techniques will be applied in achieving this. As Gudur municipality being densely populated and have agriculture as the main occupation of the region, focus would mainly be on harnessing biomass potential of the region (agricultural waste and household bio waste to energy). Like many parts of India, Gudur region also receives more than 300 sunny days, making it a good candidate for solar energy production. Thus the aim of this research is to demonstrate how better management of material flows in the region and investing in environmentally sound technologies adds economic, environmental and social value to the region both in short-term as well as in long-term.

Gudur municipality in the State of Andhra Pradesh is selected for study and the resource potential analysis has been done with the help of data from government municipal corporation, electricity sector, consulting local people and site visits. Then the energy potential of different renewable resources is calculated. It is followed by feasibility analysis for generating power with available renewable resources. The key stakeholders are identified and the barrier analysis is carried out for identified projects. An energy master-plan for the region is developed and necessary recommendations are provided to overcome identified barriers.

1.4 RESEARCH METHODOLOGY

In this study I would like to analyse the energy needs and the local energy resources potential of Gudur municipality, using Material flow Analysis (MFA) methodology. The methods include interviews with key stakeholders, personal observations, collection of data from relevant local municipal offices and reviewing documents. Thus, research method of this paper can be classified to be “Descriptive qualitative research using a case study”.

To explain the methodology in detail, relation between the available potential (theoretical) and final projects implemented to deliver useful services is depicted by following figure-4. If the outer most square[2] (1) is considered to be theoretical potential of the region (for eg. the solar energy received on the total area of Gudur municipality), the next inner square (2) shows the potential that could be harvested technically (taking into consideration, the constructed area, shading of buildings, ownership of land, legal obligation on land use etc, only certain amount of solar energy radiated on Gudur municipality could be harvested). The next inner square (3) shows the portion of technically harvestable potential that is also commercially interesting to invest in such projects. The slider shown in red is usually adjusted with time due to advancement in technology and square-3 (economically viable) moving outwards to merge with square-2. The next inner square (4) (implemented projects) is the portion of the potential that is currently being put into use and is yielding services to the region. The red slider between squares 3&4 can be influenced highly by new policies, incentives by government and changing the mind-set of people.

Current research paper starts with the identification of theoretical potential of various renewable resources in Gudur region and further calculates technically available

[2] Squares will be referenced by their respective numbers shown in figure to avoid complexity in understanding

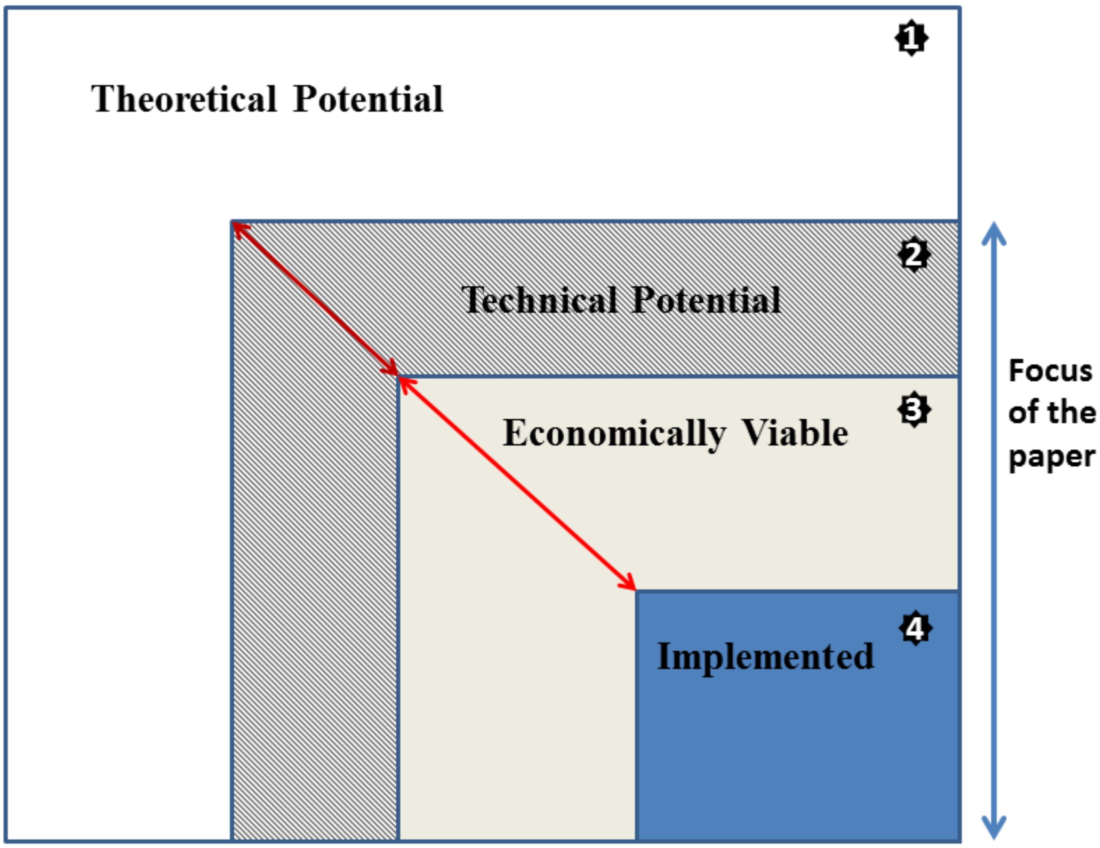

FIGURE 4: VARIOUS STAGES FROM POTENTIAL INDENTIFICATION TO PROJECT REALIZATION AND FACTORS INVOLVED

Source: Author's graphic

potential of the region. In the concluding chapter, major barriers influencing the realization of projects are identified and recommendations are provided to overcome those barriers.

1.5 Research Objectives

- To characterize energy demand and supply situation in Gudur municipality.

- Explore renewable energy potentials of the region
- Evaluation of potentials
- Identification of projects for sustainable energy production
- To calculate Regional Added Value (RAV) in economic, environmental, and social perspectives
- Analyse barriers for the implementation of identified projects
- Recommend appropriate renewable energy production systems in accordance with the factors accessibility, affordability and acceptability.

1.6 SIGNIFICANCE OF THE STUDY

The results of the study, when published:

- Can help to understand and improve the energy situation for the residents of Gudur municipality
- Resource potential assessments and cost-benefit analysis provided in the study can trigger the local government and investors to invest in sustainable energy projects
- Can be used for implementation of these concepts in other Indian municipalities and,
- Enhance existing literature for future references.

1.7 LIMITATIONS OF THE STUDY

The appropriate national, state or district statistics are used to estimate the composition of municipal solid waste, rice yield per hectare and solar irradiation in Gudur region. This is due to unavailability of recorded data for Gudur municipality. The electricity consumption/supply data in Gudur municipality used in the paper is restricted to past one year due to data unavailability (April 2013 – March 2014).

Chapter 2: REVIEW OF LITERATURE:

2.1 SUSTAINABLE DEVELOPMENT AND ENERGY RESOURCES:

United Nations Development Program (UNDP) in its article “Energy and the millennium development goals” highlights that the improvement in access to reliable and affordable energy services is a crucial factor in the achievement of millennium development goals (MDGs). Though improving energy services is not directly related to any of the MDGs (listed in Table 1), it will not be possible to achieve the MDGs without focussing on energy sector. Understandably the accessibility to quality energy services practically affects all aspects of sustainable development. High agriculture yield, provision to clean water, wellness of people, improved health services, education, increased employment opportunities, empowering women and climate change mitigation to name a few aspects (UNDP 2004).

Environment being the pillar for attaining sustainable development, it is necessary to safeguard it for future generations. The protection to environment can be achieved through transitioning to low carbon economy. In a report from Mckinsey & company, the GHG abatement opportunities have been identified in following categories: EE, supplying low-carbon energy, develop carbon sinks with re-forestation and agriculture. Energy supply sector which is currently dominated by fossil fuels has approximately 29% of GHG abatement potential (McKinsey & Company 2009).

MDGs	ENERGY LINKAGES
1 ERADICATE EXTREME POVERTY AND HUNGER	• *Energy inputs (electricity and fuels) are needed for agriculture, industrial activities, transportation, commerce, and micro-enterprises.* • *Most staple foods must be cooked, using some kind of fuel, to meet human nutritional needs.*
2 ACHIEVE UNIVERSAL PRIMARY EDUCATION	• *Teachers are reluctant to go to rural areas without electricity.* • *After dark, lighting is needed for studying.* • *Many children, especially girls, do not attend primary schools because they have to carry wood and water to meet family subsistence needs.*
3 PROMOTE GENDER EQUALITY AND EMPOWER WOMEN	• *Adult women are responsible for the majority of household cooking and water boiling activities. This takes time away from other productive activities. Without modern fuels and stoves and mechanical power for food processing and transportation women often remain in drudgery.*
4 REDUCE CHILD MORTALITY	• *Diseases caused by lack of clean (boiled) water, and respiratory illnesses caused by indoor air pollution related to the use of traditional fuels and stoves, directly contribute to mortality in infants and children.*
5 IMPROVE MATERNAL HEALTH	• *Lack of electricity in health clinics, and lack of lighting for night-time deliveries, adversely affect women's health care. Daily drudgery and the physical burdens of fuel collection and transport also contribute to poor maternal health conditions, especially in rural areas.*
6 COMBAT HIV/AIDS, MALARIA AND OTHER DISEASES	• *Electricity for radio and television can spread important public health information to combat deadly diseases.* • *Health care facilities, doctors and nurses need electricity for lighting, refrigeration, and sterilisation in order to deliver effective health services.*
7 ENSURE ENVIRONMENTAL SUSTAINABILITY	• *Energy production, distribution and consumption all have many adverse effects on the local, regional and global environment, including indoor air pollution, local particulates, land degradation, acid rain, and global warming. Cleaner energy systems are needed to address all of these to contribute to environmental sustainability.*
8 DEVELOP A GLOBAL PARTNERSHIP FOR DEVELOPMENT	• *The World Summit for Sustainable Development (WSSD) called for partnerships among public entities, development agencies, civil society and the private sector to support sustainable development, including the delivery of affordable, reliable and environmentally sustainable energy services.*

TABLE 1 : MILLENNIUM DEVELOPMENT GOALS AND SIGNIFICANCE OF ELECTRICITY

(Source: (UNDP 2004))

GHG abatement in this sector can be achieved by introducing renewable energy technologies (RET) into supply. RETs use natural sources such as biomass, energy from sun, wind, hydropower and geothermal as input to produce clean energy. These sources are usually local based leading to sustainable development of the region with almost zero net GHG emissions.

2.2 ENERGY SECURITY AND RENEWABLES ENERGIES

International Energy Agency (IEA) (2014) defines energy security on the basis of availability and affordability principles. Energy supply is considered to be secure when it is supplied uninterruptedly in adequate amount at an affordable price and the whole system is reliable. Electricity, heat, and transportation can be considered as basic inevitabilities of mankind and hence they must be made accessible and affordable to everyone (ÖLZ et al. 2007). The challenges for energy security differ with respect to each country. Approximately 20% of population living in developing countries and least developed countries have no access to electricity and up to 35% of people still depend on biomass for their primary energy needs. For such countries, providing energy access to all takes priority before considering the importance of energy security (ÖLZ et al. 2007). Lack of access to reliable energy amenities, unrestricted use of local energy sources, such as fire wood for cooking will lead to resource depletion and environmental deprivation (Bugaje 2006).

