BOTTOM-UP RENEWABLE ENERGY PLANNING APPROACH FOR SUSTAINABLE RURAL DEVELOPMENT IN INDIA

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ABSTRACT

The present work focus on domestic energy consumption pattern in rural area, per capita energy consumption for various domestic activities, potential of renewable energy in the region and integration of energy resources for sustainable rural energy development.

The objective of this study is to make an attempt to know the current energy status, choice of energy options and potential of renewable energy systems for creating sustainable livelihoods in rural areas in developing countries like India. The outline plan at decentralized level was prepared with the objective of providing energy security in the region by meeting total energy needs for cooking, lighting, heating, cooling, and appliances through various forms of available renewable energy sources.

The micro level analysis of rural domestic energy consumption pattern in Daryapur Block was carried out in 2018–19. The decentralized energy planning model developed here has been applied to a typical Indian block unit, Daryapur, which comprises of several villages. Based on the analysis made in the present work, it is found that local resources-based energy systems have the potential to meet all the energy needs of Daryapur block.

Keywords: Decentralized Energy Planning; Micro Level Analysis; Goal Programming; Scenarios.

1. INTRODUCTION

Rural population in developing countries like India solely depends on conventional fuels for their domestic energy requirement such as cooking, heating, lighting, cooling and appliances. Lack of sufficient energy sources and exploitation of forests for fuel/wood is major issue of concern (Shyam 2002). Energy is essential for economical and social development of a region or a country. Delinking economical development from energy consumption and improving energy efficiency is essential for sustainable development of the region. So, economic development is dependent on the energy system of any country (Ramachandra et. al.2006).

Economic factors are involved in improving the efficiency of energy system. The demand supply balances involve the flow of primary energy from source to service as useful energy. At each stage of the energy flow, technologies are involved with different conversion efficiencies and losses. These complexities and inter-linkages can be understood through a model, which is a simplified representation of reality.

Several authors have worked on energy planning at the micro (village) level by considering population growth and agricultural operations. They have estimated the demand and supply gap of energy and made recommendations. To bridge this wide gap between demand and supply there is a need to examine the locally available alternate energy sources along with traditional fuels for an optimal mix of the two. Centralized energy planning exercises cannot pay attention to the variations in socio-economic and ecological factors of a region. For efficient utilization of resources and unbiased sharing of benefits from development decentralized energy planning advocated these days. (Hiremath et. al. 2007).

The model developed here has been applied to a typical Indian block unit Daryapur, which comprises of 150 villages. Daryapur is famous as a cotton producing town with numerous ginning and pressing mills. It also excels in production of cereals like 'Green Gram (Moong)' and 'Red Gram (Chana/Chickpea). Soyabean production in recent years is also getting popular. Based on the analysis made in the present work, it is found that local resources-based energy systems have the potential to meet all the energy needs of Daryapur block.

2. EXPERIMENTAL

2.1 Classification of Energy Planning Models:

Energy planning models are classified as spatial, sectoral and temporal coverage, on the basis of methodology adopted. Impact of energy supply and demand on economic issues, further planning methodology approach can be classified into two categories as bottom-up and top-down approach. Bottom-up approach gives the due consideration to energy resources, technologies and energy demand and allows assessment of policy options such as technology mix, fuel mix, logistics and emissions in the energy sector at local, regional and national levels. The bottom–up approach to energy planning is useful for energy sector in isolation without consideration of its linkage with other sectors of economy (Kydes et. al.1995). The top–down approach to energy planning allows consideration of all the sectors of national economy along with their cross linkages.

2.2: Rational Behind Selecting Decision Making Method:

Review of renewable energy decision making methods is discussed in this section to identify an appropriate decision making methodology suitable for micro-level energy planning.

In order to meet energy planners' need for quantitative simulation, a liner optimization model has been developed during last several years based on the standard method of liner programming. Ramakumar et. al. (1986) presented a micro level linear programming approach for the design of integrated renewable energy systems for developing countries. Sinha & Kandpal (1991) had developed a linear programming model for determining an optimal mix of technologies for domestic cooking in rural areas of India. Joshi et. al. (1992) developed linear programming model for decentralized energy planning for three villages in Nepal. Srinivasan & Balachandra (1993) presented micro-level, bottom-up approach based linear programming model for Bangalore North Taluka. Diakoulaki et. al. (1999) discussed a bottom up approach to match the supply of available renewable resources to the particular energy demand profile at the regional level.

All the liner programming models developed so far had a single objective. Mathematically achieving such a single objective is feasible but results in outputs that have little utility. Optimizing an energy planning problem could involve multiple objectives, few may be minimizing as well as maximizing. Thus, an approach or model to optimize multiple objectives for a given set of constraints is necessary.

The MCDM techniques have been widely used in renewable energy planning for ranking of developed scenarios (Triantaphyllou et. al. 1998). The MCDM methods are classified into two categories: multi-objective decision making (MODM) approach and multi-attribute decision making (MADM) approach. MODM problems are defined and solved by several alternative optimization models, such as compromising programming (Zhu And Chow (1997), constraint method, goal programming, and fuzzy multi-objective programming Saaty (1980).

Ramanathan & Ganesh (1993) developed a multi objective goal programming model for energy resource allocation at the micro level for Chennai city in India. Mezher et al., (1998) has developed macro level energy planning model for energy resource allocation. Kanase-Patil et. al. (2010) developed integrated renewable energy system model for off grid rural electrification of remote areas. Kumar et. al. (2011) developed a linear and multi objective goal programming model for DEP for the effective utilization of renewable energy sources. The model developed here has been applied to a typical Indian block unit Kunigal which comprises of several villages. (Jinturkar & Deshmukh (2011) developed a fuzzy logic mixed integer goal programming model for cooking and heating energy planning in rural India. Shin & Hashim (2012) develop integrated electricity planning model. Kazemi & Rabbani (2013) developed An Integrated Decentralized Energy Planning Model considering Demand-Side Management and Environmental Measures. Ozcan & Serpil (2014) developed A Multi-Objective Mixed Integer Linear Programming Model for Energy Resource Allocation Problem.

