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SUSTAINABLE ENERGY ALTERNATIVES

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ABSTRACT

Energy is indispensable for economic and social development of a region. Dependence on fossil fuels has posed a serious threat due to greenhouse gas (GHG) emissions, dwindling stock of the fuel resource base. Among daily activities, about 80% of the mechanical work requires electrical energy. Dependence on the conventional energy resources for electricity generation is eroding the resources at faster rate. The process of electricity generation causes significant adverse effect on ecology by producing enormous quantity of by-products including nuclear waste and carbon dioxide. Improving energy efficiency, switch over to renewable sources of energy and de-linking economic development from energy consumption (particularly of fossil fuels) is essential for sustainable development of a region. Green energy technologies have gained importance so that they are reliable and environmental friendly. This communication analyses the sustainable energy alternatives for meeting the energy requirement at decentralised levels.

Electrical energy harvesting from solar radiations is one such promising technology which uses photoelectric effect. Solar photovoltaic (SPV) modules directly convert solar radiations to direct current (DC) electrical power which can be used for various applications (or stored in battery) or can be sent to the existing grid. Uttara Kannada is located in the west coast of Karnataka, India, receives an average solar insolation of 5.42 kWh/m^2/day annually and has more than 300 clear sunny days. This solar potential can be utilized to meet the domestic and irrigation electricity demand. Domestic demand of

the household in rural region is about 50 to 100 kWh per month and that in urban region is less than 150 kWh/month in Uttara Kannada. The solar potential assessment reveals that, domestic demand can be supplied by installing rooftop SPV modules, since less the 5% of the rooftop is required in majority of the houses and irrigation demand can be met by installing PV modules in wasteland where less than 3% of available wasteland area is sufficient.

Wind resource assessment is the primary step towards understanding the local wind dynamics of a region. Climatic average datasets of meteorological variables containing wind speed data for the period of 1961~2010 compiled from different sources were used for the potential assessment of wind speed in the district. These were validated with the data of meteorological observatories at Karwar, Honnavar and Shirali obtained from the Indian Meteorological Department, Government of India, Pune. Wind potential analysis showed the seasonal variation of wind speed in the region. Wind speed varies from 1.9 m/s (6.84 km/hr.) to 3.93 m/s (14.15 km/hr.) throughout the year with minimum in October and maximum in June and July. District experiences annual average wind of 2.5 m/s to 3.0 m/s in all taluks indicating the prospects for WECS installation. Hybridizing wind energy systems with other locally available resources (solar, bioenergy) would assure the reliable energy supply to meet the energy demand at decentralized levels.

Bioresource availability is computed based on the compilation of data on the area and productivity of agriculture and horticulture crops, forests and plantations. Sector-wise energy demand is computed based on the National Sample Survey Organisation (NSSO study) data, primary survey data and from the literature. Using the data of bioresource availability and demand, bioresource status is computed for all the agroclimatic zones. The ratio of bioresource availability to demand gives the bioresource status. The ratio greater than one indicates bioresource surplus zones, while a ratio less than one indicates scarcity. The supply/demand ratio in the district ranges from less than 0.5 to more the 2. If the ratio is less than 1 (demand > supply) then that place is fuel wood deficit place and where the ratio is more than 1 (supply > demand) then that place is referred as fuel wood surplus region. In Uttara Kannada, most of the Taluks with ever green forest cover (Sirsi, Siddapur, Yellapur, Supa and estern hilly ares of Kumta, Honnavar and Ankola) are fuel wood surplus regions where the supply/demand ratio is currently > 2 (compared to 8-9 in early 1990's). Dwindling resource base could be attributed to the decline in forest cover in the district. About 40% of the villages have adequate biogas potential to meet the domestic needs. These villages are to be considered for

dissemination of biogas technology in the district. Biogas can also be used for electricity generation and the byproduct, i.e. slurry is used for organic manure production which is a very good fertilizer. Advanced BETs will encourage the bio energy use and make the application simpler. Improved cook stoves, biomass gasification and other new bioenergy technologies are yet to available in rural areas which could change the older energy conversion pattern with higher efficiency. BETs are economically feasible and environmental friendly apart from ensuring sustenance of resources.

Keywords: *Renewable energy, energy efficiency, solar energy, wind potential, biogas.*

INTRODUCTION

Energy plays a pivotal role in the development of a region. Increasing dependency on fossil fuels has caused serious concerns at the local (energy dependency, GHG emission, pollution, etc.) and global (global warming, climate change, etc.) levels. Harvesting of energy depends on the availability of resources apart from the economic viability and technical feasibility of meeting the demand. The energy requirement of India is mainly supplied by coal and lignite followed by crude oil and petroleum products and electricity (CEA 2016; EIA 2016; TEDDY 2016; Ramachandra and Ganesh Hegde 2015). However, energy consumption in rural India is largely dependent on non-conventional energy sources due to the availability, possibility of rapid extraction, and appropriate technologies. Globalization and consequent opening up of Indian markets has led to urbanization with the enhanced energy demand in the industrial and infrastructure sectors. There is a need to navigate the energy transition for sustainable growth in socio-economic aspects of the country. Though the energy consumption per GDP (Gross Domestic Product) is higher, production of valuable goods is quite low in the country which shows that there is a need to improve the end-use efficiency. Coupled with this inefficiency, the perishing stock of global fossil fuel reserves and the growing concerns of global warming and consequent changes in the climate has necessitated the improvements in end use energy efficiency along with the exploration of cost effective, environment friendly, and sustainable energy alternatives (Ramachandra and Ganesh Hegde 2015).