IEA suggests diversification of energy sources as an option for governments to prevent significant impacts from energy insecurity. Though renewable energies are not the only option for diversification, but the advantages with renewables is that they are continuously available, and adds no pressure on environment thereby meeting objectives of energy security (ÖLZ et al. 2007). These energy resources are locally available by nature, thus can cut fossil imports leading to energy independence of the country. In order to develop more sustainable energy systems, the general requirements of sustainability need to be fulfilled. European commission describes the same in their European strategic energy technology plan as "The triangle of energy policy" as shown in figure-5 below. (Eltrop 2013)

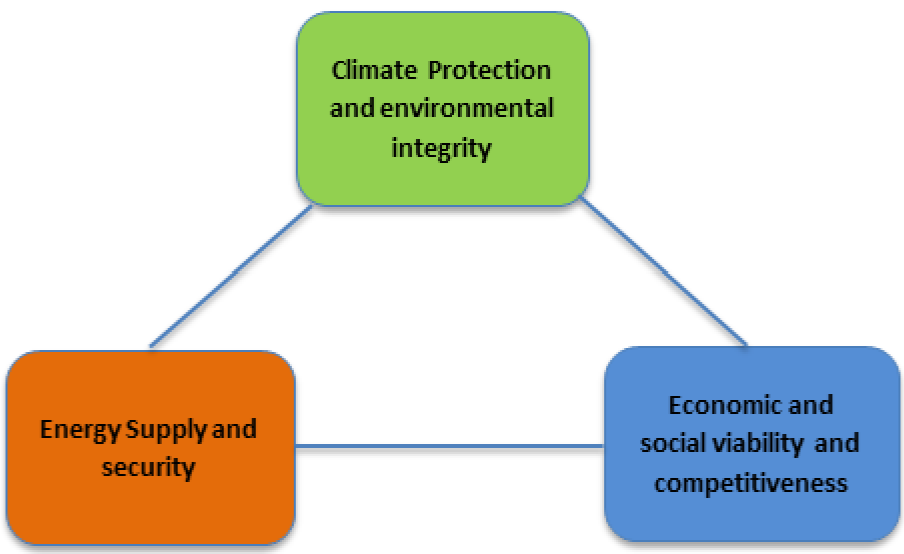

FIGURE 5: THE TRIANGLE OF ENERGY POLICY

Source: adopted from (Eltrop 2013)

Renewable energy sources are often criticized for their uneven distribution, but this can be blessing in disguise. When these sources are used locally to generate electricity for the region, the major loses that occur during power transmission from central grid can be reduced. This type of electricity generation is termed as "distributed generation". When properly planned and implemented it could be cost effective, as the load is located close to the generation thereby reducing grid infrastructure for transmitting electricity over long distances. RETs still pose high investment costs per MW installed when compared to conventional energy production. But there has been a steep reduction in these costs in last few years due to research and development in the field and market development. This trend is expected to continue for years to come. The important factor that has to be considered is the fuel costs over life span of power plants. Input fuel for electricity generation with RETs have a very low (for e.g. to purchase biomass from farmers) or zero costs. Thus, when life cycle costs and services to environment are considered RETs can be competitive (ÖLZ et al. 2007).

RETs not only can alleviate energy security risks but also contributes to regional economic growth. By activating the use of material and energy flows within the region, financial flows are kept within the region itself. Thus, RETs can form the basis for implementing circular economy within the region.

2.3 DECENTRALIZED POWER SYSTEMS:

Generating electricity as well as meeting growing demand has become challenge for all nations. In developing countries where half the people live in rural areas. Cost of delivering electricity becomes high making it too expensive to the people living there. The high costs can also be attributed to centralized grid systems, which usually depend on fossil fuels for power generation. As discussed in the previous chapter, this issue can be tackled by the introduction of decentralized systems for power production using renewable energy sources as input. They can be implemented in small scales in near proximity of demand site. Thus these systems can reduce the transmission loses and result in energy savings. Decentralized power systems have the potential to save 2.7 trillion USD in next 15 years (Yadoo 2012).

Depending on the extent of decentralization, it can be termed as Stand-alone (SA) or Grid-connected (GC). GC systems are of two types. The priority of one type of system is to supply to the local needs and any excess power would be sold/fed to the grid. An example for this system is grid connected house-hold solar roof-top systems. The second type is similar to large electric power plants but with smaller installed capacity. These decentralized stations feed power to the grid with no consideration to the needs of local people. MW range wind power plants are examples for this type of systems. Apart from initial setup costs, GC systems should also consider the cost of interfacing to the grid (Yadoo 2012).

In contrary to the GC systems, as name suggests SA systems are independent of the grid. These systems are most suited for remote locations where grid penetration is not possible. As they are not connected to the grid, they require a storage facility. Batteries are most commonly used storage systems to store electricity when there is excess generation or when there is low demand. Stored energy is supplied back to the system when there is low/no generation or to normalise peak demand (Yadoo 2012).

2.4 Regional Planning for Sustainable development:

The meaning of sustainable development changes with the field of application and the geographical location in consideration. Systematic planning is the key for attaining sustainable regional development. Scientifically approved understanding of sustainability has to be established hand-in-hand with regional priorities and interests of local stakeholders. This should be the guiding principle for future developments in innovation and technology for regional development (Varga, Kuehr 2007).

Marten and Ruediger (2007) in their summary paper on “Integrative approach towards zero emission regional planning” explains successful criteria for sustainable regional development as follows:

i. Local motivation and participation – this could be achieved by giving ownership to the local people, though planning is done from outside.

ii. Principles of sustainable development should be made clear – As the planning process involves many stake-holders, it is important to establish common understanding of sustainability.

iii. Strategic planning is important for successful implementation of initiatives

iv. Implementing initiatives with utmost importance on quality in line with final goals - which means, care has to be taken while implementing - to assure quality because most of the sustainable concepts only support, development and planning.

v. Monitoring plan to ensure sustainability – As regional development is an ongoing phenomenon, continuous monitoring and change in process is important to motivate new stakeholders. This requires development of monitoring tools.

2.5 Municipalities and Renewable Energy

Municipalities are the local administrative units of India. It is one of the four urban local bodies constitutionally classified to decentralize the power and strengthen democracy at local level (Tiwari 2002). They consists of population in the range of 40,000 to 300,000 inhabitants in the state of Andhra Pradesh (Government of AP 2011b). Municipalities in various parts of the world are taking a step forward to maximize the share of renewable supplies in their energy mix. Some have even gone to the extent of having 100% renewable energy supply. They identified the potential of such projects in mitigating climate change, strengthening local economy and job creation (Schönberger 2013). A report from REN21 states that cities and regional governments can significantly influence the implementation of renewable energy in local energy generation mix. With the political mandate they can be ideal drivers of change. This can be accomplished by conducting programs to increase awareness, introducing incentives for local entrepreneurs and having a dialogue to bring different stakeholders together (REN21 2009).

Local governments in municipality can organize community based energy planning (CEP). CEP when done correctly can result in sustainable development of municipalities giving following benefits: (Natural Resources Canada 2009)

- Utilization of regional resources to produce energy, thereby reducing energy costs in long-term and increase energy security,
- enable communities to have better control on their energy systems and thereby giving opportunity to plan their future needs,
- the ability to establish long-term energy use and efficiency goals and better predict their future energy costs,
- reduction in emission with investment in environmentally sound technologies,
- increased employment opportunities for local citizens.

Thus energy projects when implemented and managed properly can improve the local conditions of the region.

2.6 Zero-Emission Strategy

The basic idea behind any "zero emission strategy" is to close the material and energy flows completely. There are two ways of achieving it: a) using materials as the basis for new products, within relevant industrial/ business/ life cycles, and b) returning materials – completely – in natural form, to their natural substance cycles. The aim of ”zero emissions“ provide the basis for innovative management concepts – for companies, and for all relevant levels, from individual companies to industrial / commercial parks and to entire municipalities, cities and regions. Most of the products and fuels required by the region are delivered from outside the region (from National or International sources) leading very low or no value creation in the region. Zero emission strategies call for recognizing the regional available potential. Figures-6&7 shows the change in metabolism of a region on application of MFM.

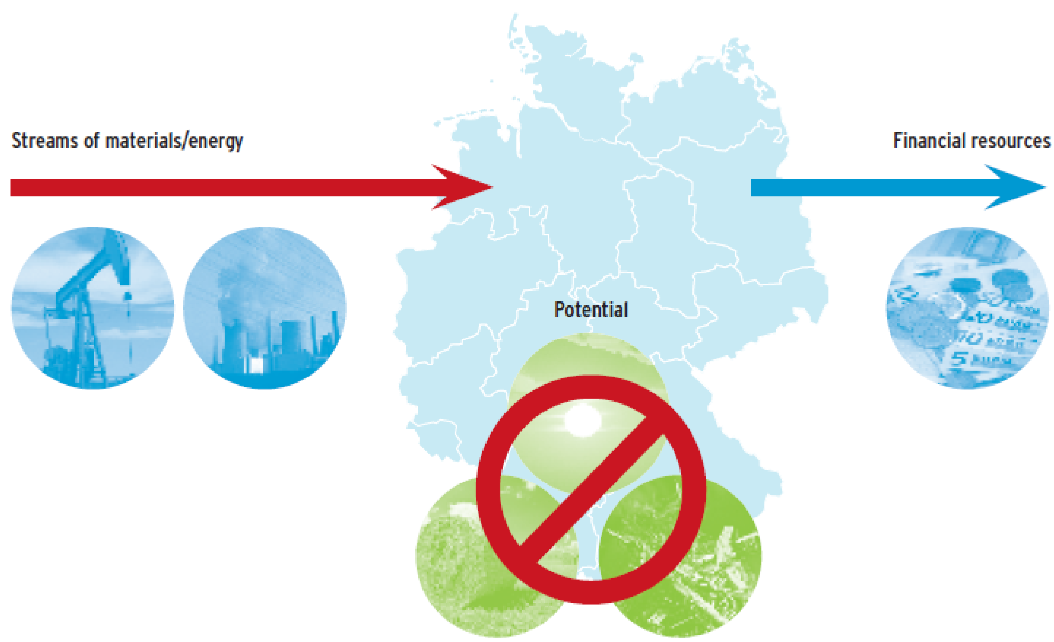

FIGURE 6: NO “MATERIAL FLOW MANAGEMENT” – REGIONAL VALUE CREATION DOES NOT STAY IN THE REGION.

Source: (BMU Germany 2009)

Potential assessment should be carried out using scientifically approved methodology to understand the metabolism of the system in its current state. This process is called material flow analysis which results in the clear understanding of all material (and energy) flows of the system (BMU Germany 2009).

Following options can be considered for analysis:

- Municipal solid waste which includes waste resulting from households, public & private operations within the system,
- Wastewater for energy and nutrient recovery, and left over residues (for e.g. sewage sludge) after treating wastewater,
- Biomass generated from agricultural production, and organic waste from cattle breeding
- Greenery waste from forests and landscape management,
- Renewable energy potentials of the region
- Energy flows that are not being utilised currently such as waste heat

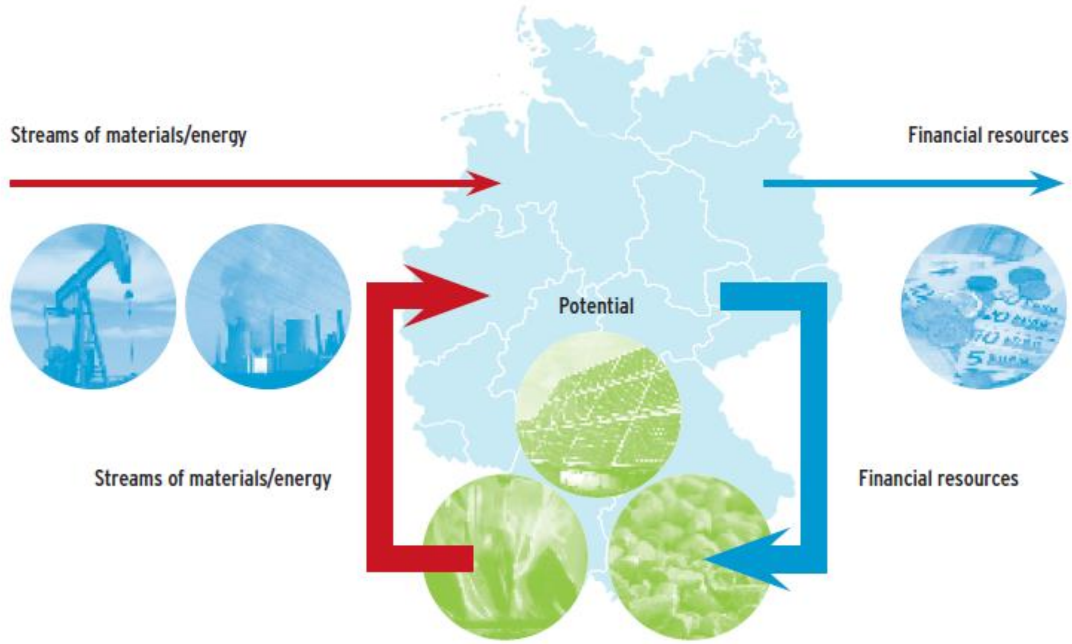

FIGURE 7 "MATERIAL FLOW MANAGEMENT" – REGIONAL VALUE CREATED STAYS IN THE REGION

Source: (BMU Germany 2009)

The above mentioned options can be used to start the analysis. MFA starts with large material streams on the regional level to understand the metabolism of the region. Based on the result of this step, analysis is taken to the next lower level focussing on certain flows. This analysis is carried out step by step down to individual processes involved in the material flows.