In the light of the above, it can be seen that the multi-objective and weighing or scaling approaches are suitable for a micro-level planning. When there is a need to trade-off against one or more competing objectives, MOLP is used and also referred to as goal programming. Therefore, in the present study multi-objective weighted approaches are adopted for developing & prioritizing the energy plans in a local region.

2.3: Data Needs for DEP

Energy use patterns are closely linked to agro-climatic and socio-economic conditions. Energy problems in rural areas are also closely linked to soil fertility, land-holding, livestock holding, etc. Energy planning of any region should be based on the existing levels of energy consumption. However, the information available in published form is either at the state level or at the national level Deshmukh et. al, (2014). Hence, a detailed energy survey was conducted to understand the domestic energy use patterns in various socio-economic zones. The secondary data is collected from respective government offices & used to prepare framework for the primary survey. Table 2 shows the demography of study region.

Bottom-Up energy planning model requires the following set of data

- Socio-economic features, employment, gender issue etc.
- Land use, forests land, wasteland, fallow land, cropping pattern, etc.
- Energy activities, end use devices, efficiency of devices.
- Energy efficiency, energy conversions, energy use
- RET (Renewable Energy Technologies) and FF (fossil fuel) technologies.
- Biomass production for energy, area under forests and plantations, biomass productivity, production and availability of crop residue for energy.

- **Table 2: Demography of surveyed villages** (Census of India 2011)

Name	No of H-H	Population	Male	Female	P_06	Main CL-M	Main CL-F	Marg. CL-P	Marg. CL 3_6_P	Marg. CL 0_
Daryapur Total	41867	175061	89680	85381	17942	10349	2237	1695	1370	325
Daryapur / Urban	7625	36463	18590	17873	3769	1022	64	78	75	3
Daryapur / Rural	34242	138598	71090	67508	14173	9327	2173	1617	1295	322
Ajitpur	28	115	55	60	17	1	6	0	0	0
Bhambora	80	326	164	162	27	22	11	0	0	0
Jasapur	140	478	230	248	36	39	1	1	1	0
Antargaon	139	523	265	258	52	69	1	7	7	0
Wadal Gawhan	193	729	374	355	52	38	15	0	0	0
Shiwar Bk.	353	1306	659	647	152	62	24	4	4	0
Darapur	489	1839	943	896	181	167	18	3	3	0

Shingnapur	800	3142	1606	1536	341	110	20	28	25	3
Pimplod	952	3870	1995	1875	426	287	61	28	23	5
Yeoda Bk.	2918	12095	6149	5946	1308	583	136	102	81	21

- *(H-H: Number of Households) (P_06: 0-6 Age Group Persons) (Main CL-M: Main Workers Cultivators – Males) (Main CL-F: Main Workers Cultivators – Females) (Marg. CL-P: Marginal Workers Cultivators – Persons) (Marg. CL 3_6_P: Marginal Workers Cultivators worked for 3 - 6 moths during last year – Persons) (Marg. CL 0_3_p: Marginal Workers Cultivators worked for 0 - 3 moths during last year – Persons) (Non Workers – Persons)*
- **2.5: Renewable Energy Resource Availability of Study Region:**
- ***2.5.1: Wind & Solar Energy:*** To generate electricity from wind power the annual average wind power densities of more than 200 Watts/m^2 at 50 meter above ground level (MAGL) is required. The annual average wind power density of the study region is less than 200 Watt/m^2 hence there is no potential for wind energy in the study region.
- Solar thermal technologies have a special relevance in India. Fortunately, a selected region lies in high radiation zones where the annual averaged daily solar radiation on a horizontal surface is in the range of 5.4 - 6.4 kWh/m2. India has an unlimited scope in developing the various solar energy based appliance. Some technologies like solar water heating, solar cooling; solar photo voltaic conversion and solar pumping are utilized for the fulfillment of rural domestic energy need.
- ***2.5.2: Biomass Energy:*** From Table 5 it can be clearly seen that the present biomass has potential to generate 8.3 x 10^8 MJ of energy per year if utilized in the form of biomass briquette / pallet that can be utilized for variety of application i.e. heating, cooking, electricity generation etc Deshmukh et. al, (2014).

- **Table 5: Biomass and Biomass Energy Availability of Region**

Number of Villages	Total Land (in hectors)	Partially Irrigated Land (in hectors)	Firewood availability tons/year	Agricultural residue, tons/year	Raw-Biomass energy available, MJ/year	Biomass energy available if utilized in the form of Producer Gas, MJ/year
136	**70000**	**7000**	**10500**	**45000**	***8.325 x 10^8***	**6.5 x 10^8**

2.5.3: Biogas Energy: The survey questionnaire was also designed to estimate energy resource availability of the villages. 25kg of dung can produce 1 m^3 of biogas or 20.14 MJ of energy per day (Ramanathan and Ganesh, 1995a) As all the families do not keep cattle and during the field visits, it is also observed that in most of the families 5-20% dung available is used for making dung cakes and 80-95% is then used in agriculture. Presently out of total dung cake produce 8 to 13% dung cake are used for cooking and heating activity of the region. The remaining 92 to 87% of dung available is utilized as fertilizer. Table 6 shows the estimated dung available, dung cake consumption and biogas availability per day for the surveyed villages **Table 6: Live stock, dung availability/utilization and biogas potential**