Renewable sources of energy such as solar and wind are emerging as viable alternatives to meet the growing energy demand of the burgeoning population. Strengthening of transmission and distribution network with the integration of local generating units (REbased standalone units) would help in meeting the demand. Distributed generation (DG) with micro grids are required to minimize transmission and distribution (T and D) losses, and optimal harvesting of abundant local resources (such as solar, biofuel, etc). The focus of the current communication are i) understanding the energy scenario in India; ii) sector- and source-wise energy demand with the scope for energy conservation; and iii) prospects of renewable energy with smart grids to meet the distributed energy demand while optimizing harvest of local energy sources (Ramachandra et al., 2014a; 2014b; 2014c).

Per capita energy consumption varies across countries (based on the analysis of 2004-05 and 2014-15). It is higher in developed nations (USA-7.3 TOE, Canada-7.6 TOE, Japan 3.7 TOE) compared to the developing (India-0.6 TOE, China-1.8 TOE, Brazil-1.4 TOE) and less developed nations (<0.4 TOE). Figure 1 compares the energy consumption per capita versus GDP (Gross Domestic Product) per capita among the countries (Top 25 GDP countries). Norway (99,933 million USD) tops in GDP per capita followed by Switzerland (79,024 million USD), Australia (65,430 million USD) and Sweden (55,341 million USD) which shows the effective utilization of energy. The per capita GDP value of India is 1555.50 million USD, which is lowest among these countries. But, Energy consumption per GDP (Energy intensity) of India is higher, hinting the inefficient use of energy. Figure 2 compares the energy intensity (the ratio of energy consumption per GDP) versus GDP per capita of various countries. Energy intensity of India is about 0.42 kgoe/million USD which is more than 12 times that of Switzerland (0.033 kgoe/million USD), more than 4 times that of Germany (0.092 kgoe/million USD), more than 3 times that of USA (0.137 kgoe/million USD) and about 1.3 times that of China (0.325 kgoe/million USD). The prosperity of a nation depends on the efficient use of energy or the energy intensity than the per capita energy consumption.

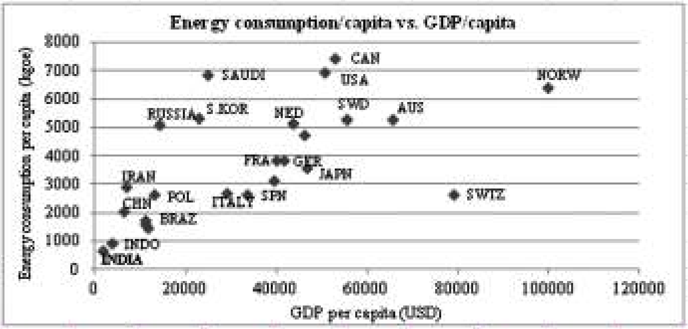

Figure 1: Country-wise energy consumption per capita versus GDP per capita

Most of the Asian countries have high energy intensity (energy/GDP) and lower per capita consumption, which illustrates the inefficient use of energy. This highlights the need of improved end use efficiency to enhance the GDP with the present level of energy consumption (Ramachandra and Ganesh Hegde 2015; Ramachandra 2011; Ramachandra, Loerincik and Shruthi 2006).

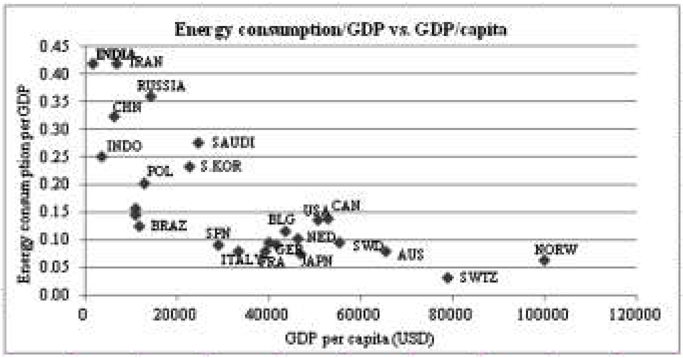

Figure 2: Country-wise energy consumption per GDP versus GDP per capita

Global studies also emphasize the efficient use of the energy have also demonstrated the relationship between efficient energy consumption and economic growth. Emission of greenhouse gases (GHG) is proportional to energy utilization and is found higher in developing countries due to the inefficient use of energy.