This analysis will result in the identification of potentials, important stakeholders in the region and probable sponsors for the implementation of projects. The potentials thus identified are converted to project ideas after brain-storming within the MFM team. Relevant projects are finalized on consultation with stakeholders. All the results of analysis are aggregated into material-flow-management master plan. The master plan defines business plans for the various individual projects and measures, and it serves as a guide and navigator for a zero-emissions strategy (BMU Germany 2009).

When a region's material and energy streams are closed, the region's related financial streams remain within the region. With efficient management of material flows, products and services can be offered more reasonably, with no job losses still resulting in higher capital-inflows. Savings resulting from reduced energy consumption, directly benefits regional economic cycles. "Zero emissions" is thus much more than just a new approach in environmental and climate protection. "Zero emissions", and the related idea of a complete close-cycle economy, provide the basis for sustainable economic and industrial policies. Thus resulting in promotion of innovation-related modernisation, which aims to promote specially small and medium-sized enterprises (SME) (BMU Germany 2009).

2.7 Biomass potential in India and available technologies

India being agriculture based country has high availability of biomass. It is one of the important sources of energy for domestic and industrial requirement in the country. Biomass is used as domestic cooking fuel most commonly in rural parts of India. In addition to this, it also serves on a small scale as fuel for industries and in power production. The biomass resources in India are estimated to be about 500 million metric tons per year as of 2011. Ministry of New and Renewable Energy, India

(MNRE) estimated to have a potential of 18,000 MW from agricultural and forestry residues alone in India, which correspond to around 25% of total biomass (MNRE - India 2011). As of August 2012, the total installed electrical capacity of biomass and bagasse power plants is 3,587 MW (Central Electricity Authority 2012). It is evident from above data that biomass to energy has high potential in India, yet being under used. It can be a significant contributor to power sector, especially in satisfying electricity demands of rural India. Various activities involved in this sector can trigger jobs and can have positive impact on the villagers (Rajkumar 2005). Unlike other renewable energy technologies, biomass projects create more non-technical jobs for the villagers helping them in earning their livelihoods.

In order to activate the biomass potential and increase the utilization effectively, Government of India provides various fiscal incentives for project developers. Table2

Item	Description
Accelerated Depreciation	80% depreciation in the first year can be claimed for the following equipment required for co-generation systems: 1. Back pressure, pass-out, controlled extraction, extraction–cum-condensing turbine for co-generation with pressure boilers 2. Vapour absorption refrigeration systems 3. Organic rankine cycle power systems 4. Low inlet pressures small steam turbines
Income Tax Holiday	Ten years tax holidays.
Customs Duty	Concessional customs and excise duty exemption for machinery and components for initial setting up of projects.
General Sales Tax	Exemption is available in certain States

TABLE 2: FISCAL INCENTIVES FOR BIOMASS POWER GENERATION

(Source: (MNRE Biomass 2014))

shows the list of such incentives. Apart from them, few others are briefly explained as follows. Capital subsidy is given one time during the installation of the project. Amount of subsidy varies depending on the type and size of the biomass power plant. Other important type of incentive is renewable energy certificates (REC), which are issued to power producers if they feed-in power to the grid at a tariff fixed by the state government in the region of their installation. RECs can be traded in a special market to raise additional capital for the project. Comes next is the most common type of incentive available globally, which is under Clean Development Mechanism (CDM). Eligible projects that are registered under CDM receive carbon reduction certificates termed as Certified Emission Reductions (CER). These CERs can provide additional revenues to sustain the project (MNRE - India 2011). More detailed explanation of CDM projects is provided in sections to follow.

Power generation by Combined Heat & Power (CHP) systems, using biomass as input are seeing rapid growth in India. Biomass is also being widely used as additional fuel in coal-fired power plants. These plants are referred to as coal/biomass co-fired power plants. Most of the biomass needs for these industries can be met by resources within the local reach. However, in case of large power plants, biomass is collected and transported from other regions (MNRE - India 2011).

Combustion is the most widely used technology in India for generation of power/heat using biomass. Various projects in the country illustrated that this technology is economically viable for sizes between 5 $MW_{Electric}$ to 35 $MW_{Electric.}$ A wide range of agricultural residues are currently being used as input to these power plants, which include residues from sugarcane, rice etc. However, the major challenge identified for this sector is securing the supply of biomass feed-stock in long term. Sector is also lacking clear incentives and special recognition from the government (MNRE Biomass 2014).

Appropriate technology should be selected based on the type of biomass to be processed and the size of the plant desired.

2.8 CDM FOR SUSTAINABLE DEVELOPMENT

Renewable energy projects reduce the emission of GHGs. If the project can be registered under Clean Development Mechanism (CDM), it can gain additional income from carbon credits, which may make project financially attractive. UNFCCC facilitates the trading of such credits to help the Annex-I countries to achieve their voluntary emission reduction targets agreed upon in Kyoto Protocol. Similarly, Program of Activities (PoA) provides the organizational and methodological framework to bundle various projects with similar goal within a single registered CDM program activity (UNFCCC 2012b). This approach helps in reducing the transaction costs and administrative workload for the project developers.

As defined by the UNFCCC,

"*A CDM programme of activities (PoA) is a voluntary coordinated action by a* *private or public entity which coordinates and implements any policy/measure or stated goal (i.e. incentive schemes and voluntary programmes), which leads to anthropogenic GHG emission reductions at source or net anthropogenic greenhouse gas removals by sinks that are additional to any that would occur in the absence of the PoA, via an unlimited number of CDM Program Activities (CPAs)*" (UNFCCC 2012b).

In recent years, government of India (MNRE) perceived clean development mechanism program of activities (CDM PoA) "as a new window that can be taken up to induce sustainable development and promote renewable energy technologies particularly pertaining to households, small enterprises and rural areas in India" (MNRE-Govt of India 2009). Following Table 3 depicts some of the recent PoAs registered from India at UNFCCC.

Project title	Year of registration	Awarded CERs
Programmatic CDM for Promotion of Solar Power Generation in India	2014	7905
Energy efficiency through Micro irrigation system	2013	3473
Greenlight solar PV lighting	2012	56,397
Solar water heating program	2012	31,500

Improved cooking stoves program	2012	11,005

TABLE 3: LIST OF SELECTED REGISTERED POAS FROM INDIA

Source: (UNFCCC 2014)

This shows the growing interest towards sustainable projects in India, but still there is a long way to go.

2.9 Energy Savings:

As discussed in the introduction chapter, the residential and commercial buildings have the great potential in saving energy. The top 10 priorities for Energy efficiency, according to "2020 vision" of European Union (European Commission, Directorate-General for Energy and Transport 2007) are:

i. Performance standards and labelling of products
ii. Building performance and low-energy houses
iii. More efficient power generation and distribution
iv. Fuel efficiency of cars
v. Finance for energy efficiency investments
vi. Energy efficiency in new EU member states
vii. A coherent use of taxation
viii. Awareness
ix. Energy efficiency in cities

x. Energy efficiency worldwide

Though the priorities may differ incase of an Indian municipality, most of them are important and relevant. The main priority would be to raise the awareness in people about the importance of energy efficiency.

The major sectors that can be considered for energy savings in a municipality are: agricultural activities, municipal water and sewage supply, street lighting, commercial buildings, small and medium enterprises (SME). The study in 2007-2008[3] identified the conservative potential for savings is about 15% of the electricity consumption in India (National Productivity Council 2009). Thus energy conservation also plays a major role in providing energy security. However, analysing energy saving options in detail is beyond the scope of the paper.

2.10 Conclusions drawn

The energy security for Gudur municipality is to guarantee the sustainable supply of electricity without brown outs or black outs. Since electricity is necessary to carry out all the business and agricultural operations, water purification and supply to house-holds, and other services such as street-lighting, functioning of Government offices

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[3] Due to advancement of technology and increased awareness in the field, the current savings potential from energy efficiency improvement could be much higher than 15%.

etc. the energy availability will enhance the living standards of the people in region. As the major portion of electricity supply currently for the region is fossil based (Coal based thermal power) and the energy prices keep hiking each year having additional burden on the people of the region.

The paper proposes the sustainable energy projects for the region using the resources of the region, it reduces the dependence on the fossil energy and thereby there will be decrease in the energy prices after few years of implementing the projects. Material flow analysis shows all the material flows in the region both existing and inactive flows. This analysis helps not only in identifying the sustainable energy projects but also realising other flows that can be activated to add value to the region. The other aspect of MFA is stakeholder analysis, this can help in forming key stakeholder network and results in improving regional synergy.

Biomass potential of the region will be analysed and suitable technology would be identified for energy production. One-size-fits-all solution is not feasible for any region, therefore a master plan should be developed based on resources identified during material flow analysis.

Government of India has identified the importance of developing renewable energy projects as key move to enhance energy security and capacity building of the regions and country as a whole. There is a need to understand policies and various incentives in place for such projects. The developers need to make use of the advantages being offered for sustainable projects, which can make the projects even financially attractive for investors. CDM can be an option for all the renewable energy projects as all these projects results in emission reduction compared to the baseline scenario. Close networks have to be developed within the region to educate end users about the potential of energy savings and methods to carry out the same.

Chapter 3: GUDUR MUNICIPALITY

Gudur municipality is located in Sri Potti Sree Ramulu Nellore district. Nellore is the Southern most coastal district in the state of Andhra Pradesh, in India. Figure-8 depicts the location of Gudur municipality.

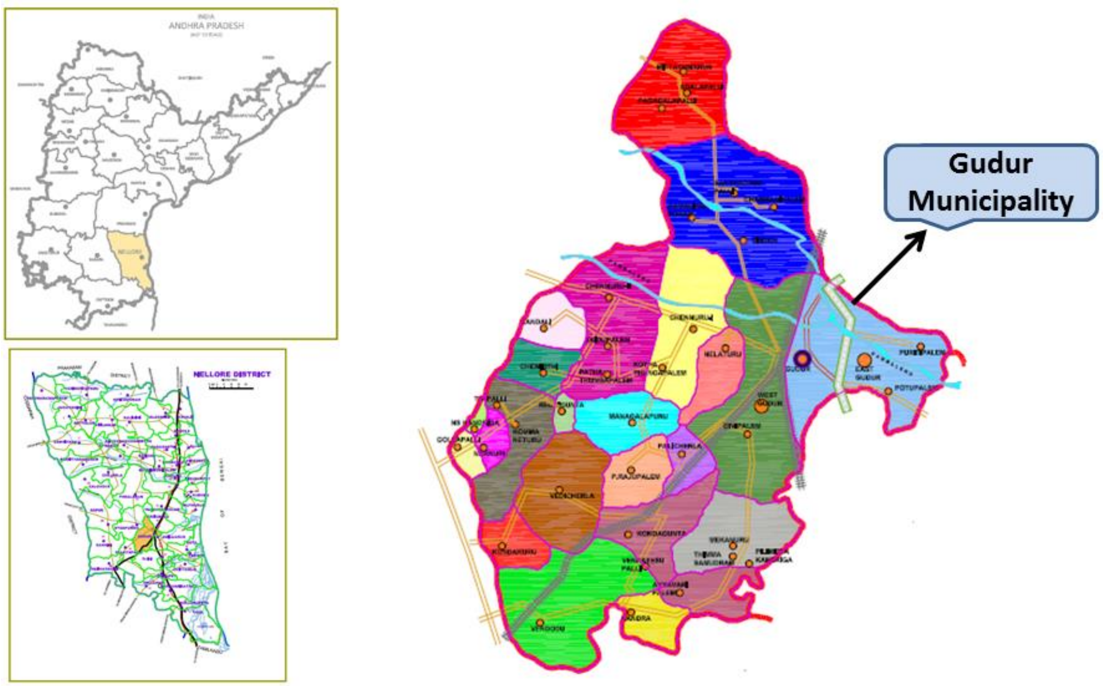

FIGURE 8: AREA MAP SHOWING ANDHRA PRADESH, NELLORE DISTRICT & GUDUR MANDAL - HIGHLIGHTING GUDUR MUNICIPALITY

Source: Based on (Government of AP 2014a)

It is formed in the year 1954, shortly after independence (in 1947) from British rule in India. Municipality is spread geographically in the area of 9.14 km^2 and has a population of 73,617 as per census in 2011. Municipal council is the responsible local administration body in municipality (Government of AP 2011a). Paddy (rice) is one of the principal crops grown in the region (Government of AP 2014b). The area map in Figure 8 shows the municipality of Gudur as well as surrounding villages, collectively called Gudur Mandal. The current situation of electricity (supply & demand) and resource potential analysis is carried out in sections to follow.