Particulars	**Cow**	**Buffalo**	**Ox**	**Goats**	**Horse**	**Donkey**	**Pig**	**Total**
Total number as per Census**	16018	21053	4632	23626	36	710	158	66233
Daryapur Urban No. **	1600	3150	463	2363	10	200	100	7886
Daryapur Rural	14418	17903	4169	21263	26	510	42	58331

No. **								
Manure Available per Cattle Kg/day*	8	12	10	0.4	--	--	--	
Total Dung available Kg/day	115344	214836	41690	8505.2	--	--	--	371870
% Moisture*	40%	50%	40%	30%	--	--	--	
Dry Dung Available Kg/day	69206	107418	25014	5954	--	--	--	201638
Present % Utilization for Dung cake	10%	6%	10%	Nil	--	--	--	
Present % Utilization as Fertilizer	90%	94%	90%	100%	--	--	--	
Total Biogas Potential of Daryapur rural©	(14875 m^3/day i.e. 4462440 m^3/year) / 24964873 kWh/year #							
Biogas Potential assuming 20% Dung Utilized for Biogas Production	5130555 kWh/year *(Approx:513 x 10^4 kWh/year)*							

* Observed Values during survey. # considering 300 days in a year / **SAO Department of Agriculture and Department of Veterinary Daryapur, Dist.-Amravati / © 25 kg of dung produce 1 m^3 of biogas or 20.14 MJ of energy [Ramanathan and Ganesh, 1995a]

2.4: Present Energy Consumption Scenario (PECS)

Two hundred sample household from ten identified villages are select for micro level analysis of domestic energy consumption pattern. The data collected to determine domestic energy need of the surveyed region in the form of questioner and corresponding activity wise Per Capita Energy Consumption (PCEC) calculations are made. PCEC for each domestic activity is determine from every selected household of sample village and the average PCEC of all selected household of same sample village is applied to that village.

Table 2 show the annual end-use energy requirement associated with present energy consumption scenario. Table 3 shows that the study village is dependent on grid electricity for end-uses such as lighting, cooling and appliances. For thermal end-uses such as cooking and heating, mainly biomass and dung cakes are used. Heavy dependence on grid electricity is due to its present lower cost for the region and social acceptance of commercial energy systems. The present energy consumption scenario is taken as a reference scenario for the purpose of comparison of projected scenarios in terms of associated total energy cost, maximum use of local resources, employment generation and emissions.

Table 2: Estimated Total Actual End-use Energy Requirement

Energy End-use	Energy requirement per person per day kWh/day	Population of the surveyed region	Annual Energy requirement kWh/year	Annual Energy requirement MWh/year
COOKING	0.5039	138598	25491429.2	25491.43
HEATING	0.17145	138598	8673358.89	8673.36
LIGHTING	0.0429	138598	2170236.78	2170.24

COOLING	0.08499	138598	4299497.06	4299.50
APPLIANCE	0.0199	138598	1006706.57	1006.71

Table 3: Estimated actual Annual Energy Required kWh/annum

Resource	Annual Energy Required kWh/annum				
	Cooking	Heating	Lighting	Cooling	Appliances
Biomass	17716543	6869300	-	-	-
Dung cake	2039314	1188250	-	-	-
Ks	637286	615808	368940	-	-
LPG	5098286	-	-	-	-
GE	-	-	1736189	4299497	1006706
PV	-	-	65107	-	-
Total	**25491429**	**8673359**	**2170237**	**4299497**	**1006706**

2.5: Mathematical Representation of Model

The mathematical representation of the model is in terms of expressions stating objectives and constraints, as follows (Deshmukh S. S. & Deshmukh M. K. 2009). Nine single objective-functions are developed out of which five functions i.e. cost, use of petroleum product, CO_X emission, SO_X emission, NO_X emission are minimization type. Four objective functions i.e. employment generation, system efficiency, social acceptance and use of local resources are maximization type. The factors considered while defining objective functions are

- In rural area cost of the energy directly affect its utilization hence it should be minimum. The cost refers to the actual cost of energy delivered at the end use point
- System efficiency directly affect on the consumption of energy resources. The system efficiency is computed as a product of external and end-use device efficiency.
- The social acceptance of energy systems is important while promoting energy resource use.
- When energy is considered as a sub-system of the economic system, it facilitates the employment generation. The employment generation opportunities should be maximized.
- The use of local resources should be maximized to reduce dependence on commercial energy sources and to achieve self dependence in energy sources utilization.
- The use of petroleum products should be minimized to reduce dependence on imported commercial energy sources.
- The pollutants generate by utilizing different energy resources impacts on the human activities, productivity, health and environment hence it should be minimize Three major pollutants i.e. carbon oxides (CO and CO2), sulphur oxides, and nitrogen oxides are considered in this case (Mezher et. al. 1998).