SCOPE FOR RENEWABLE ENERGY

Assessment of Renewable energy potential in Uttara Kannada district

Uttara Kannada district is located between 13° 55´ and 15° 31´ latitudes and 74° 9´ and 75° 10´ longitudes (figure 1). The regions with undulating hills, rising steeply from a narrow coastal strip bordering the Arabian Sea to a plateau at an altitude of 500 m, with occasional hills rising above 600 to 860 m lies in the central part of Western Ghats. Topographically, the district lies in three distinct zones namely narrow and flat coastal zone, abruptly rising ridge zone and elevated flatter eastern zone. The coastal zone is thickly populated with coconut clad villages. Ridge zone is a part of the main range of Western Ghats, which runs north to south, parallel to the coast. The flat eastern zone joins the Deccan plateau. The taluks, which comprises the narrow flat coastal zone, are: Karwar, Ankola, Kumta, Honnavar and Bhatkal. Similarly, taluks, which comprises the ridge zone, are: Supa, Haliyal, Yellapur, western Sirsi, and western Siddapur. Flatter eastern zone includes Mundgod, eastern Sirsi and eastern Siddapur. Four agro-climatic zones based on geography and climate are coastal, evergreen, dry deciduous and moist deciduous. There are 1291 villages, 7 towns, 5 city municipal corporations/town municipal corporations/outward growth/census towns and 2 reservoirs in the district [http://uttarakannada.nic.in/].

It is the 4th biggest district of the state having population of 14,36,847, with more than 70% of the people live in rural area or in semi urban area. District is located in central Western Ghats with rich ecology. More than 75% of the total area is forest covered and has 140 km costal belt. The geographical heterogeneity is responsible for the diverse growth of vegetation in the district. Taluks of the district are categorized under 4 different types of forests which are

- Ever green forests normally found in Sirsi, Siddapur and eastern hilly regions of Honnavar, Kumta and Ankola Taluks.
- Semi Deciduous forest, found in slopes of Ankola, Kumta, Karwar, Honnavar, Siddapur and Sirsi.
- Deciduous forests are mostly found in Haliyal, Supa and Mundgod region.
- Forest in the coastal region, normally found in Kumta, Honnavar, Ankola, Karwar and Bhatkal region.

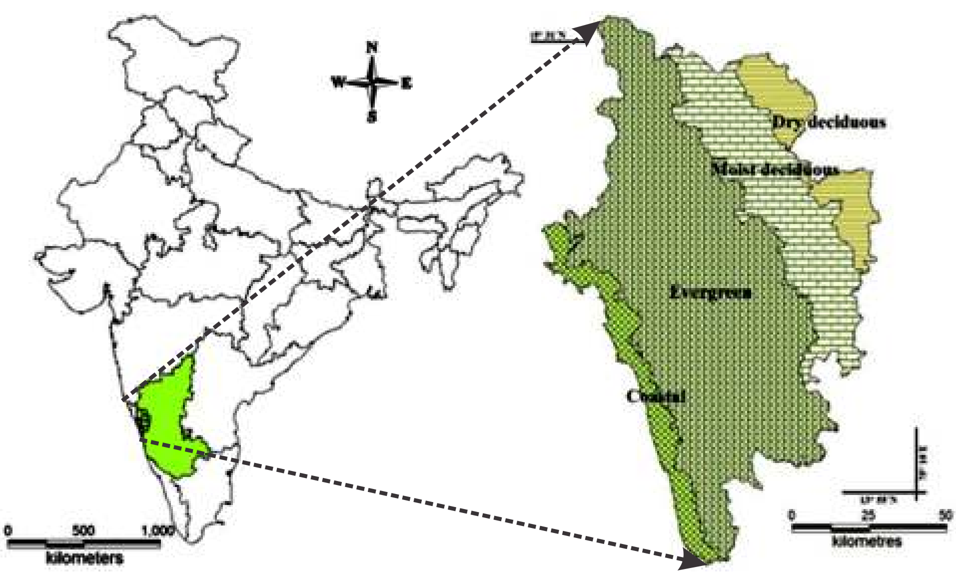

Figure 3.1

Figure 3.2

Figure 3.1 gives the location of the study and Figure 3.2 gives the climatic zones and forest types of Uttara Kannada. Extent of the forest cover and type of forest has a major effect on bio energy supply. Evergreen forest found in most of the places in the central region followed by moist and dry deciduous forests (Ramachandra et al., 2014a; 2014b; 2014c).

Scope for Solar energy

Solar energy has a wide range of applications by converting it into thermal energy and electric energy. Parabolic trough system, central receiver system or parabolic dish system for solar-thermal energy conversion is used and photovoltaic cell (PV cell) is used for solar to electric energy conversion. Solar PV cell converts solar radiation into direct current (DC) electric power using photovoltaic effect. The domestic electricity demand in India can be met by installing solar PV modules in an outdoor area or using rooftop PV modules. Rooftop PV system generates direct current (DC) electrical power using photovoltaic effect. This power can be stored in a battery or used as per the requirement. It uses a part of roof area (depending upon the PV module size and output) for installing PV modules which acts as an energy source. The generated electricity is stored in batteries, used directly or it fed to the grid using inverter circuit. The National Solar Mission (NSM) launched in 2010, targets 200 MW off-grid solar based photovoltaic (PV) capacity by the end of its first phase in 2013. Ministry of New and Renewable Energy (MNRE), Govt. of India (GoI), has already achieved more than 12.5 GW by 2016 [http://www.mnre.gov.in/].