3.1 Electricity Situation

The Gudur municipality is divided into two parts, Town-I and Town-II for the supply of electricity. Data collection is done by consulting, concerned grid maintenance engineer. As data is not computerized yet, it was not possible to get the historical data beyond past one year. Figure 9 below shows the monthly electricity consumption of Gudur municipality for past one year. Electricity supplied per annum is calculated to be 36,355.7 MWh/year or 36.36 GWh/year.

As per central electricity authority report, the state of Andhra Pradesh has an annual deficit of 6.9% in supplying the required electricity for the year 2013-14. The deficit is expected to go upto 15.3% for the upcoming year 2014-15 (Central Electricity Authority 2014).

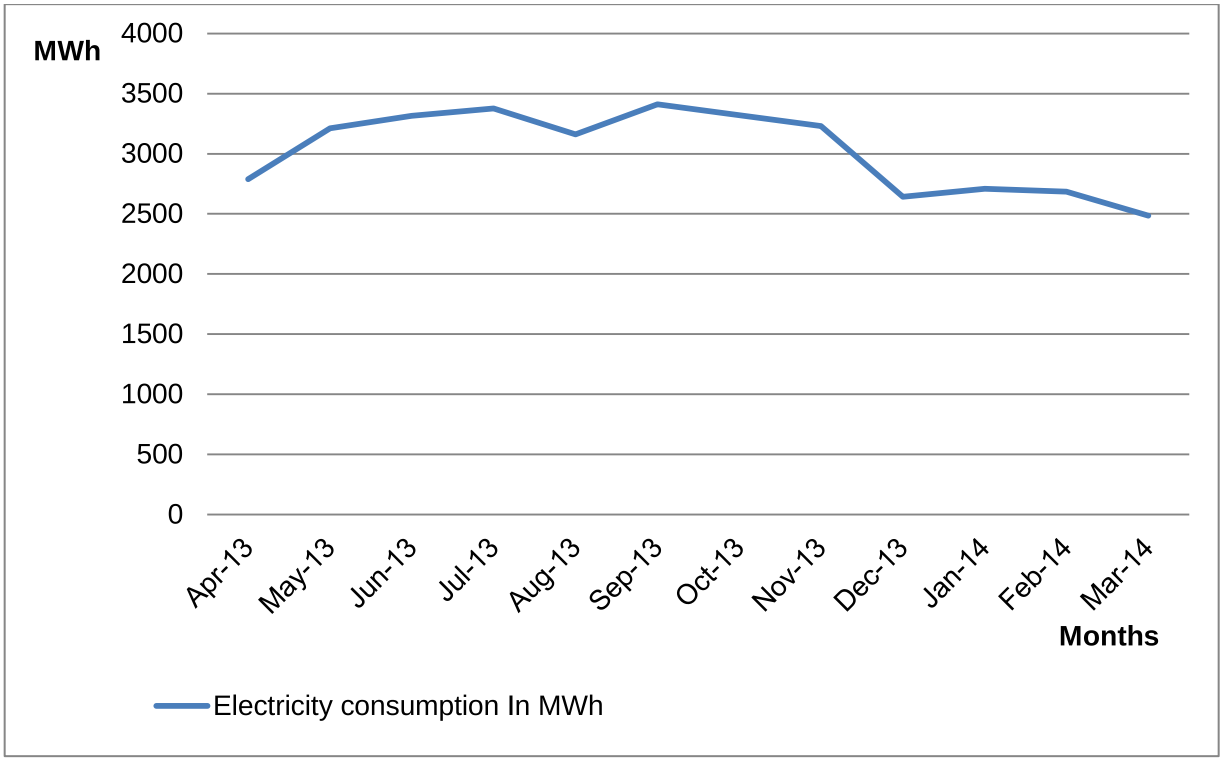

FIGURE 9: ELECTRICITY CONSUMPTION IN GUDUR MUNICIPALITY 2013-14

Source: Author's illustration

Table-4 below shows the monthly deficit of electricity in the state of Andhra Pradesh for the year 2013-2014.

Month	**Deficit in %**
April-2013	17.20
May-2013	15.40

June-2013	11.40
July-2013	9.60
August-2013	0.40
September-2013	0.70
October-2013	3.80
November-2013	0.30
December-2013	1.60
January-2014	3.80
February-2014	7.50
March-2014	7.90

TABLE 4: MONTH-WISE ELECTRICITY DEFICIT (%) IN ANDHRA PRADESH (2013-2014)

Source: (Central Electricity Authority 2014)

Using the data in above Table-4, the actual demand can calculated using below relation,

$$\text{Demand} = \text{Supply} + (\text{Supply} \times \%\ \text{Deficit})$$

Therefore, electricity demand curve for Gudur municipality is given as follows in Figure 10. To be on conservative side, an average deficit of 10% is considered to estimate the actual demand of Gudur Municipality. This leads us to the total electricity demand of 39.99 GWh/year

36,355.7 MWh/year + (36,355.7 MWh/year x 0.1) =

39,991.2 MWh/year or 39.99 GWh/year

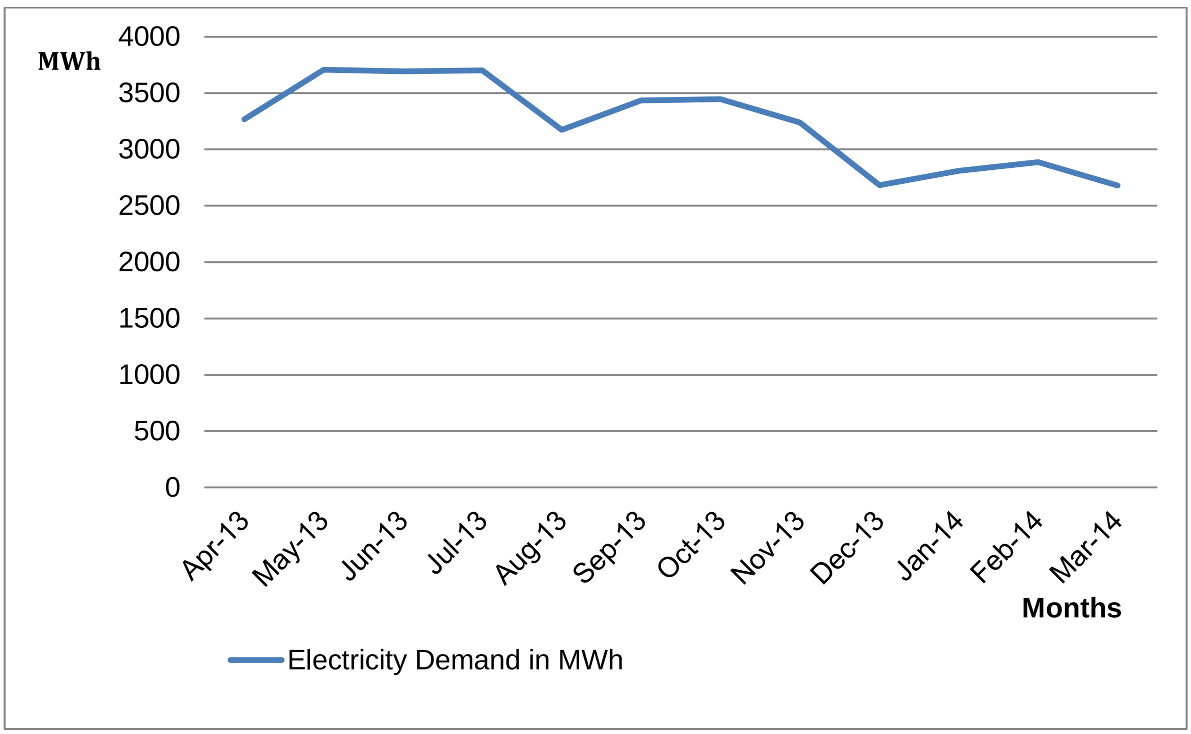

FIGURE 10: ELECTRICITY DEMAND IN GUDUR MUNICIPALITY 2013-14

Source: Own Illustration

Apart from energy aspect, 10% deficit should also be seen in social perspective. It is equivalent to having no power supply on an average of 2.5 hours a day. This can have huge impact on businesses and social life of people in the region. Individuals that can afford, have the battery-backed-up inverter systems which are used to run minimum required equipment such as lamps, fans. These systems are often environmentally unfriendly, manufactured with no quality control, resulting in poorer efficiency.

Gudur is connected to state electricity grid, which in turn falls under Southern Grid of India. The grid emission factor (Combined margin) ($EF_{Grid,CM}$) for Southern grid in India is given as 0.91 tCO_2/MWh in the latest CO_2 baseline database, 2013 prepared by CEA for CDM project developers (Central Electricity Authority 2013). Using this emission factor, total CO_2 emissions that can be attributed to the current electricity consumption of Gudur municipality is 33,083.7 tCO_2/year.

$$\text{Total } CO_2 \text{ Emissions} = \text{Electricity supplied x } EF_{Grid,CM}$$

$$36{,}355.7 \text{ MWh/year x } 0.91 \text{ } tCO_2\text{/MWh} = 33{,}083.7 \text{ } tCO_2\text{/year}$$

Generation of electricity using renewable energy resources has the potential to mitigate these huge emissions, as they generally have very low or no net CO_2 emissions. Potential analysis of identifies renewable energy streams is carried out in the sections to follow.

3.2 Resource Potentials and Electricity Generation

As part of the field research, various material flows are analysed in the region of Gudur. The main focus is restricted to three major flows of the region namely, agricultural residues, Municipal Solid Waste (MSW) and solar energy potential. To be more specific:

- Rice cultivation alone is considered in analysing agricultural residues as rice is the major crop of the region
- Organic portion of municipal solid waste of Gudur municipality is considered when dealing with waste sector. The boundary for waste is restricted to Gudur municipality area.
- Due to lack of data related to roof-top area and the complexities involved in realising non-shaded roof-top area of houses in the municipality, solar energy potential is calculated for free areas, non-agriculture lands, which are under governmental control.

3.2.1 Rice Residues to Energy

As mentioned in introduction to this chapter, rice is the most cultivated crop in the region. Due to this fact, there is a potential for energetic utilization of agricultural residues from rice cultivation. The residues available are rice husk and rice straw (Lim et al. 2012).

From various studies available, the relation between rice husk and straw to the yield of rice is chosen as follows:

Rice Straw: 1.53t (tons) per ton of grain produced

Rice husk: 0.33t per ton of grain produced

The above relation is considered to be appropriate as it is chosen from a recent study based in India (Purohit 2009). In total, 1.88t of residue per ton of grain produced is available.

$$1.53\text{t/ton of grain} + 0.33\text{t/ton of grain} = 1.88\text{t/ton of grain produced}$$

Since biomass has different applications in developing countries such as cattle feeding, roof thatching, composting etc, (IARI 2012) 50% can be considered to be available for recovery. Therefore total residue available for recovery per ton of grain produced is 0.94t.

As per records, total agricultural land Gudur Mandal[4] (Shown in Figure 8) is 10,396 Ha. 5000 Ha is considered for the study considering the fact that, common practice in the region is to leave the residues on farm to help improve soil condition. Residues are collected once in 2 years from each land. Average grain yield per hectare in the region (Nellore district) is 4473 kg/Ha (Cheralu C 2010). Therefore total grain produced per year in the region is 22,365 ton/year.

$$5000\text{ Ha} \times 4473\text{ kg/Ha} \times 1/1000\text{ ton/kg} = 22{,}365\text{ t/year}$$

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[4] Mandal is Gudur municipality and surrounding villages

Total agricultural residue available in the region is 21,023 t/year.

22,365 t/year x 0.94 t/ton of grain = 21,023 t/year.

Currently, most of the residue is left on the field or burnt to clear due to lack of alternative economically viable solutions and clear incentives. On-field burning of residues also leads to particulate emissions and release of greenhouse gases such as CO_2, Methane (CH_4) and Nitrous Oxide (N_2O). Smoke released due to biomass burning is found to be one of the major causes for respiratory diseases in rural India (IARI 2012).