$$Min\ Cost = \sum_{i=0}^{5}[\sum_{i=0}^{m}(C_{ij}X_{ij})] \qquad (01)$$

$$Max\ Efficiency = \sum_{i=0}^{5}[\sum_{i=0}^{m}(\acute{\eta}_{ij}X_{ij})] \qquad (02)$$

$$Max\ Local\ Resources = \sum(X_{ij}) \qquad (03)$$

$$Min\ Petroleum\ Product = \sum(X_{ij}) \qquad (04)$$

$$Max\ Employment\ Genaration = \sum_{i=0}^{5}[\sum_{i=0}^{m}(E_{ij}X_{ij})] \qquad (05)$$

$$Max\ Social\ Acceptance = \sum_{i=0}^{5}[\sum_{i=0}^{m}(S_{ij}X_{ij})] \qquad (06)$$

$$Minimization\ of\ COx\ emission\ i.e. \sum_{i=0}^{5}[\sum_{i=0}^{m}(CO_{ij}X_{ij})] \qquad (07)$$

$$Minimization\ of\ SOx\ emission\ i.e. \sum_{i=0}^{5}[\sum_{i=0}^{m}(SO_{ij}X_{ij})] \qquad (08)$$

$$Minimization\ of\ NOx\ emission\ i.e. \sum_{i=0}^{5}[\sum_{i=0}^{m}(NO_{ij}X_{ij})] \qquad (09)$$

Abbreviations used in equations:

C_{ij} is the unit cost of energy at end-use point,

X_{ij} is the quantum of energy used at the end-use point

$\acute{\eta}_{ij}$ be the system efficiency of the device at end use.

E_{ij} is the employment generation factor.

S_{ij} is the social acceptance of energy system.

CO_{ij}, SO_{ij} and NO_{ij} is the carbon, sulphur oxide and nitrogen oxide emission factors in resource-end-use combination

Subscript ij denotes the end-use resource combination.

2.5.1: Developing Demand & Supply Constraints Equations:

After developing objective function next step is to develop constraint equations for considered problem. In the present study we are considering only energy required for rural domestic activities i.e. cooking, lighting, heating, cooling and appliances.

The various energy resources can be used to fulfill the domestic activity need. In the present study eleven resources are considered through which energy need of five domestic activity can be fulfill. Practically it is not possible to fulfill the energy need of region through every resource because of the certain limitation as:

- The solar thermal cookers cannot cook all varieties of food and therefore total cooking requirement cannot be met. As such, solar thermal cookers can be used for low-temperature cooking purposes only, which form approximately 20% of the total cooking requirement therefore, the potential limit for the use of solar thermal cookers is assumed to be 20% of the total cooking energy requirement (Sinha & Kandpal 1991).
- Cooking pattern of the region indicates that the dung cakes are not fully consumed for the cooking and heating applications. During the survey, it is observed that in most of the families 10-15% dung available

is used for making dung cakes. Therefore, it is assumed that 1% of the dung cakes produced are used for cooking and heating applications.

- Biogas Potential assuming 20% Dung Utilized for Biogas Production
- Biomass potential assuming 40% of the available biomass in the region

The demand constraints develop for these activities are as:

i. **Cooking Energy Constraint:**

$$Cooking\ energy\ requirement\ i.e. \sum_{i=0}^{m} X_{ij} \geq Total\ cooking\ energy\ requirement \quad (10)$$

ii. **Lighting Energy Constraint:**

$$Lighting\ energy\ requirement\ i.e. \sum_{i=0}^{m} X_{ij} \geq Total\ Lighting\ energy\ requirement \quad (11)$$

iii. **Heating Energy constraint:**

$$Heating\ energy\ requirement\ i.e. \sum_{i=0}^{m} X_{ij} \geq Total\ Heating\ energy\ requirement \quad (12)$$

iv. **Cooling Energy Constraint:**

$$Cooling\ energy\ requirement\ i.e. \sum_{i=0}^{m} X_{ij} \geq Total\ Cooling\ energy\ requirement \quad (13)$$

v. **Appliances Energy Constraint:**

$$Appliance\ energy\ requirement \sum_{i=0}^{m} X_{ij} \geq Total\ Appliances\ energy\ requirement \quad (14)$$

The demand constraints develop for these activities are as:

vi. **Limit solar thermal usage for cooking:**

$$\sum (X_6) \leq 20\%\ of\ the\ total\ cooking\ energy\ requirment \quad (15)$$

vii. **Limit for use of dung cake for cooking and heating:**

$$\sum \left(\frac{X_{ij}}{\acute{\eta}_{ij}}\right) \leq 1\%\ of\ the\ dung\ availability, \quad (16)$$

viii. **Biogas Energy Constraint:**

$$Potential\ limit\ for\ biogas\ energy\ i.e. \sum \left(\frac{X_{ij}}{\acute{\eta}_{ij}}\right) \leq 20\%\ of\ the\ Available\ biogas\ energy, \quad (17)$$

ix. **Biomass Energy Constraint:**

$$Potential\ limit\ for\ biomass\ energy\ i.e. \sum \left(\frac{X_{ij}}{\acute{\eta}_{ij}}\right) \leq 40\%\ of\ the\ Available\ biomass\ energy \quad (18)$$

2.6: Mathematical Programming

The present optimization model consists of 9 objective functions subject to 9 constraints. Therefore this type of problem can be solved by using goal programming technique. In goal programming technique, objective functions are referred to as goals and these goals may be either overachieved or underachieved. The deviation variables, W, are defined to represent the overachievement or underachievement of the goals as follows. Further, the pre-emptive goal programming is used, where there is a hierarchy of priority levels for the goals, so that the objective functions are optimized in the order of priority. Based on the objectives and constraints provided in the problem formulation section, a pre-emptive goal programming model has been developed, first by defining goals for each of the objectives, and then by minimizing the sum of the deviation variables. The objective function is solved individually and the optimized value for each objective is used as the corresponding goal.