The monthly average GHI (Global Horizontal Irradiance) datasets from NASA and NREL were compared and validated with surface data based model. Figure 4.1 illustrates the monthly variability of solar radiation. The values indicate that adequate solar energy is available in the region. Higher resolution NREL GHI data were used to study the solar energy potential in Uttara Kannada. Solar maps generated for monsoon, winter and summer seasons, show seasonal availability and regional variability of GHI (Figure 4.2). The seasonal average GHI is highest in summer (6.65–6.95 kWh/m^2/day), moderate in winter (5.70–5.85 kWh/m^2/day) and lowest in monsoon (4.50–5.20 kWh/m^2/day). Annual average GHI values were considered for assessing the technical potential of solar energy in Uttara Kannada (Ramachandra et al., 2014a).

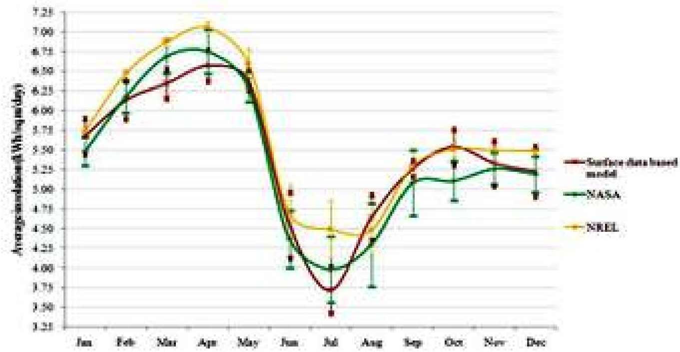

Figure 4.1: Solar insolation in Uttara Kannada

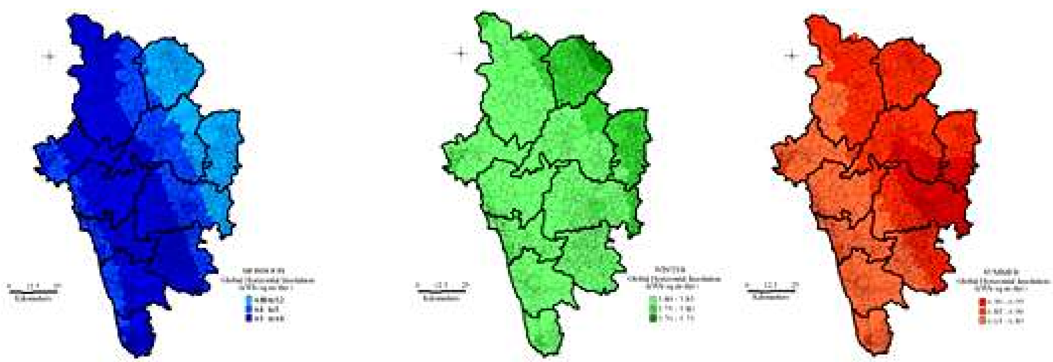

Figure 4.2: Seasonal variations of solar radiation in Uttara Kannada

Figure 4.2 illustrates the seasonal variations of solar insolation in Uttara Kannada. Solar insolation ranges from 4.5 to 6.95 kWh/m^2/day in the districts throughout the year. During Monsoon season, district gets the insolation ranges from 4.5 to 5.2 kWh/m^2/day. Coastal and the eastern part of the central (moist deciduous) region receives insolation of 4.8-5 kWh/m^2/day. The central region (Evergreen) gets the lowest insolation ranges from 4.5 to 4.8 kWh/m^2/day during monsoon. Eastern most part (dry deciduous) receives higher insolation of 4.89-5.2 kWh/m^2/day. The monthly average electric energy consumption per household is about 50 to 100 kWh in Uttara Kannada. This electricity demand can be met through solar rooftop PV system, which ensures continuous supply of electricity compared to the current system of depending on grid with uncertainties. The average roof area of an urban household is about 1,200 square feet (120 m^2) and that of rural household is 2,000 to 2,500 square feet (200-250 m^2). The portion of this rooftop is sufficient to harvest electrical energy using solar photovoltaic (SPV) system. Table 1 gives the area of PV cell required to generate electric energy at varied efficiencies (like 4, 8, 12 and 16%). Rooftop SPV is a standalone or an off grid system and hence do not face any uncertainty such as grid interventions and hence it would be more reliable. The system uses a part of rooftop area for installing PV modules which will be less than 5% of the total roof area. Though the initial cost of such systems is high, it has a payback period of 5 to 7 years and has a life span of more than 20 years.