Thus, residues when alternatively used for energy generation by applying appropriate technology can have economic, social and ecological benefits for the region. The stored chemical energy in biomass can be converted to heat energy on combustion. Energy content of biomass is given by its heating value and higher heating value (HHV) of rice husk and straw is given as 15.46 MJ/kg or 0.0155 TJ/t (B.M. Jenkins et al. 1998). Therefore, total energy content of the rice residues in Gudur region is 326 TJ/year.

21,023 t/year x 0.0155 TJ/t = 325.85 TJ/year

326 TJ/year / 3.6 TJ/GWh = 90.55 GWh/year

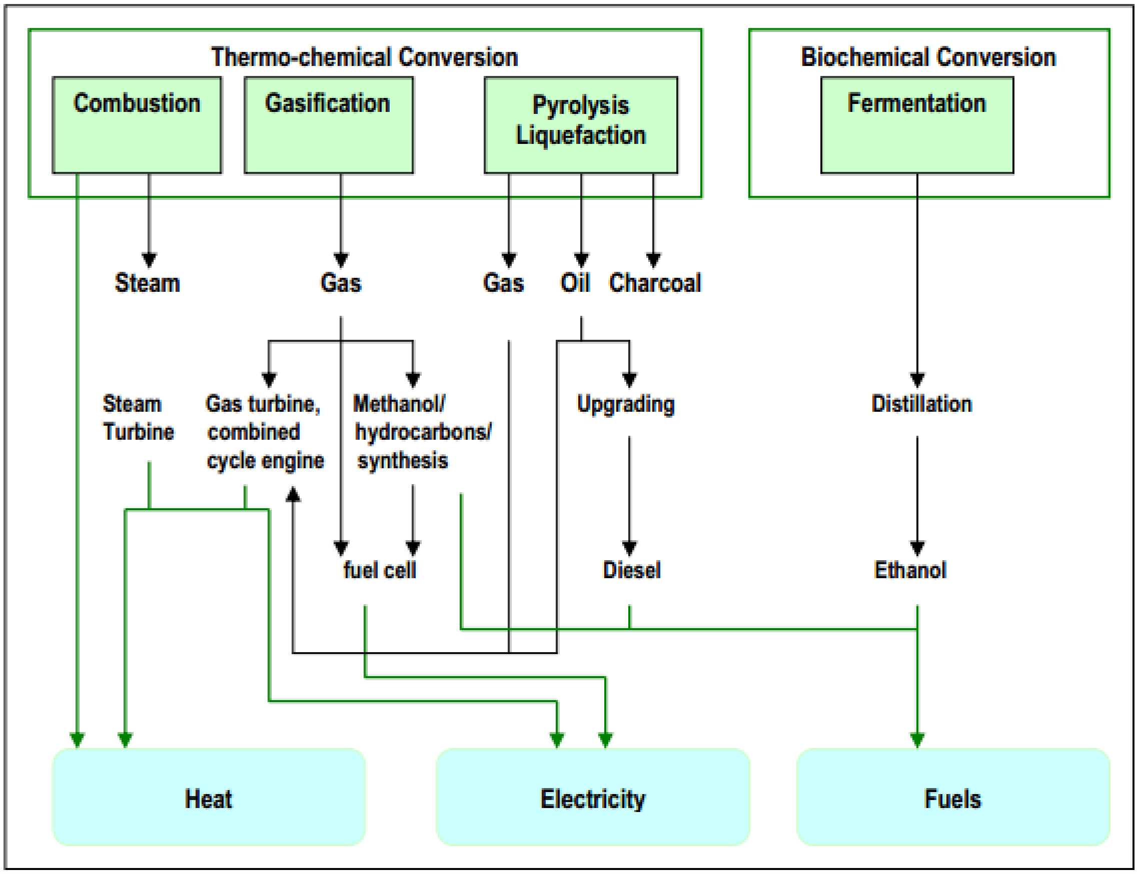

FIGURE 11: WAYS FOR ENERGETIC UTILIZATION OF AGRICULTURAL RESIDUES

Source: Taken from (UNEP 2009)

Figure 11 above depicts the options available for utilization of agricultural biomass waste for energetic utilization. Route to be followed depends on characteristics of biomass and the end product desired. As the scope of current paper is to look for options to generate electricity, combustion of residues is chosen for further calculation. In recent years, CHP systems proved to be more effective than conventional combustion systems. CHP has overall efficiency of 85%, out of which

40% electrical efficiency and 45% thermal efficiency based on lower heating value (LHV) (Martínez 7/1/2014). Therefore the total useful energy generation potential from rice residues based on HHV can be considered as 30% electrical and 35% thermal. Which is 27.165 $GW_{Electric}$/year and 31.69 $GW_{Thermal}$/year

$$90.55 \times 0.30 = 27.165\ GWh_{Electric}/year$$

$$90.55 \times 0.35 = 31.69\ GWh_{Thermal}/year$$

Electrical energy can be fed into power grid. Rice residues used in the project are collected at end of harvesting season[5] and to be stored for rest of the year. Thermal energy can be used for drying rice residues before storage to avoid fouling and enhance their durability as they are collected once a year during harvest and have to be preserved to use throughout the year. Alternately, thermal energy can be used in adsorption cooling systems to generate cooling for industry or large commercial buildings in the municipality. However, analysing the thermal energy utilization in detail is beyond the scope of this paper. Only, electric energy output is analysed further in detail to find out the installed capacity of the system being proposed.

A CHP plant is assumed to be operated on an average for 90% of the time in a year taking into account the maintenance activities and other activities leading to 10% down-time. This accounts to system operating time of approximately 7800

[5] Major portion of Gudur region has only one harvesting season per year

hours/year. Electric installed capacity of the system can be calculated to be 3.48 $MW_{Electric}$.

$$27.165 \text{ GWh/year} \times 1000 \text{ MWh/GWh} \;/\; 7800 \text{ hours/year} = 3.48 \text{ MW}_{Electric}$$

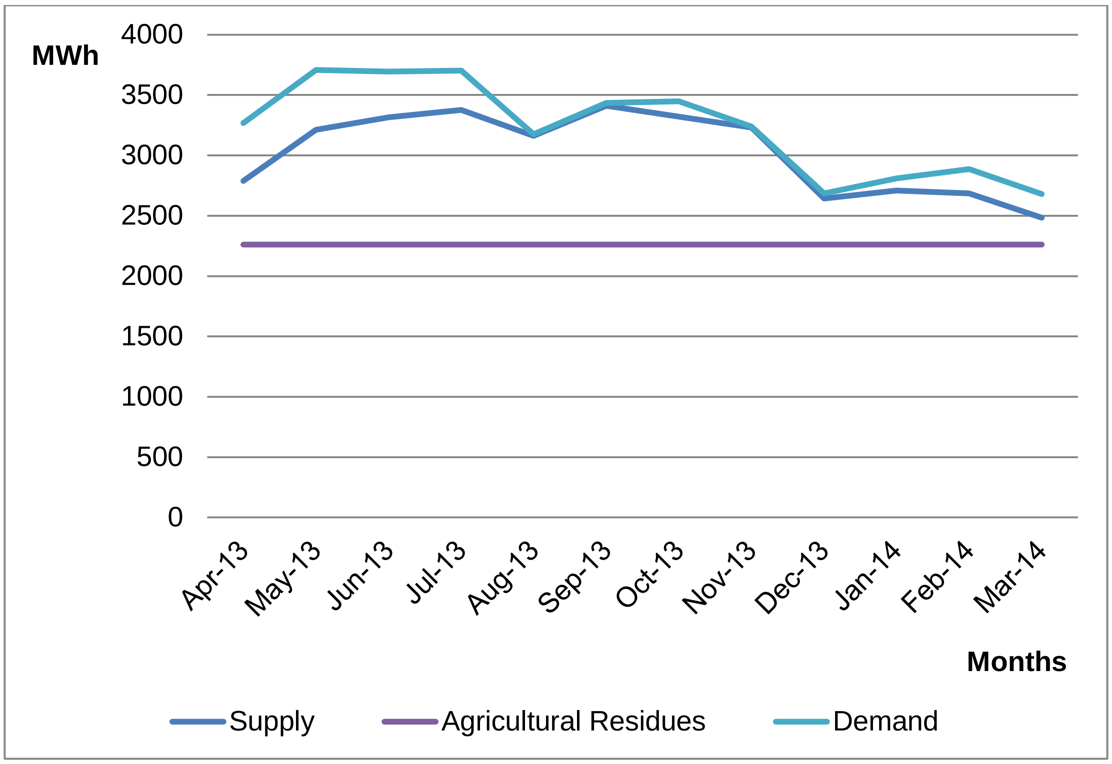

FIGURE 12 CURRENT ELECTRICITY SUPPLY & DEMAND AND ELECTRICITY PRODUCED FROM AGRICULTURE RESIDUES

Source: Own illustration

The Figure-12 shows the demand, supply and electricity generated from agriculture residues. It can be seen that 74.7% and 67.9% of current supply and demand respectively, be satisfied with electricity produced from rice residues.

3.2.2 SOLAR ENERGY POTENTIAL

Gudur municipality, located at 14° 8' 0" North latitude and 79° 51' 0" East longitude receives an average solar radiation of 5.095 kWh/m^2/day or 1860 kWh/m^2/year. Figure 13 below shows the monthly variation of average solar radiation available per day in Gudur region (Synergy Enviro Engineers 2014).

As mentioned in the introduction of this chapter, barren & uncultivated land alone is considered for calculating solar energy potential. There is 1586 Ha waste land in Gudur Mandal, out of which 87 Ha is present directly in Gudur municipality.

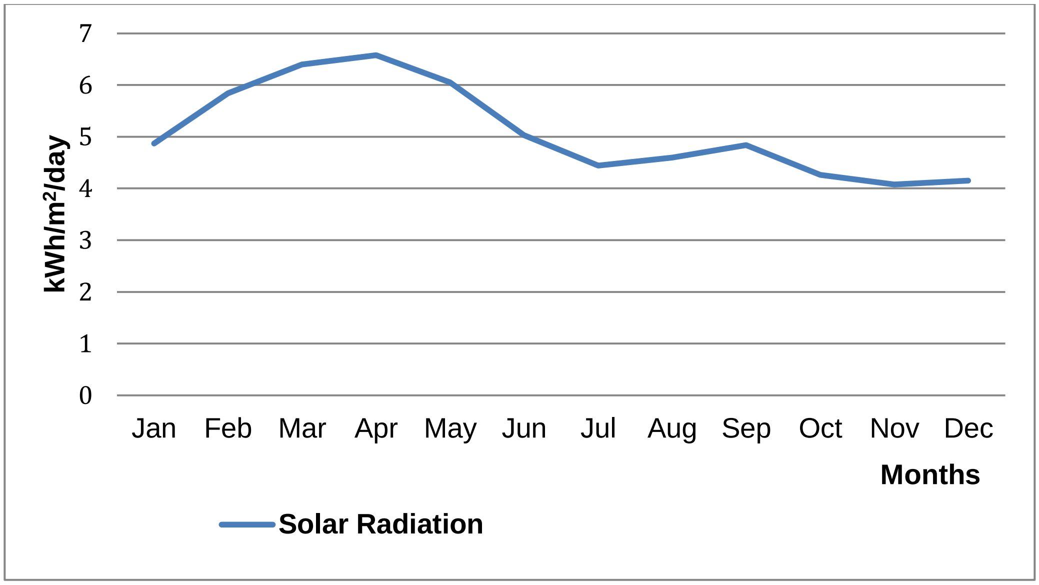

FIGURE 13: MONTHLY VARIATION IN SOLAR RADIATION IN GUDUR REGION

Source: Own graphic based on (Synergy Enviro Engineers 2014)

This accounts to the total theoretical area of 870,000 m^2 in the surroundings of Gudur. However due to certain barriers, the total area that can be considered available for solar PV installation is 15%. The barriers identified are land ownership, topological, geographical barriers, availability of land at single location etc. This results in available area of 130,500 m^2.