The goal programming model is described as follows:

$$Minimize \sum d_j^- + d_j^+ \qquad where\ (j = 1, 2, \ldots..9)$$

Subjected to constraints:

$$(\sum_{i=1}^{41}(C_{ij}X_{ij})) + W_1 d_1^- - W_1 d_1^+ = b_1 \qquad (01)$$

$$(\sum_{i=1}^{41}(\acute{\eta}_{ij}X_{ij})) + W_2 d_2^- - W_2 d_2^+ = b_2 \qquad (02)$$

$$(\sum(X_{ij})) + W_3 d_3^- - W_3 d_3^+ = b_3 \qquad (03)$$

$$(\sum(X_{ij})) + W_4 d_4^- - W_4 d_4^+ = b_4 \qquad (04)$$

$$(\sum_{i=1}^{41}(E_{ij}X_{ij})) + W_5 d_5^- - W_5 d_5^+ = b_5 \qquad (05)$$

$$(\sum_{i=1}^{41}(S_{ij}X_{ij})) + W_6 d_6^- - W_6 d_6^+ = b_6 \qquad (06)$$

$$(\sum_{i=1}^{41}(CO_{ij}X_{ij})) + W_7 d_7^- - W_7 d_7^+ = b_7 \qquad (07)$$

$$(\sum_{i=1}^{41}(SO_{ij}X_{ij})) + W_8 d_8^- - W_8 d_8^+ = b_8 \qquad (08)$$

$$(\sum_{i=1}^{41}(NO_{ij}X_{ij})) + W_9 d_9^- - W_9 d_9^+ = b_9 \qquad (09)$$

$$\sum_{i=1}^{11}(X_{ij}) \geq Total\ cooking\ energy\ requirment\ (10)$$

$$\sum_{i=12}^{18}(X_{ij}) \geq Total\ Lighting\ energy\ requirement\ (11)$$

$$\sum_{i=19}^{27}(X_{ij}) \geq Total\ Heating\ energy\ requirement (12)$$

$$\sum_{i=28}^{32}(X_{ij}) \geq Total\ Cooling\ energy\ requirement\ (13)$$

$$\sum_{i=33}^{37}(X_{ij}) \geq Total\ Appliances\ energy\ requirement (14)$$

$$\sum(X_6) \leq 20\%\ of\ the\ total\ cooking\ energy\ requirment (15)$$

$$\sum(\frac{X_{ij}}{\acute{\eta}_{ij}}) \leq 1\%\ of\ the\ dung\ availability, \quad (16)$$

$$\sum(\frac{X_{ij}}{\acute{\eta}_{ij}}) \leq 20\%\ of\ the\ Available\ biogas\ energy, (17)$$

$$\sum\left(\frac{X_{ij}}{\acute{\eta}_{ij}}\right) \leq 40\%\ of\ the\ Available\ biomass\ energy\ (18)$$

Where;

b_j = is the goal value for the objective j

d_1^- & d_1^+ = underachievement and overachievement of goal.

W_j = is the weighting factor for d_1^- & d_1^+ = b_j - L_j

L_j = Worst possible value for objective j. [i e. minimum value for objective j (for maximization type objective) i e. maximum value for objective j (for minimization type objective)]

2.4: Development and Selection of Scenarios for Implementation:

Six different scenarios for the base year 2018-19 are developed by considering alternative priorities to the objective functions. Business as Usual Scenario is based on the direction in which the selected location is headed. Assuming continued moderate economic growth, energy consumption pattern and modest technological improvement, this scenario leads to adverse environmental impacts, ranging from regional acidification to climate change. Thus this scenario leads to a higher dependence on carbon-intensive fossil fuels, resulting in high energy-related emissions and falls short of achieving a transition towards sustainable development. This scenario is subdivided into two2 sub-scenarios. 1) Business as Usual No Priority Scenario, 2) Business as Usual Equal Priority Scenario 3) Economic Objective Scenario 4) Security-Acceptance Scenario 5) Cost-Employment Generation Scenario 6) Efficiency Scenario. Further these six scenarios are sub divided into seven sub scenario. The developed scenarios are evaluated on the basis of associated cost emissions, use of local resources and employment and optimal scenario is suggested for implementation (Deshmukh S. 2011). The developed optimization model is solved using WINQSB software package.

RESULTS AND DISCUSSION

This section presents the results of energy resource allocation at Daryapur Block level for the base year 2019 - 20. Different scenarios are developed for the base year & year 2025 with an aim of identifying the optimal scenario for implementation. The selection of scenario is carried out on the basis of cost incurred in energy supply, associated emissions, employment potential and use of local resources. The optimization model is solved by using WINQSB package. Daryapur Block has 74 Panchayats (GPs) and 150 villages out of which 133 villages are in existence and 17 villages are migrated in past few years (Census of India 2011). The summary of decentralized energy planning for different scenarios is explained in detail in the following sections.

3.1 Options for Cooking Energy Needs

Energy resource allocation in Daryapur block shows that out of total cooking energy need 69.5% of the energy need can be fulfilled by solid biomass, 8% by dung cake, 20% by LPG and 2.5% through kerosene as cooking fuel under the PECS scenario. The result of optimization without assigning priority to objective function shows that, use of dung cake, biogas, solar thermal and PV electricity should be promoted for cooking end-use. Energy resource allocation in BAUNP scenario also shows that dung cake, biogas, solar thermal and solid biomass can meet 1.43%, 20.13%, 18.61%, 59.83% of total cooking energy requirements. In EOS-1, SAS-2, ES-1 & ES-2 scenario, LPG is major resource of cooking energy because of high efficiency of the device and social acceptance of the community. Fig. 1 gives the details about energy resources allocation for heating activity in various scenarios.

