Mainstreaming Access to Modern Energy Services in Rural India: A Low Carbon Strategy

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Abstract: India's energy challenges are multi-pronged. It is manifested through growing demand for modern energy, fossil fuel dominated energy system facing resource crunch, need for creating access to quality energy to the large section of deprived population, vulnerable energy security, local and global pollution regimes and need for sustaining economic development. In this paper, we make an attempt to address these issues by broadly classifying energy challenges into (i) Climate change mitigation challenge and (ii) Rural energy access challenge and assess feasibility of biomass energy as panacea for dealing with these challenges. The results establish the fact that the adoption of biomass energy-based route for rural energy empowerment is a win-win situation for all stakeholders. Households can enjoy the benefits of modern energy services at affordable cost; rural entrepreneurs can run profitable energy enterprises; carbon markets can have access to large quantity of CERs; the government can have the satisfaction of securing energy access to a large section of rural population; and globally, there is a benefit of climate change mitigation. The proposal is to adopt a public-private-partnership-driven 'business model' with innovative institutional, regulatory, financing, and delivery mechanisms. The proposed innovations are: creation of *rural energy access authorities* within the government system as leadership institutions; establishment of *energy access funds* to enable transitions from the regime of "investment/fuel subsidies" to "incentive-linked" delivery of energy services; *integration of business principles* to facilitate affordable and equitable energy sales and carbon trade; and treatment of *entrepreneurs as implementation targets*. It is proposed that the delivery of energy services would be through micro-energy enterprises and ESCOs would function as intermediaries between these enterprises and the international carbon market in aggregating the CERs and trading them under CDM. The results suggest that the proposition is profitable with IRRs in the range of 15%-45% for entrepreneurs and 47%-89% for ESCOs. This proposal targets 100% access to modern energy carriers by 2030 through a judicious mix of conventional and biomass-based energy systems with an investment of US$35 billion. The estimated annual cost is about US$9 billion for a GHG mitigation potential of 213Tg CO_{2e} at an abatement cost of US$41/t$CO_{2e}$.

1. Introduction

Climate change is the most important global environmental challenge facing humanity. Historically, compared to developed countries, developing countries like India have contributed little to green house gas emissions (GHGs). However, spectacular growth observed in consumption of energy as well as other resources indicates that India is likely to emerge as one of the significant emitters of GHGs in the future. Imperatives of high GDP growth and all inclusive development will cause high demand for resources and resultant

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emissions. There will be pressures internally as well as internationally to alter the path of development by adopting environment friendly alternatives. In the long run this might prove advantageous to the country. India can thus leapfrog the process of development through adopting advanced technologies, which are energy efficient and use renewable sources of energy. Among the renewable energy sources, biomass energy is the most versatile energy carrier and there are technologies which can transform various forms of biomass into energy carriers that are useful for human kind. Technologies, which are almost at the end of commercialization chain, are accessible and these can transform variety of biomass into gaseous fuels for heat energy, electricity for providing almost every type of service and biofuels for motive or transport energy. We believe that biomass energy can play a significant role in achieving the dream of low carbon energy future set above for India. Such a pathway, if adopted effectively, can provide a sustainable, self-reliant and secure energy system for India. Additionally, it would help India in achieving the targets related to climate change that are likely to be fixed in the near future.

India has a formidable challenge to face in ensuring security of access to modern energy carriers to the large majority of the population, predominantly rural. Though 74% of the Indian villages were electrified as on 2005; only 54.9% of the households had access to electricity and the remaining depending on kerosene lamps for lighting. In comparison, about 92% of the urban households had access to electricity for lighting in 2005. About 42% of the households had access to LPG for cooking as on 2005. With respect to rural-urban divide, in 2005, only 9% of the rural households had access to LPG whereas about 57% of urban households had that privilege. About 75% of the rural households still depend on fuel wood for their cooking energy needs with only 3% having access to kerosene for cooking. Thus major challenge for India is to bridge the access gap in modern energy services for cooking and lighting. The above results indicate the failure of the prevailing policies, governance and institutions in achieving this goal. The changed global situation has provided many new opportunities for countries like India to bridge this energy access gap. First, India has adequate renewable energy resource potential, mainly the biomass, to produce adequate quantum of modern energy carriers to meet the energy needs. Second, advanced renewable energy (low carbon) technologies, which are versatile and robust enough to perform at various scales and in rural regions have reached near commercialization stage. Third, global climate change mitigation imperatives have resulted in market mechanisms that have created demand for carbon credits, which can be translated into revenue opportunities for reducing the cost of energy access. Fourth, the wrongly-targeted energy subsidies, having failed to provide affordable access to modern energy services, can now be re-launched as operational incentives for energy access projects. Effective combination of these four opportunities can be used to create "Rural Energy Enterprises" to produce multiple products – modern energy services, carbon credits, livelihood opportunities and rural employment – turning out into a profitable rural energy access venture. This paper makes an attempt to prove the feasibility of such a concept in the context of rural India by addressing each of above five issues.