Total theoretical solar energy available on chosen area of 130,500 m^2 of waste and barren lands in Gudur region with average solar irradiation of 5.095 $kWh/m^2/day$ or 1860 $kWh/m^2/year$ is 242.73 GWh/year.

$$130{,}500 m^2 \times 1860\ kWh/m^2/year \times 10^{-6}\ GWh/kWh = 242.73\ GWh/year$$

Solar photovoltaic (PV) system uses solar cells to convert light energy from sun (Irradiation) to electricity. When the area is covered with PV modules, depending on the latitude of the region, the panels would have to be oriented and inclined to give maximum yield. This may require to increase the distance between rows of panels to avoid shading (Christian Synwoldt 12/15/2013). Considering these factors, 80% of estimated available area is said to be covered with solar panels and can generate electricity. Apart from this, solar cells have an electrical efficiency of approximately 10%. These factors lead us to the total electricity generation potential from solar PV system in the region to be 19.42 GWh/year.

$$242.73\ GWh/year \times 0.80 \times 0.1 = 19.42\ GWh/year$$

Considering 8 m^2 area, required for 1 kWp installation the capacity of the SPV power plant is approximately 13.05 MW_p.

$$130{,}500 \text{ m}^2 \times 0.8 / (8 \text{ m}^2/\text{kW}_p) = 13{,}050 \text{ kW}_p$$

The proposed SPV system can displace up to 50% of the total electricity demand of Gudur municipality. Monthly variation of solar energy generation from proposed project is shown in Figure-14 below.

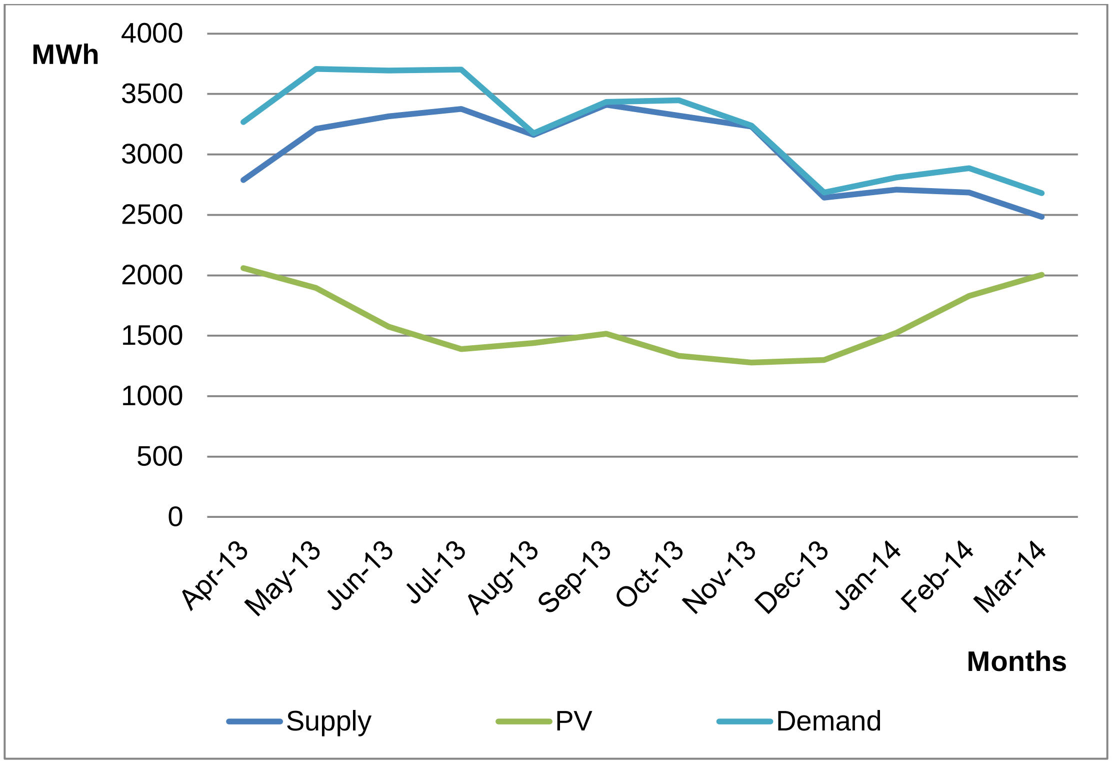

FIGURE 14: CURRENT ELECTRICITY SUPPLY & DEMAND AND ELECTRICITY PRODUCED FROM SOLAR PV

Source: Author's graphic

3.2.3 MUNICIPAL SOLID WASTE

As per the field research results, Gudur municipality on an average generates 45 tons per day (TPD) of solid waste, out of which approximately 30 tons is collected and disposed to open dump site by municipal council. Department does not have records for the composition of the waste. Hence, composition of Municipal Solid Waste (MSW) is taken from a recent study (Annepu 2012) conducted on Indian solid waste sector as this is an extensive study focusing on all types of cities and towns in the country. The study divided MSW into three categories Compostables, Recyclables and Inert materials and provided their respective composition in MSW. This composition is considered to be appropriate for our current case of Gudur. Table-5 below shows the components in different categories of waste and their composition by weight in south India and corresponding amount (in tons) calculated for Gudur municipality.

MSW Components	Materials	Percentage by weight	Collected in Gudur municipality (tons/year)
Compostables	Food waste, land-scape, and tree trim-mings	53.41%	5848.4

Recyclables	Paper, cardboard, plastics, glass, metals	17.02%	1863.69
Inerts	Stones and silt, bones, and other inorganic materials	29.57%	3237.9

TABLE 5: COMPONENTS AND THEIR COMPOSITION IN MSW IN SOUTH INDIA

Source: (Annepu 2012)

As the above composition is calculated at dump site and not at generation point, this gives the as-is amount of organic waste in MSW of Gudur. The organic content of waste alone is considered for the scope of this study, which amounts to 5848 t/year.

Total waste collected per year = 30 TPD x 365 = 10,950 t/year

Organic waste per year = 10,950 t/year x 53.41% = 5848 t/year

According to a study from German Environmental Ministry, anaerobic digestion of one ton of organic waste has a potential to yield 80 to 140 cubic meters (m^3) of biogas depending on quality of the input material (BMU Germany 2012).

A conservative value of 110 m^3 of biogas yield per ton of organic waste is considered for this study. Total biogas that can be produced from organic content of MSW is 643,280 m^3/year.

$$5648 \text{ t/year} \times 110 \text{ m}^3 = 643{,}280 \text{ m}^3\text{/year}$$

Biogas has a Methane (CH_4) content of 50-65 percent. CH_4 has the energy content of 9.97 kWh/m3 (BMU Germany 2012). Assuming CH_4 content of 60% in biogas, total energy content of MSW is equal to 3,848,101 kWh/year

$$643{,}280\ m^3/year \times 0.6 \times 9.97\ kWh/m^3 = 3{,}848{,}101\ kWh/year$$

The energy calculated above is potential energy content of biogas and it needs to be converted to electrical energy using a CHP plant. Cogeneration plant combusts biogas as input fuel and produce heat and electricity. As seen in previous section, overall efficiency of CHP plant is 85%, which is combined electrical efficiency of 40% and thermal efficiency of 45% (Martínez 7/1/2014).

From the total available potential of 3,848,101 kWh/year of from organic portion of MSW, 1,539,240.4 $kWh_{Electric}$/year units of electricity can be generated.

$$3{,}848{,}101\ kWh/year \times 0.4 = 1{,}539{,}240.4\ kWh_{Electric}/year$$

Assuming CHP plant operates for 90% of time in a year, which accounts to approximately 7800 hours/year, the installed electrical capacity of CHP plant is calculated as 197.3 $kW_{Electric}$.

$$1{,}539{,}240.4\ kWh_{Electric}/year\ /\ 7800\ hours/year = 197.3\ kW_{Electric}$$

This gives the total technically possible electricity potential of organic MSW in Gudur municipality considering as-is situation. It can be noticed from Figure 15 below that, electricity produced from anaerobic digestion of MSW is approximately

4% of the total demand which is significant. MSW considered is from the dump site of Gudur municipality, collected through a system with low collection efficiency. Hence, there is a scope for more generation when collection efficiency is increased an waste from surrounding villages, and other organic waste streams such as cattle manure etc., are combined in the process. The advantage with biogas based CHP

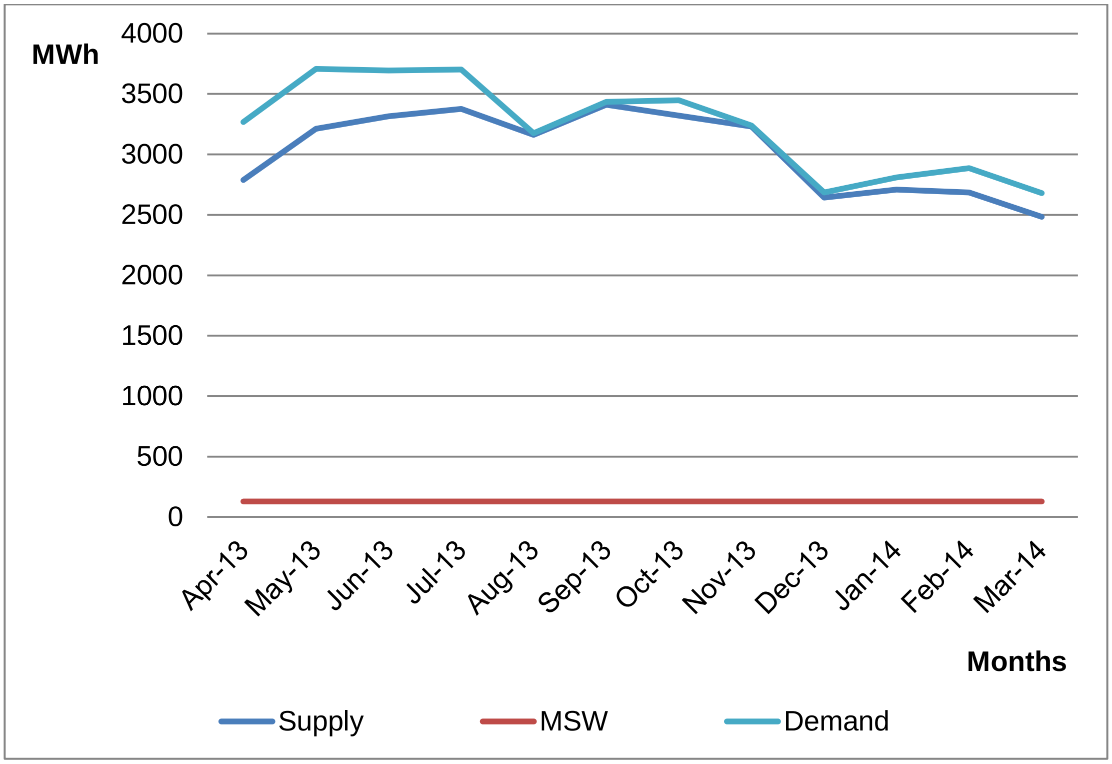

FIGURE 15: CURRENT ELECTRICITY SUPPLY FROM GRID AND ELECTRICITY PRODUCTION POTENTIAL FROM MSW

Source: Own illustration

plants is that they could generate electricity for base-load as waste is constantly available round the year. However, they could also act as reserve power similar to diesel generator as biogas can be stored and be combusted as and when required.

3.3 INTERIM CONCLUSIONS

Figure 16 shows the total energy demand in Gudur municipality and the energy that can be generated from selected streams of renewable sources as described in previous sections. It is evident that total electricity generated by all three sources (agricultural residues, solar PV and Municipal solid waste) of renewables can satisfy the needs of Gudur municipality all-round the year[6]. The total electricity generated from proposed projects is 48.125 GWh/year which is not only higher than the current supply of 36.36 GWh/year but also that of actual demand[7] which is 39.99 GWh/year. This leads us to the excess available energy of approximately 20.3 % in the region, which can be made available in the grid to deliver clean energy to other regions of the state. One should also note that this energy generation potential is calculated using conservative approach and as-is state of resources. When the flows are streamlined and organized, their actual potential can even increase further.

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[6] The analysis carried out in this paper shows on high-level the potential of renewable sources of the region to cover the electricity demand (yearly) of Gudur. However, actual implementation of such system need the analysis of daily load demand curve of Gudur and match it with appropriate capacities of renewable energy systems and involve backup systems where necessary. It is out of scope of this report.

[7] Meeting demand implicates 24-hour reliable power supply.

Apart from electricity generation, proposed projects have huge potential in Carbon-di-oxide equivalent (CO_{2e}) savings. The detailed calculation of emission reduction potential is carried out and attached as **Appendix** of this paper. Appropriate methodologies (& tools) that are formulated by UNFCCC are applied to proposed projects to demonstrate their carbon emission reduction potential.