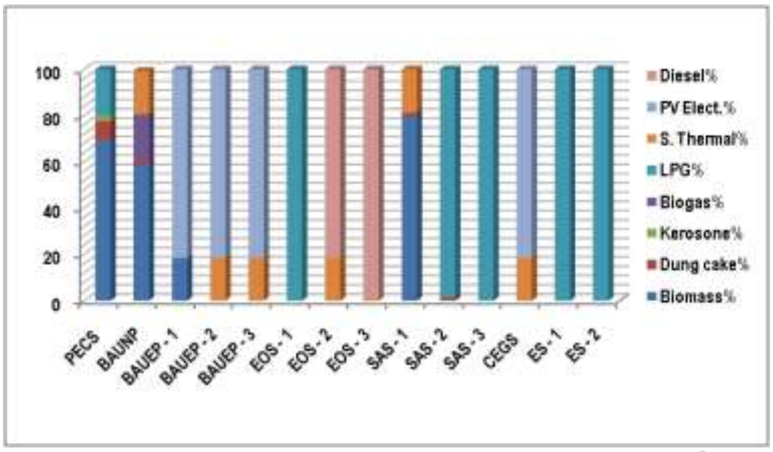

Fig. 1- Cooking Energy Consumption Pattern for Various Scenarios

3.2 Option for Water Heating Energy Needs

Under PECS biomass, dung cake and kerosene are the major resources for heating energy requirement. Under all scenarios solar thermal and biogas is the optimized resource which can fulfill the total heating energy need individually or in combination. The result of optimization reveals that 59.5 % of total heating energy need of the region can be fulfilled by using biogas in EOS-1, SAS-1, SAS-3, ES-1 and ES-2 scenario. Fig. 2 gives the details about energy resources allocation for heating activity in various scenarios.

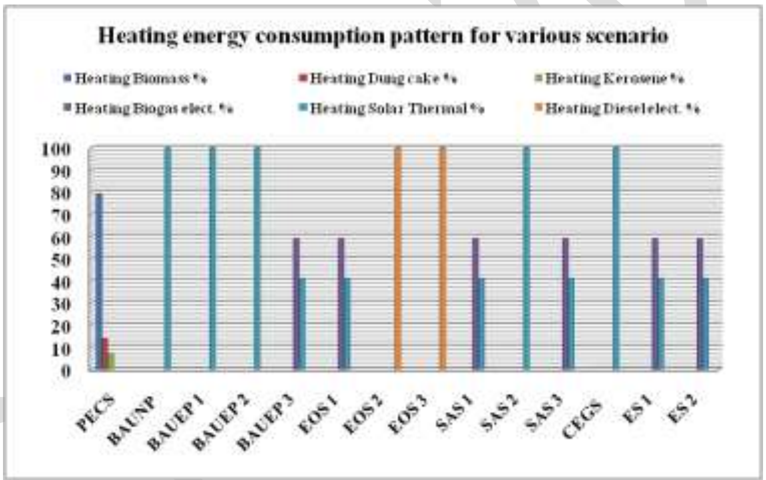

Fig. 2- Heating Energy Consumption Pattern for Various Scenarios

3.3 Option for Home Lighting Energy Needs

Energy resource allocation under PECS shows that total lighting energy requirement is fulfilled through 80% grid electricity, 3% PV electricity and 17% kerosene. PV electricity appears as the optimal source of electricity for lighting in BAUEP, SAS-1 and CEGS scenarios, where cost minimization is not the priority. When cost, social acceptance and efficiency is on the priority list, the result of the optimization shows that kerosene is the option for heating energy need in EOS-1, SAS-1, SAS-2, ES-1 and ES-2 scenario. Fig. 3 gives the details about energy resources allocation for heating activity in various scenarios

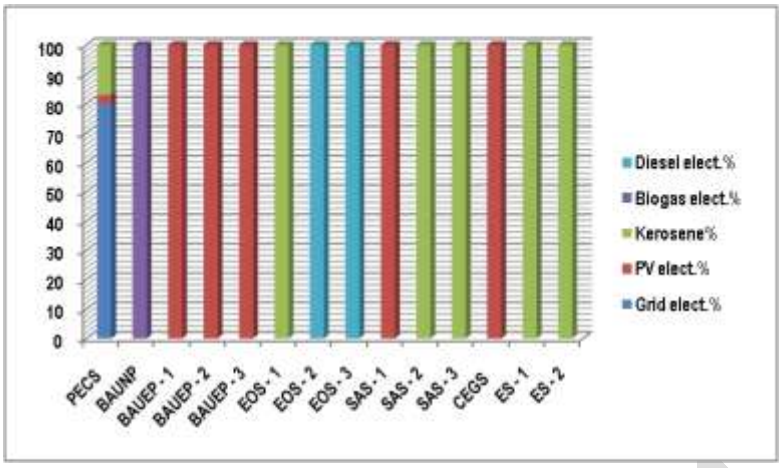

Fig. 3- Lighting Energy Consumption Pattern for Various Scenarios

3.4 Option for Cooling & Electrical Appliances Energy Needs

In PECS total cooling and electrical appliances energy needs get fulfilled by grid electricity. The result of the optimization shows that PV electricity should be the option to grid electricity in most of the cases. Fig. 2 shows the energy resources allocation for different scenarios of cooling activity. Fig. 4 gives the details about energy resources allocation for heating activity in various scenarios.