2. Biomass potential

Biomass is typically classified into two types, woody and non-woody. Woody biomass is derived from forests, plantations and forestry residues. Non-woody biomass comprises agricultural and agro-industrial residues, and animal, municipal and industrial wastes. The proposal is to use woody biomass for electricity generation through biomass gasification route and soft-biomass (including cattle dung) for biogas production through bio-methanation route.

2.1 Biomass potential for power generation

India's biomass resource base for power generation is substantial, which is used very inefficiently. In addition, there are large tracts of degraded lands that can be used for growing additional biomass. An area of about 107 million hectares has been estimated to be degraded with 64 million hectares categorized as wasteland, which includes degraded forests (GOI, 2005). As per the estimates, the minimum waste-land area that might be available for biomass production is about 35 million hectares. If about 5 million hectares of land by the side of highways and rail tracks is added to this, the total land available for raising plantations becomes 40 million hectares. In addition, there would be significant potential from farm forestry with farmers raising trees on bunds and in fields. Agro-forestry can also be promoted through contract farming whereby corporate bodies can organize groups of farmers to produce the required biomass under contract through development of wastelands.

Apart from plantations, surplus agricultural wastes and agro-industrial residues can also be utilized for electrical energy generation. About 450 MT (Million Tonne), including sugarcane bagasse and leaves, of these resources are generated every year in the country (Table 1). About half of the surplus residues are burnt in the fields causing serious air pollution. The potential for additional generation of woody biomass in the country has been estimated at 255 MT. Out of this, forests wastelands are estimated to contribute 171 MT and the marginal cropland to contribute the rest of 84 MT.

Table 1: Ultimate bioenergy potential for expanding rural energy access

Main category	Sub category	Area Mha	Biomass resource with energy potential	Potential energy end use	Physical quantity (MT/year)	Energy potential
Crops	Rice	46.1	Straw + husk	Gasification for power	41	4,700 MW
	Maize	6.6	Stalk + cobs		6.2	700 MW
	Cotton and others	16.8	Stalk, coconut shells, fronds		240	28,000 MW
	Sugarcane	5.5	Bagasse + leaves	Cogeneration for power	163.5	8,900 MW
Crop land	Marginal crop land	14	Woody Biomass	Gasification for power	84	9,700 MW
Waste land	High potential	28.5			171	20,000 MW
Dung	Cattle		Dung	Biogas for cooking	660–1190	336 PJ/year
Soft-biomass			biomass	Biogas for cooking	300–600 (dry)	2,415 PJ/year

Source: Based on (Ravindranath, et al, 2005, Planning Commission, 2003, Sudha, et al, 2003, MoRD, 2005, Kishore, et al, 2007)

2.2 Biomass potential for cooking

Currently, biogas is produced in India only through cattle dung as the feedstock. There are various estimates of dung availability in India ranging from 660 to 1190 MT per year. India has the highest bovine population of about 273 million (Kishore, et al, 2007) that produces a total dung of 1,190 MT/year and if all of the dung is converted into biogas that leads to a production of 35.7 billion m^3 of biogas per year. All of this cattle dung is not available for biogas production and even if the total recoverable dung of 458 MT per year (Vijay, 2006) is used for biogas, it is possible to produce 16 billion m^3 of biogas per year, which can generate 336 PJ of energy per year (Table 1). The biogas generated will be adequate to meet the cooking energy requirements of about 250 million people. Another alternative is to use soft-biomass as feedstock to produce biogas. The non-fodder soft biomass available in India is estimated to be between 300-600MT (dry) per year (Ravindranath, et al, 2005). Even if we assume that only 300 MT of dry soft-biomass is available per year for biogas production that can produce about 90 billion m^3 of biogas per year at 0.30 m^3 of biogas per kg of dry biomass.