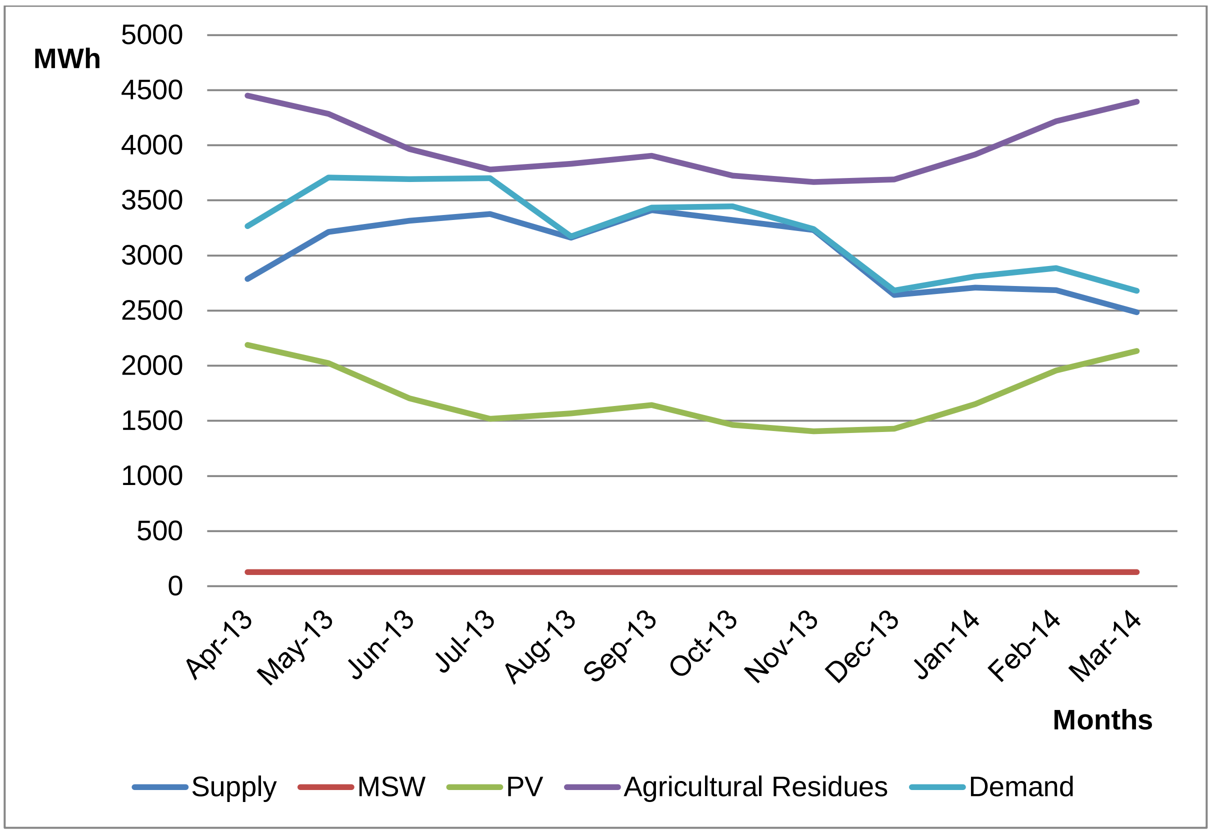

FIGURE 16: LOAD MATCHING OF CURRENT ELECTRICITY SITUATION WITH RENEWABLE ENERGY PRODUCTION

Source: Author's graphic

The proposed projects have GHG savings potential of 66,499 tCO_{2e}/year. These projects when registered as CDM or CDM-POA, will have an opportunity to raise a portion of their capital by selling the achieved carbon credits. Emission reduction when calculated over the project life span of 20 years has a huge potential of 1.33 mil. tCO_{2e}. Table 6 below summarises the key results for the identified projects.

Project	Installed electric capacity ($MW_{Electric}$)	Electricity produced per year ($MWh_{Electric}$/year)	CO_{2e} savings per year (tCO_{2e}/year)
Rice residues to energy project	3.48	27,165	66,499
Solar PV project	13.05	19,420	
MSW to energy project	0.197	1539	

TABLE 6: SUMMARY OF RESULTS

Source: Author's work

The combination of identified projects is ideal for the grid due to the fact that, intermittent nature of solar electricity generation can be balanced by bio based power plants. Barriers for realizing proposed renewable energy projects are discussed in next chapter and appropriate recommendations are provided to overcome those barriers.

Chapter 4: CONCLUSIONS AND RECOMMENDATIONS

The scenario proposed in this paper undoubtedly involves significant amount of project risks in implementing, but one should also take into consideration the added value that can be generated by changing the metabolism of identified sectors in Gudur municipality. Sections to follow summarizes the regional added value that can result from implementation of proposed projects, barriers for implementing, and ends with recommendations to overcome those barriers.

4.1 REGIONAL ADDED VALUE

The added value to the region is demonstrated qualitatively in this section. Quantitative description of regional added value is beyond the scope of this paper. As seen from the previous chapter, electricity demand of Gudur can well be replaced with electricity generated from renewables by activating regional resources and implementing appropriate projects. Though the situation of purchasing electricity from the grid will not change even after introduction of the proposed projects, but the source of energy is now emerging from the region. This implies amount paid to utility to purchase electricity will be spent in Gudur region in various stages of running proposed projects. Stages include procurement of agricultural residues from farmers, managing waste collection system with improved collection efficiency, operation and maintenance of power plants, etc. Change in electricity production system will trigger both technical and non-technical job opportunities for the citizens of municipality.

Project operators can collaborate with technical and engineering colleges present in Gudur municipality for training of employees and in-return offering students with practical internships and hands-on experience.

Currently, all the collected MSW ends up in a dumpsite next to a fresh water canal, which brings irrigation water for agriculture. Leachate produced due to decomposition of organic portion of waste ends up in polluting the water. Furthermore, waste is openly fired to reduce the volume generating huge amounts of toxic substances to atmosphere. MSW to energy project separates the organic portion of waste and utilizes it for energy generation alleviating pollution due to leachate. As MSW will now be generating value, municipal corporation of Gudur can utilize the generated revenues to develop resource centre concept for managing MSW. This would reduce the ill effects of MSW treatment system on environment and public health in Gudur.

As discussed in previous chapter, the agricultural residues are burnt or left on field due to lack of options for their utilization. On developing the proposed rice residues to energy project, the project developers will pay certain amount (per ton of residues) to farmers to procure the residues. This could help farmers to have additional income and reduce their dependency on bank loans to raise money for investment in next cropping season. This will also have positive impact on reducing urbanization.

Apart from the above stated values, the region when becomes energy self-reliant can act as a role-model for other municipalities and regions in the country. Having stated all the positive effects, there are certain barriers that curb the implementation of these projects. Barrier analysis is carried out in next section to identify such barriers and appropriate recommendations are made to overcome them.

4.2 Barrier Analysis and Recommendations

Going back to the analogy of turning potential into sizable projects explained in methodology section of the paper, factors that could be influenced are analysed in this section. Following Figure 17 depicts the sphere of influence on shifting the bar from potential to projects. The process of moving square-3 towards square-2 depends on the advancement in the research and development of technologies. The impact of policy or people on this movement is minor. Only factor that can be influenced in this section specific to proposed projects is to make the agriculture residue available for electricity generation by networking with farmers. Whereas, moving square-4 to merge with square-3 can greatly be influenced by policy makers: by introducing appropriate policy reforms, developing infrastructure, creating proper environment for investors, increasing awareness among people, connecting relevant stakeholders, encouraging strong relation between academia and industry, allocating adequate budget for sustainable projects, having strict goals and agenda to counter climate change and lastly involving local governments in decision making.

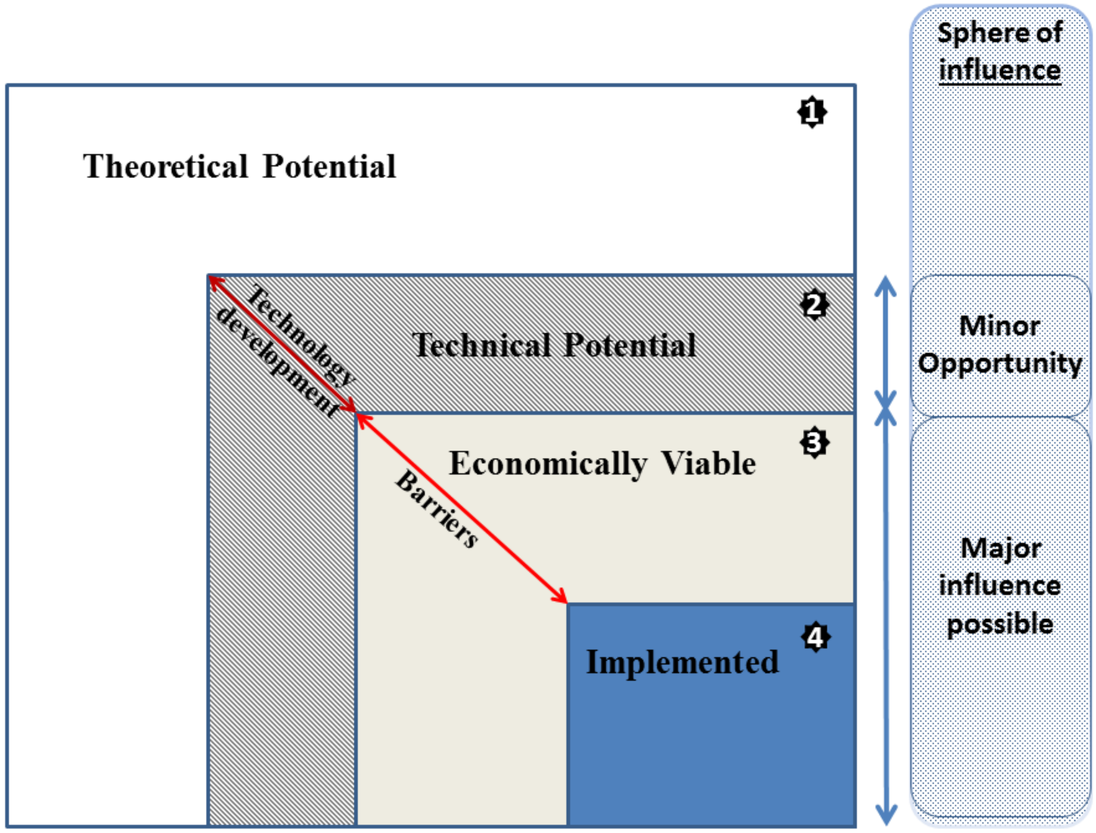

FIGURE 17: SCOPE FOR INFLUENCING THE IMPLEMENTATION OF SUSTAINABLE PROJECTS

Source: Own graphic

The alternative scenario to the proposed project activities would be to continue drawing electricity from the grid, as there is no budget allocated in municipality for energy projects for next five years. The major barrier to the proposed project activities is identified to be lack of seed money or capital for investment. Although, there are subsidies in place from MNRE for promoting renewable energy projects, it requires more policy changes to kick-start. The second barrier to implementation of proposed projects is technological barrier. As technologies to be used in projects are state-of-the-art and are not being used extensively in the state/country, there could be following barriers:

- Lack of skilled labour and/or lack of proper training facilities
- Lack of implementation of infrastructure and logistics (especially in collection of rice residues from field and storing them
- Due to above two barriers and the lack of know-how in handling the technologies, there is a risk of technological failure

Apart from above mentioned barriers, the reluctance from utilities to have high percentage of renewable energy in grid is also the barrier for implementation of proposed project activities.

Technology barriers can be eliminated by investing in knowledge building by conducting trainings, awareness campaigns etc, and by involving academia to work in close relation with industry. Also, by developing co-operations with countries that pioneer in using renewable energy technologies. In this way, barrier due to lack of technology can be nullified. Similarly investment barriers can be handled by making policy changes such as having renewable purchase obligation on utilities, providing guarantee and encouraging corporates to invest in sustainable projects etc.

The other important barrier is identified as "barrier due to prevailing practice", in electricity sector the prevailing practice is to have energy generated from centralized power plants, transported through long transmission & distribution networks and sold at subsidized rates. With respect to agricultural residues is to burn residues on field or allow them to decompose. Similarly, in-case of MSW is to transport waste to dump site away from municipality with no treatment.