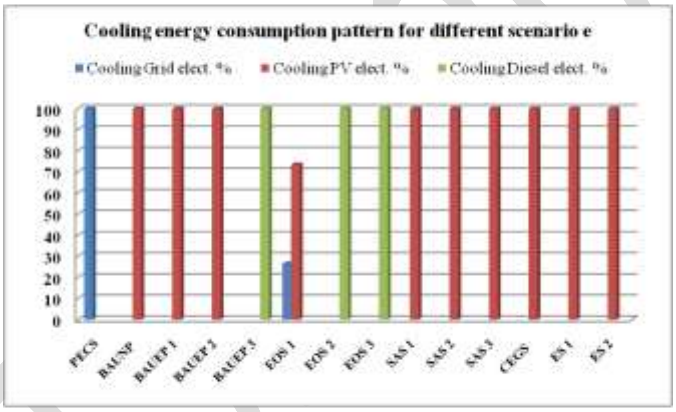

Fig. 4- Cooling Energy Consumption Pattern

3.5 Employment Generation, Associated Costs and Emissions under Different Scenarios for Daryapur Block

The associated costs, emissions and employment under different scenarios for Daryapur block are presented in Table 10, fig. 3 Results obtained from the analysis show that CEGS is the least cost, high employment and emission free scenario.

Table 10: Associated costs and emissions under different scenarios Base Year 2017-18

Scenario	Case	Priority to objective functions	Total cost associated million $/year	Emissions associated in Tons/year		
				COx	SOx	NOx,
PECS	1	Actual as per surveyed data	1.30	28588.4	43.72	148.4
BAUNP	1	No Priority	1.91	57.71	6826.36	1210.82
BAUEP	1	1-Emission 2-Economics 3-Scecurity Acceptance	0.94	0	0	0
	2	1-Economics 2-Emission 3-Scecurity Acceptance	0.24	0	0	0
	3	1-Economics 2-Scecurity Acceptance 3-Emission	0.24	2271.5	31.3	2.75
EOS	1	1-Cost 2-Employment Generation 3-Efficiency 4- Other objective	2.55	6498.69	343.47	0
	2	1-Employment Generation 2-Cost 3-Efficiency 4- Other	0.82	12646.5	193.08	17.05

	3	1-Employment Generation 2-Efficiency 3-Cost 4- Other	0.82	14169.9	213.95	18.9
SAS	1	1-Petroleum Product 2-Local Resources 3-Social Acceptance 4- Other objective function	1.32	969.67	214.93	30.16
	2	1-Local Resources 2-Petroleum Product 3-Social Acceptance 4- Other objective function	2.48	4517.65	124.96	0
	3	1-Social Acceptance 2-Local Resources 3-Petroleum Product 4- Other objective function	2.49	5553.03	338.96	0
CEGS	1	1- Cost & Employment Generation 2- Other objective	0.17	0	0	0
ES	1	1-System Efficiency 2- Other objective function	2.49	5553.03	338.96	0
		1-System Efficiency 25% increase 2- Other objective	2.49	5553.03	338.96	0
Economic Objective :- Cost, System efficiency, Employment generation						
Security Acceptance:- Petroleum Product, Local Resources, Social Acceptance						
Emission:- COx, SOx, NOx						

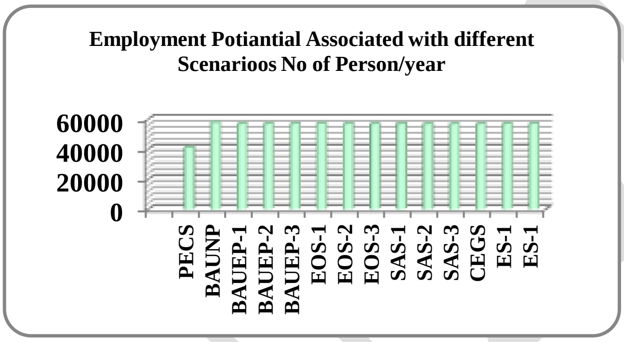

Figure 3: Annual Employment Potential

Table 11 gives the briefing about surplus energy resources in % after allocation of energy to the activities for various scenarios. This unutilized locally available energy can be used to fulfill the energy needs of another region or use to complete the energy need of another sector in the defined region. Separate analysis is required to identify the need of another sector of the region which should be fulfilled by utilizing excess energy resources available in the region.

Table 11: Quantity of Surplus Resources after Allocation to Various Scenarios

Scenario	Solar Energy Cooking %	Dung Cake Energy %	Biogas Energy %	Biomass Energy %
PECS	100	0	46	74
BAUNP	0	0	0	100
BAUEP - 1	0	100	100	100
BAUEP - 2	0	100	100	100
BAUEP - 3	0	100	100	100
EOS - 1	0	100	100	100
EOS - 2	100	100	100	100
EOS - 3	100	100	100	100
SAS - 1	0	0	0	78
SAS - 2	100	0	100	100
SAS - 3	100	100	0	100
CEGS	0	100	100	100
ES - 1	100	100	0	100
ES - 2	100	100	0	100

CONCLUSION

The energy needs of the region can be used to define a region. The energy plans are developed to fulfill the objective of meeting energy requirements subject to certain limit or constraints. These constraints correspond to resource availability, technology options, cost of utilization, environmental impact, socio-economic impact, employment generation, for the present as well as in future. The objectives of energy plans for the new region are related to socio-economic development.

Decentralized energy planning approach can be a useful way to meet the domestic energy need of rural India and regulatory bodies can exercise better control through this mechanism as against demand and supply side management. Better insight into the energy consumption and utilization pattern in Central parts of Vidharbha (India) has been attempted. Energy resource allocations have been carried out using all possible objective-functions considered in energy planning process.

WINQSB has been found useful to build energy forecast system based on existing energy consumption and supply database, to generate various futuristic scenarios The present model suggests that renewable energy based systems have the potential to meet all rural energy needs. At the block level, enormous potential of agriculture biomass and solar energy is available which is excess after satisfying the domestic energy needs of the region. High employment generation and carbon mitigation could also be achieved by adopting BAUEP and CEGS scenarios.