Table 1: Rooftop area (m^2) required for installing SPV[1]

PV module efficiency (%)	PV capacity (Watts)	100	250	500	1000	2000	4000	10000
4	Rooftop area required (m^2) for SPV	30	75	150	300	600	1200	2400
8		15	38	75	150	300	600	1500
12		10	25	50	100	200	400	1000
16		8	20	40	80	160	320	800

[1] *Ministry of New and Renewable Energy (GoI)*

Decentralized Wind Applications

Uttara Kannada district located in the west coast and in Western Ghats region of Karnataka state is blessed with good wind potential. Harnessing of wind energy could play a prominent role in meeting the energy demand in the region since electricity supply is unreliable in most of the times. Wind energy potential in the district could meet the regional electricity demand through wind energy conversion system (WECS) avoiding plenteous greenhouse gas (GHG) emission and fossil fuel. It can be harnessed locally in a decentralized manner for applications in rural areas and remote areas such as water pumping for agriculture and plantations. Wind driven electric generators could be utilized as an independent power source and for purposes of augmenting the electricity supply from grids. In coastal densely populated taluks like Karwar, Kumta and Bhatkal in Uttara Kannada District, decentralized production of electricity would help local industries, especially seasonal agro processing industries like cashew, etc. WECS (Wind energy conversion systems) can be hybridized with solar, biomass and any other available local energy resource to provide cent percent reliable power since wind flow is maximum during monsoon when solar insolation and dry biomass availability is lesser. Figure 5.1 shows the comparison of mean wind speed in five India Meteorological Department, Government of India (IMD) stations. At higher elevations in the district mean wind speed is comparatively higher and also in coastal region. Wind speed recorded at Honnavar and Shirali stations are lower which are placed at an elevation of 26 m and 45 m respectively (Ramachandra et al., 2014b).

Wind speed is seasonal dependent which is normally at its maximum during monsoon season. Wind speed varies from 1.9 m/s (6.84 km/hr.) to 3.93 m/s (14.15 km/hr.) throughout the year resulting minimum in October and maximum in June and July. Annual average wind sped in the district ranges from 2.54 ± 0.04 m/s (9.144±0.144 km/hr.) in Haliyal taluk to 2.70 ± 0.05 m/s (9.72±0.18 km/hr.) in Karwar taluk. Figure 5.2 gives the taluk wise annual average wind speed of the district. Ample amount of electrical energy can be generated using blowing wind through wind farms which could meet the major fraction of the current electricity demand of the district through decentralized generation.

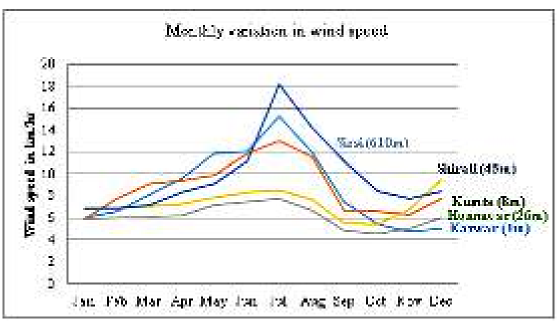

Figure 5.1: Monthly variation in wind speed

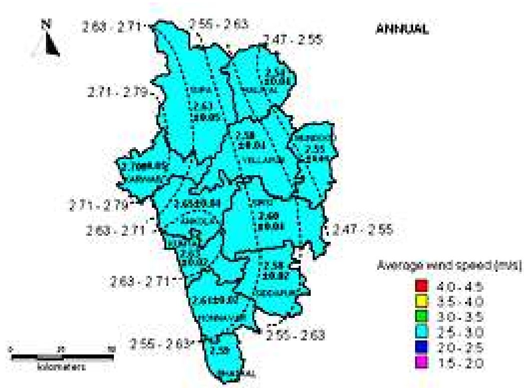

Figure 5.2: Average annual wind speed of Uttara Kannada

District experiences annual average wind of 2.5 m/s to 3.0 m/s in all the taluks which opens wide range prospects for WECS installation. Hybrid wind (with other locally available resources) energy systems would assure the reliable energy supply for domestic and irrigation demand. Small and medium scale WEC systems are feasible for the community level installation which leads to abundant amount of carbon dioxide emission reduction.

Prospects of Bioenergy

Rural population of India mostly depends on bio energy for cooking, space and water heating. Though most of the energy need is harvested from fossil fuels, 70% of the rural population depends on the bio energy for their domestic usage in the country. About 70% of the Indian population lives in rural area where 75% of the primary energy need is supplied by bio energy resources. Also, about 22% of the urban households depend on firewood, 22% on kerosene and 44% on LPG for cooking in the country. Bio energy resources are renewable in nature and combustion would not produce poisonous gases and ash with sufficient oxygen supply. A village level study on the present scenario of domestic energy consumption will help to assess the demand and supply of bio energy in the country. Uttara Kannada district in Karnataka state, India is chosen for bio energy assessment which has evergreen as well as moist and dry deciduous forest. In the district majority of the people live in rural area or in semi urban area, mostly dependent on forest, agricultural and livestock residues for domestic energy need (Ramachandra et al., 2014c).