It needs paradigm shift to change the business-as-usual situation and invest in sustainable energy projects like the ones put forward in this paper. Government should take initiative to increase awareness of people with respect to renewable energy technologies. Each municipality or city is different and appropriate choice of different technologies available has to be made, looking deep into potentials and requirements of the region. Context specific solutions have to be implemented instead of generic solutions.

Energy is an absolute necessity for our lives and economic activity. Low energy costs are crucial for poverty alleviation, especially for developing countries like India. However, the price of energy has to reflect the expenses for supply as well as the environmental impact caused due to type of energy source used. This is often ignored when comparing electricity from fossil energy sources to that from renewable energy sources. Policy makers should take this into consideration and promote renewables by providing favourable environment for project developers. It has to be agreed that transformation of existing system into renewable and sustainable system is highly complex for which technology and policies have to go hand-in-hand. Such change can take place only with right incentives and right drivers.

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Appendix

The environmental performance of recognised projects is expressed in terms of their CO_{2e} savings compared to business as usual situation. CO_{2e} is calculated using the methodologies formulated by United Nations Framework Convention on Climate Change (UNFCCC) to be used by CDM project developers. Since all three proposed projects are of less than 15MW capacity, the "Indicative simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories" methodology is applicable. Emission reduction potential of proposed project activities is calculated in following sections. CO_{2e} savings by injecting renewable energy into grid is calculated combined for all projects at the end.

Emission reduction potential of MSW to Energy project

Emission from decomposition of MSW at dumpsite is calculated using "Emissions from solid waste disposal sites" (UNFCCC 2012a) methodological tool of UNFCCC as follows:

$$ER_{MSW,y} = BE_{Electricity,grid,y} + BE_{CH4,SWDS,y} - PE_{MSW,y} - LE_{MSW,y}$$

$ER_{MSW,y}$	Emissions reduction potential of MSW to energy project in year y (tCO_{2e}/year)
$BE_{Electricity,grid,y}$	CO_{2e} savings by injecting renewable energy into grid in year y

(Will be calculated together with other two project activities at the end) (tCO_{2e}/year)

$BE_{CH4,SWDS,y}$ Methane emission from Solid Waste Disposal site (SWDS) in year y (tCO_{2e}/year)

$PE_{MSW,y}$ Project emissions from MSW to energy project activities (tCO_{2e}/year)

$LE_{MSW,y}$ Leakage emission[8] from MSW to energy project (tCO_{2e}/year)

CH_4 emissions from the MSW dumpsite is given by

$$BE_{CH4,SWDS,y} = \varphi_y * (1 - f_y) * GWP_{CH4} * (1 - OX) * \frac{16}{12} * F * DOC_{f,y} * MCF_y * \sum_{X=1}^{Y} \sum_{j} W_{j,x} * DOC_j * e^{=k_j(y-x)} * (1 - e^{-k_j})$$

$BE_{CH4,SWDS,y}$ Methane emission from Solid Waste Disposal site (SWDS) in year y

φ_y Model correction factor (Default value, 0.85)

f_y Fraction of methane captured at the SWDS (Value 0)

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[8] The term leakage refers to emissions occurring outside of project boundary that are directly attributable to the proposed project activity and are measurable

GWP_{CH4}	Global Warming Potential of Methane tCO_{2e}/tCH_4 (Default value 21)
OX	Oxidation factor (Default value, 0.1)
F	Fraction of methane in SWDS gas (Default value, 0.5)
$DOC_{f,y}$	Degradable Organic carbon in MSW (Default value, 0.5)
MCF_y	Methane Correction Factor (default value, 0.4)
W_j	Amount of solid waste type j disposed or prevented from disposal in the SWDS in the year x (t) (5848 tons/year)
K_j	Decay rate of waste type j (assumed for wet tropical climate, 0.1)
DOC_j	Fraction of degradable organic carbon in the waste type j (for India, 18%) (IPCC-NGGI 1996)
j	Type of residual waste types in MSW

To avoid complexity, all the organic part of MSW is considered to be of same type with DOC_j of 18%. The total baseline emission from 5848 t/year of MSW of Gudur municipality is calculated to be 215 tCO_{2e}/year.

Project emissions ($PE_{MSW,y}$) in this case are emission from combustion of biogas for electricity production and can be neglected. $LE_{MSW,y}$ are assumed to be zero as the potential is calculated using available organic waste ending up at dump site and no change in existing collection system is desired.

$$ER_{MSW,y} = 215 \text{ tCO2e/year}$$

Emission reduction potential of MSW to energy project is 215 tCO2e/year.

EMISSION REDUCTION POTENTIAL OF RICE RESIDUES TO ENERGY PROJECT

CO_{2e} reduction potential for rice residues to energy project activity is calculated using following equation:

$$ER_{RRE,y} = BE_{Electricity,grid,y} + BE_{biomassdecay,y} – PE_{biomass,y} – LE_{biomass,y}$$

$ER_{RRE,y}$	Emissions reduction potential of rice residues to energy project in year y (tCO_{2e}/year)
$BE_{Electricity,grid,y}$	CO_{2e} savings by injecting renewable energy into grid in year y (Will be calculated together with other two project activities at the end) (tCO_{2e}/year)
$BE_{biomassdecay,y}$	Baseline methane emissions from biomass decay (tons of CO2 equivalent)
$PE_{biomass,y}$	Project emissions from rice residues to energy project activities (tCO_{2e}/year)

$LE_{biomass,y}$ Leakage emission from rice residues to energy project (tCO_{2e}/year)

Rice husk and straw would have been left to decay on field in the absence of proposed project activity. The estimate of CO2 avoidance by project activity can be calculated by applying UNFCCC approved methodological tool namely “Avoidance of methane production from biomass decay through controlled combustion” (UNFCCC 2007). The baseline emissions are the amount of methane from the decay of the biomass or organic waste treated in the project activity. IPCC default emissions factors are used.

First step is to calculate the methane decay factor of biomass

$$CH_4\_IPCC_{decay} = (MCF \times DOC \times DOCF \times F \times 16/12)$$

Where:

$CH_4\_IPCC_{decay}$ IPCC CH4 emission factor for decaying biomass in the region of the project activity (tons of CH4/ton of biomass or organic waste)

MCF methane correction factor (fraction) (default is 0.4)

DOC degradable organic carbon (fraction) (default is 0.3)

DOCF fraction DOC dissimilated to landfill gas (default is 0.77)

F fraction of CH4 in landfill gas (default is 0.5)

On substituting the default values, the methane decay factor is calculated to be 0.0616 tCH_4/tbiomass

Next step is to calculate the baseline emissions in CO_{2e} given by following equation,

$$BE_{biomassdecay,y} = Q_{biomass} \text{ x } CH4\_IPCC_{decay} \text{ x } GWP\_CH_4$$

$BE_{biomassdecay,y}$ Baseline methane emissions from biomass decay (tons of CO2 equivalent)

$Q_{biomass}$ Quantity of biomass treated under the project activity (tons) (21,023 t/year)

GWP_CH_4 GWP for CH_4 (tons of CO2 equivalent/ton of CH_4)

$BE_{biomassdecay,y}$ (tCO_{2e}/year) = 21,023 tbiomass/year x 0.0616 tCH_4/tbiomass x 21 tCO_{2e}/tCH_4

$BE_{biomassdecay,y}$ (tCO_{2e}/year) = 27,195 tCO2e

Total emissions that could be reduced by project activity by avoiding decay of agricultural biomass are 27,195 tCO_{2e}.

Similarly project emissions resulting from controlled combustion of biomass is given by,

$$PE_{biomass,y} = Q_{biomass,y} \times E_{biomass} (CH_{4bio\_comb} \times CH_4\_GWP + N_2O_{bio\_comb} + N_2O\ \_GWP)$$

Where,

$PE_{biomass,y}$	Project activity emissions (tCO_{2e})
$Q_{biomass,y}$	Quantity of biomass treated under project activity (tbiomass/year)
$E_{biomass}$	Energy content of biomass (TJ/tbiomass)
CH_{4bio_comb}	CH4 emission factor for biomass and waste (which includes dung and agricultural, municipal and industrial wastes) combustion (t of CH4/TJ, default value is 0.3)
CH_4_GWP	GWP for CH_4 (tCO_{2e}/tCH_4, default value is 21)
$N_2O_{bio\_comb}$	N_2O emission factor for biomass and waste (which includes dung and agricultural, municipal and industrial wastes) combustion (t of N_2O /TJ, default value is 0.004)
N_2O_GWP	N_2O (tCO_{2e}/tN_2O, default value is 310)

$$PE_{biomass,y} = 21{,}023 \text{ tbiomass/year} \times 0.0155 \text{ TJ/t} \times (0.300 \times 21 + 0.004 \times 310)$$

$$PE_{biomass,y} = 2456\ tCO_{2e}/year$$

The emissions resulting from the transportation of biomass from agricultural land and rice mills to project site can be attributed to Leakage emissions ($LE_{biomass,y}$) from biomass to energy project. This is given by the following equation:

$$LE_{biomass,y} = (Q_{biomass,y} / CT_{biomass,y}) \times DAF_{ricehusk,y} \times VF_{cons} \times NCV_{diesel,y} \times EF_{CO2,diesel}$$

$LE_{biomass,y}$	Leakage emissions resulting from rice residues to energy project (tCO_{2e}/year)
$Q_{biomass.y}$	Quantity of biomass used in project activity (tbiomass/year) (21,023 tbiomass/year)
$CT_{biomass,y}$	Average truck carrying capacity for ricehusk transportation (t), (default value 10)
$DAF_{biomass,y}$	Average distance per trip for residues transportation (km)
VF_{cons}	Average diesel consumption for vehicle (gm/km) (from literature 195.20)
NCV_{diesel}	Net calorific value of diesel (TJ/Gg) (IPCC default value 43)
$EF_{CO2,diesel}$	CO_2 emission factor for fuel (diesel) ($kgCO_2$/TJ) (default value 74100)

From the field research, the farthest village from Gudur for the collection of rice residues is found to be Gollapalli village which is 26 km. Considering the fact that the trucks has to travel empty in one direction and the road conditions in the region, the average distance per trip for residues transportation ($DAF_{biomass,y}$) is assumed to be 45 km (with full load). Substituting the appropriate values in above equation leakage emissions are calculated as 58.84 tCO_{2e}/year.

Total emission reduction potential of rice residues to energy project (excluding grid electricity displacement) is 24,680 tCO_{2e}/year

$$ER_{RRE,y} = BE_{Electricity,grid,y} + BE_{biomassdecay,y} – PE_{biomass,y} – LE_{biomass,y}$$

$$ER_{RRE,y} = 0 + 27{,}195\ tCO_{2e}/year – 2456\ tCO_{2e}/year – 58.84\ tCO_{2e}/year$$

$$ER_{RRE,y} = 24{,}680\ tCO_{2e}/year$$

EMISSION REDUCTION FROM GRID CONNECTED RENEWABLE ENERGY GENERATION

The baseline scenario is that the electricity delivered to grid by project activity would have otherwise been generated by operation of grid-connected power plants and by the addition of new generation sources into the grid. The baseline emission is the product of electrical energy baseline $EG_{BL,y}$ expressed in MWh of electricity produced by the renewable generating unit multiplied by the grid emission factor[9] (UNFCCC 2005).

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[9] Combined margin grid emission factor is chosen for this study

$$BE_y = EG_{BL,y} \times EF_{CO2,grid,y}$$

BE_y	Baseline emissions in year y (tCO_{2e})
$EG_{BL,y}$	Quantity of net electricity supplied to the grid as a result of the implementation of renewable project activities in year y (MWh)
$EF_{CO2,grid,y}$	CO_2 emission factor of the grid in year y (t CO_2/MWh), default for Southern India grid is 0.91)

Considering 5% of electricity generated for auxiliary consumption of project activities and transmission loses.

$$BE_{Electricity,y} = 48.125 \text{ GWh} \times 1000 \text{ MWh/GWh} \times 95\% \times 0.91 = 41{,}604 \text{ t/year}$$

Aggregate Emission reduction potential of proposed projects

Total emissions reduction potential of all three proposed project activities is 66,499 tCO_{2e}/year.

$$ER_{total} = BE_{Electricity,y} + ER_{MSW,y} + ER_{RRE,y}$$

$$ER_{total} = 41{,}604 + 24{,}680 + 215 = 66{,}499 \ tCO_{2e}/year$$