REFERENCES

1. Shyam M, (2002) "Agro-residue based renewable energy technologies for rural development". *Energy for sustainable development,* 6(2):37-42.
2. Ramachandra T. V., Yves Loerincik, Shruthi B. V., (2006) "Intra and inter country energy intensity trends". *International Journal of Energy and Development*; 31(1):43–84.,
3. Hiremath R. B., Shikhab S., Ravindranath N. H., (2007) Decentralized energy planning; modelling and application-a review, *Renewable and Sustainable Energy Reviews* (11) 729-752. doi:10.1016/j.rser.2005.07.005
4. Kydes Andy S., Shaw Susan H., McDonald Douglas F., (1995) Beyond the horizon: Recent directions in long-term energy modeling:, *Energy,* 20 (2): 131-149
5. Census of India (2011), available at: www.censusindia.gov.in/pca/default.aspx
6. Deshmukh S. J., Betlejewska Renata Stasiak, Ingole Sachin, Bhuyar Lalit, (2014) "DSS for rural domestic energy planning – case study of a block in central India" *International Journal of Energy Sector Management* Vol. 8 No. 1, 27-55 DOI 10.1108/IJESM-06-2013-0007
7. Deshmukh S. S., Deshmukh M. K. (2009) "A new approach to micro level energy planning – A case of northan parts of Rajasthan", *Renewable & Sustainable Energy Review,* 13(3), Pages 634-642; Link: https://doi.org/10.1016/j.rser.2007.11.015
8. Deshmukh Sandip, (2011), "Energy Resource Allocation in Energy Planning", *Handbook of Renewable Energy technology,* 801-846. Link: http://www.worldscientific.com/doi/abs/10.1142/9789814289078_0029
9. Diakoulaki D., Sarafidis Y., Papayannakis L., Zervos A., (1999) "A regional planning approach for the promotion of renewable energies" *Renewable Energy* 18 (3), , Pages 317–330
10. Iniyan S., Suganthi L., Jagadeesan T. R., Samuel A. A. (2000) "Reliability based socio economic optimal renewable energy model for India", *Renewable Energy* (19) 291-297.

11. Jinturkar A. M., Deshmukh S. S., (2011) "A fuzzy mixed integer goal programming approach for cooking and heating energy planning in rural India". *Expert Systems with Applications* (38) 11377–11381
12. Joshi Bharati, Bhatia T. S. Bansal N. K. (1992) "Decentralized energy planning model for a typical village in India", *International Journal of Energy Research* 17 (9), 869–876,
13. Kanase-Patil A. B., Saini R. P., Sharma M. P., (2010) "Integrated renewable energy systems for off grid rural electrification of remote area". *Renewable Energy* (35) 1342–1349
14. Kazemi Seyed Mahmood and Rabbani Masoud., (2013) "An Integrated Decentralized Energy Planning Model considering Demand-Side Management and Environmental Measures" *Journal of Energy* Volume, Hindawi Publishing Corporation. http://dx.doi.org/10.1155/2013/602393
15. Kumar B., Hiremath R. B., Balachandra P., N. H. Ravindranath N. H., (2011) "Implications of Decentralized Energy Planning for Rural India", *Journal of Sustainable Energy & Environment* (2) 31-40
16. Mezher T., Chedidy R., Zahabi W.., (1998) Energy resource allocation using multi-objective goal programming: the case of Lebanon, *Applied Energy* (61) 175-192.
17. Ozcan Evren Can, Serpil Erol (2014) "A Multi-Objective Mixed Integer Linear Programming Model for Energy Resource Allocation Problem": The Case of Turkey, *Gazi University Journal of Science 27(4):1157-1168*
18. Ramakumar R, Shetty P. Sudhakara, Ashenayi K., (1986) "A linear programming approach to the design of integrated renewable energy systems for developing countries", *IEEE Trans Energy Conver* EC-I (4) 18–24
19. Ramanathan R. Ganesh L. S., (1993) "A multi-objective programming approach to energy resource allocation problems", *International Journal of Energy Research* (17) 105-119.
20. Ramanathan R., Ganesh L. S, (1995) "Energy alternatives for lighting in households: An evaluation using an integrated goal programming - AHP model", Energy 20 pp: 63-72.
21. SAO Department of Agriculture and Department of Veterinary Daryapur, Dist.-Amravati
22. Saaty T. L. (1980). The Analytic Hierarchy Process Planning, Priority Setting, Resource Allocation. *McGraw-Hill, New York*, http://www.lamsade.dauphine.fr/mcda/biblio/Author/SAATY-TL.html
23. Shin Ho Wai and Hashim Haslenda (2012) "Integrated Electricity Planning Comprise Renewable Energy and Feed-In Tariff". *American Journal of Engineering and Applied Sciences* 5 (1): 53-58, ISSN 1941-7020
24. Sinha C. S., Kandpal T. C., (1991) Decentralized versus grid electricity for rural India: The economic factors, *Energy Policy* (19), 441-448.
25. Srinivasan R, Balachandra P, (1993) "Micro-Level Energy Planning in India: A Case Study of Bangalore North Taluka", *International Journal of Energy Research (*17) 621-632.
26. Triantaphyllou E., Shu B., Sanchez S. Nieto, and Ray T., (1998) "Multi-criteria decision making: an operations research approach", *Journal Encyclopedia of electrical and electronics engineering* (15) 175-186
27. Zhu Jinxiang, And Chow Mo-Yuen, (1997), "A review of Emerging Technique on Generation Expansion Planning" *IEEE Trans on Power Systems*, 12 (4): 1722-1788.