Fuel wood is one of the prominent forest by-products collected (normally by women and children) which is used for cooking and water heating through burning. Major domestic energy need is shared by fuel wood in the rural regions where the people collect it from nearby forest. The availability of the fuel wood for the consumers is depends on the closeness of the forest, type of the forest and methods of extraction. Figure 6.1 gives the availability of fuel wood in the districts annually. Since fuel wood is the cheapest primary energy source hence the demand will be high depending upon the availability. If the demand for the fuel wood increases then it may lead to deforestation or consumers may switch over to some other fuels such as LPG, electricity or kerosene due to the lack of availability. The annual fuel wood availability in the district ranges from less than 1,000 tonnes to 56.000 tonnes. In majority of the villages of Sirsi, Siddapur, Kumta and Honnavar Taluks, availability of fuel food ranges from 1,000 to 5,000 tonnes per annum. In northern villages of Haliyal and Supa Taluks availability of forest bio mass per annum is less than 1,000 tonnes to 5,000 tonnes. Availability of fuel wood is high in the central region of the district. In eastern part of Karwar and Ankola and southern part of Supa fuel wood availableness is 10,000 to 25,000 tonnes per annum. There are few villages Supa and Yellapur Taluks where the bio-mass availability is 25,000 to 56,000 tonnes in a year.

Figure 6.2 gives the supply to demand ratio of available forest bio mass (fuel wood) in the district. The supply/demand ratio in the district ranges from less than 0.5 to more the 2. If the ratio is less than 1 (supply < demand) then that place is fuel wood deficit place and where the ratio is more than 1 (supply > demand) then that place is fuel wood surplus region. In Uttara Kannada, most of the Taluks with ever green forest cover (Sirsi, Siddapur, Yellapur, Supa and estern hilly ares of Kumta, Honnavar and Ankola) are fuel wood surplus regions where the supply/demand ratio is more than 2. The villages with semi and moist deciduous forests (Western parts of Mundgod and Haliyal, Eastern parts of Bhatkal and Karwar) are also forest bio mass surplus places where the availability ratio is more than 1. The coastal and the extreme eastern part of the district (coastal villages of Karwar, Ankola, Kumta, Honnavar and Bhatkal with eastern part of Mundgod and Haliyal) are the fuel wood deficit places. The bioresource supply is dwindling in the district evident from the reduced bioresource supply to demand ratio from 8-9 (in 90's) to 2. This necessitates sustainable energy management approaches with augmentation of forest resources.

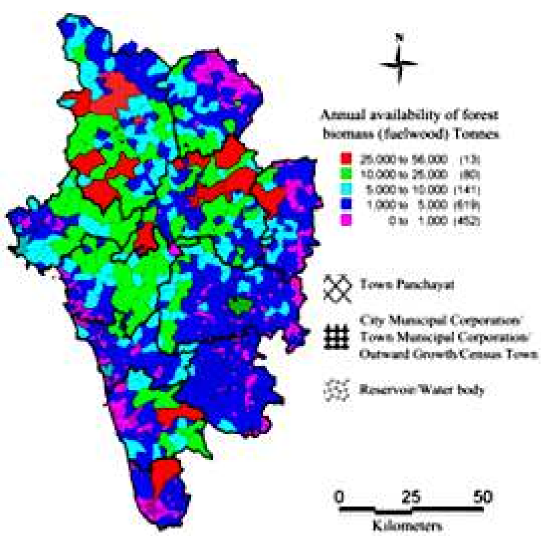

Figure 6.1: Availability of forest biomass (fuel wood) in tonnes/annum

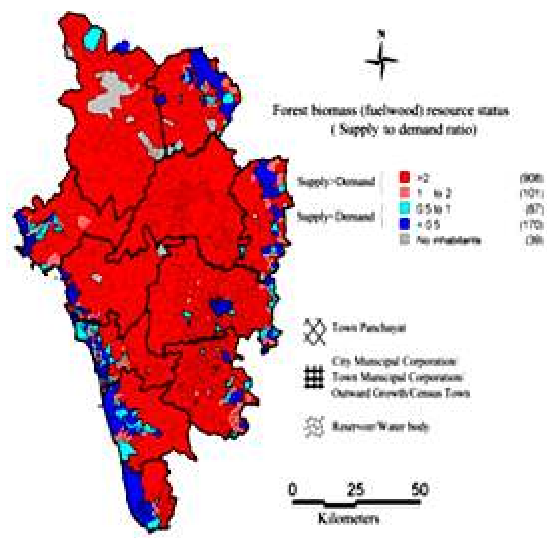

Figure 6.2: Fuel wood resource status (Supply to demand ratio)

Biogas:

Farmers in Uttara Kannada are very much dependent on livestock for their agriculture and horticulture practices. Animal residue is the main feedstock for the production of biogas as well as manure. Dung available from each cattle varies from 3-4 kg to 8-10 kg (from coastal to hilly region). Similarly average dung produced from a buffalo is 12-15 kg and from a hybrid one is 15-18 kg. There are about 3,66,949 cattle and 1,18,669 Buffaloes in Uttara Kannada. By considering 3 kg dung production from a cattle in coastal area and 8 kg in hilly area, total dung production from cattle is about 6,32,058.46 tonnes per year. Similarly by considering the dung production per buffalo as 12 kg/day, total dung obtained is 5,19,770.22 tonnes per year. Assuming gas production of 0.036 m^3 per kg of dung, assessment shows that biogas produced from livestock residue could meet the 50% of the gas demand in Uttara Kannada district (100% dung produced is considered to generate biogas). Figure 7.1 gives the annual biogas production from livestock residues in Uttara Kannada. It is evident that in majority of the villages in the district, annual biogas energy generated from biogas ranges from 0.1 to 0.5 million kWh. In 340 villages of Mundgod, Haliyal, Karwar and Siddapur taluks biogas energy generation is 0.5 to 1 million kWh. Few villages in Bhatkal, Honnavar and Mundgod taluk have biogas based energy production of 1-12 million kWh per annum. Figure 7.2 gives the availability to demand ratio of biogas resource in the district. In more than 50% of the villages (625 villages) the availability is less than demand; which are called biogas energy deficit regions. In 334 villages of Siddapur, Yellapur and Supa taluks supply to demand ratio is between 1 and 2. There are 275 villages in Ankola, Mundgod and eastern Yellapur taluk, availability is more than twice of biogas demand. About 40% of the villages have adequate biogas potential to meet the domestic needs. These villages are to be considered for dissemination of biogas technology in the district.

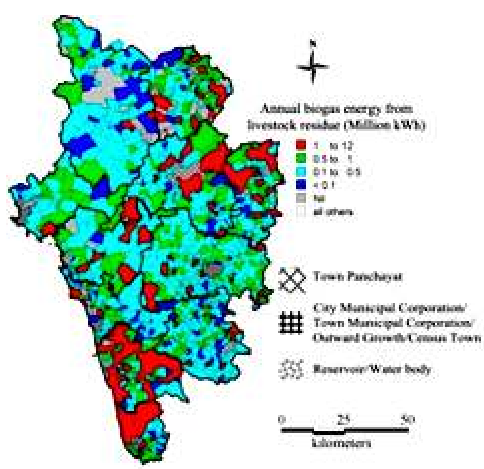

Figure 7.1: Annual biogas production from livestock residues

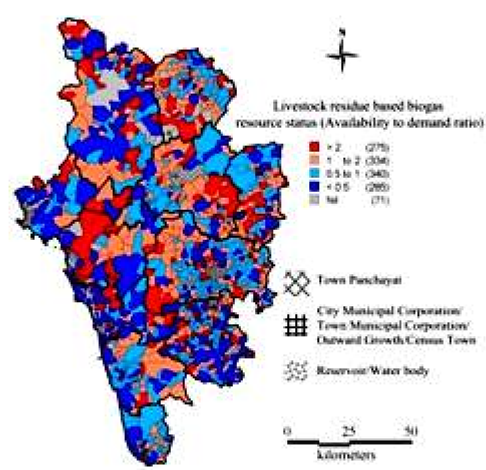

Figure 7.2: Biogas resource status (supply to demand ratio)

End-use efficiency improvement

More than 70 per cent of the population resides in rural regions and 85 per cent of the energy requirement is met by traditional fuel through energy inefficient devices. Industrial energy consumption is also inefficient in most of the cases due to the aged equipment, lack of lubrication, torn out parts, and non-scientific combustion. The overuse of energy resources in the commercial domain and unmetered energy supply for irrigation pumps have aggravated the energy crisis.

The primary need of energy resources in rural India is for cooking, water/space heating, and lighting. Most of the energy for cooking and heating is supplied by bioenergy (fuel wood, dung cake, etc.) which is locally available. However, the conventional cook stoves used for combustion of biomass have lower thermal efficiency (<10 per cent). Compared to these, improved cook stoves (ICS) have higher efficiency (20–30 per cent) and there is a scope to reduce 27 to 42 per cent of the fuel wood requirement (Ramachandra et. al, 1999). A typical rural household consumes about 5l of kerosene every month. Average electricity consumption in rural household ranges between 50–60 kWh/month which is mainly used for lighting, entertainment, water pumping, and air cooling. About 30–40 per cent of energy conservation is possible in the domestic sector using CFL/LED lamps for lighting, energy efficient heaters, and coolers (Ramachandra and Ganesh Hegde, 2015).

The domestic energy requirement of an urban household is supplied by electricity, LPG (Liquefied Petroleum Gas), fuel wood, etc. Even though an urban household consumes about 11 kg of LPG per month, 22 per cent of the urban households depend on firewood and kerosene as primary energy need. Electricity is the main source of lighting, cooling, and water heating in urban area where the consumption ranges from 100–125 kWh per month (Ramachandra et al., 1999; Ramachandra et al., 2014c). Use of ICs, CFL/LED lamps, and energy efficient heaters and coolers can conserve a significant amount of energy. Solar water heater and rooftop solar PV installation can substitute electricity and biomass consumption for lighting and water heating, respectively (Ramachandra et al., 2014a).

Energy conservation in irrigation pump sets is possible by avoiding over capacity installation, maintenance and lubrication, selecting proper foot valves and pipelines, drip irrigation, and sprinkler installation, etc. Energy supply for agricultural purposes is to be metered and tariff has to be applied on the basis of installed capacity. This would help in the optimal irrigation of agriculture fields. Wind pumps and solar PV pumps can be installed for small area irrigation (5–10 hp) which would replace the diesel or kerosene fueled pumps (Ramachandra et al., 2014a; 2014b).

Industries are the highest energy consumers in India which use all forms of energy resources. Many of the Indian industries use coal, oil, and electricity. About 30–40 per cent of energy conservation is possible with upgradation of equipment and technology. However, there is a need to reform policies and tariffs for industrial energy consumption to promote captive generation through renewable energy sources. Energy consumption in the commercial sector has increased considerably during the last decade. Energy conservation in the commercial sector through interventions in lighting technologies (LED/CFL), green buildings, and energy efficient equipment would reduce the energy consumption and decrease the energy intensity (Ramachandra T V, et al., 2011).

Innovations in Energy Sector

Development of economically viable and technically feasible new energy harvesting technologies is expected to change the present energy mix. Technology innovation in non-fossil energy resources - solar thermal and PV, bioenergy, off-shore wind, hydrogen, artificial photosynthesis, etc. would meet the future energy demand The current focus is on bioenergy, bio-oil, and biological hydrogen production. Technologies like bio-oil and ethanol production from algae would significantly replace the fossil oil for transportation and electricity generation. Many of these technologies are in the lab scale at the moment and thus, have shown great potential in cutting down the cost and also tapping a wide range of renewable energy sources (Ramachandra et al., 2013).

In the face of increasing CO_2 emissions from conventional energy (gasoline) and the anticipated scarcity of crude oil, a worldwide effort is underway for cost effective renewable alternative energy sources. Efforts are in progress at Energy & Wetlands Research Group, CES (http://ces.iisc.ernet.in/energy), at the Indian Institute of Science, Banaglore, towards developing the gasoline secreting diatom solar panels to produce gasoline from diatoms sustainably. Diatoms being the major group of planktonic algae (Figure 8) can be used sustainably for production of bio-fuel, by the usage of diatom-based solar panels. Studies have shown that diatoms could make 10 to

200 times as much oil per hectare as oil seeds (Ramachandra et al., 2009; Ramachandra et al., 2013) and the techniques involved towards developing oil secreting diatoms to minimize the cost of oil extraction. It was found that some diatoms secrete more lipid content when subjected to unfavorable environment or culture conditions, such as nutrient starvation or extreme temperatures. Unlike crops, diatoms multiply rapidly. Some diatoms can double their biomass within an hour to a day's time. Since each diatom creates and uses its own gas tank, it is estimated that diatoms are responsible for up to 25 per cent of global carbon dioxide fixation. This means that while diatoms can be cultivated for oil extraction, they can automatically reabsorb carbon dioxide in the process. Diatoms may have a major role to play in the coming years with regard to the mass production of oil. This entails appropriate cultivation, harvesting and extraction of oil, using advanced technologies that mimic the natural process while cutting down the time period involved in oil formation.

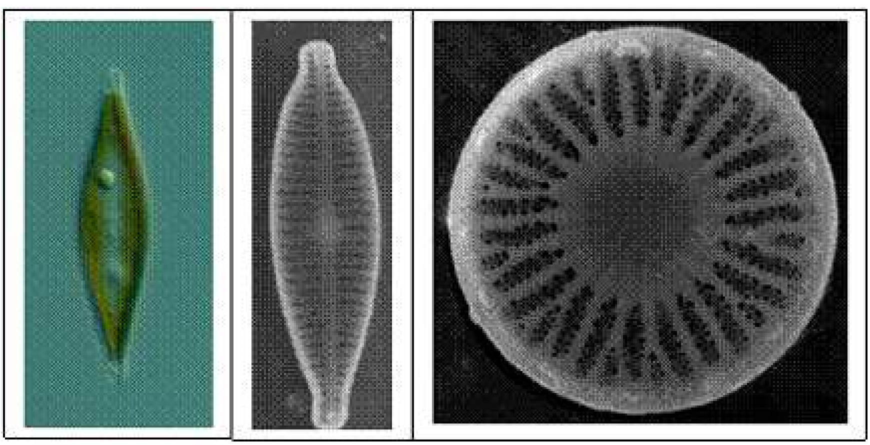

Figure 8: Pennate and centric diatoms (Navicula sp., with an oil droplet)

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