3. Bioenergy technologies: technical potential and achievement

3.1 Biogas technology for cooking

Biogas, a mixture of about 60% methane and 40% carbon dioxide, is a combustible gas, which is the product of anaerobic fermentation of cellulosic materials such as animal dung, plant leaves and waste from food processing and households. Biogas can be combusted directly as a source of heat for cooking. The slurry produced after digestion can be used as valuable fertilizer. Two popular designs of digesters have been developed; the Chinese fixed dome digester and the Indian floating cover biogas. The digestion process is the same in both digesters but the gas collection system is different in each. In the floating cover type, the water sealed cover of the digester is capable of rising as gas is produced and acting as a storage chamber, whereas the fixed dome type has a lower gas storage capacity and requires good sealing if gas leakage is to be prevented (ITDG, 2004).

In India, several types of biogas plant designs have been promoted of which the two most widely promoted are the floating drum (KVIC design) and the fixed dome (modified Chinese design). Biogas plants are designed for operation at either the household or the community level as an ideal fuel for meeting cooking energy needs in rural areas. At the household level, the cumulative number of biogas plants built from 1982 to 2006 is estimated to be 3.83 million (MNRE, 2007) against a potential of 12 to17 million. The total number of large community and institutional biogas plants installed until 2006 was about 3902, and only 1228 plants were built during 1999-2006. This is a small achievement compared to the potential for a community biogas plant each in the majority of the 500,000 villages.

3.2 Biomass gasification technology for electricity

Biomass, particularly woody biomass, can be converted to high-energy combustible gas for use in internal combustion engines/alternators for electricity generation. Biomass gasifiers are devices performing thermo chemical conversion of biomass through the process of oxidation and reduction under sub-stoichiometric conditions. Various capacities in the range of 1 kg/hr to about 500-kg/hr gasifier systems are presently under use. These systems are used to meet both power generation using reciprocating engines or for direct usage in heat application. The prime movers are diesel engines connected to alternator; where diesel saving up to 80% is possible (Mukunda, et al, 1994). Among the biomass power options, small-scale gasifiers (of 20 to 500 kW) have the potential to meet all the rural electricity needs and leave a surplus to feed into the national grid. Indigenously developed technologies for biomass gasifiers, which are readily available from a few manufacturers, have been demonstrated successfully for their rural electrification potential, though on a relatively smaller scale. The total installed capacity of biomass gasifier systems as on 2006 is nearly 76 MW (MNRE, 2007).

3.3 Medium-term potential and achievements

India has a large potential to meet the modern energy needs of cooking and electrification for lighting (Table 2). These estimates of potential are typically medium term (2031-32), and are technically and economically feasible. India has implemented a large number of programs to promote bioenergy technologies. However, it can be observed from Table 2 that the spread of bioenergy technologies is marginal compared to the potential available. Lack of effective policies, institutions and participation from private sector are the main reasons for such a lackluster performance. The government needs to address these issues in order to speed-up the deployment of bioenergy technologies.

Table 2: Bioenergy technology potential and achievements

Item	Potential	Energy Potential	Cumulative Achievements (as on 31-12-2009)
Bioenergy power generation (MW)			
Waste land for bioenergy plantation	20 million hectares	45,000 MW	0
Surplus biomass	120-150 MT/year	16,000 MW	1154.69 MW
Bioenergy for cooking/heating			
Cattle dung	458 MT/year	16.03 billion M^3/year	1.22 billion M^3
Soft biomass	300 (dry) MT/year	90 billion M^3/year	0

Source: Based on (Planning Commission, 2006, MNRE, 2010, Ravindranath, et al, 2005, Vijay, 2006)

4. Rural energy: current status

4.1 Rural cooking energy

About 70% of the population in India lives in rural areas. The rural energy scenario is characterized by inadequate, poor and unreliable supply of energy services and large dependence on traditional biomass fuels. Non-commercial biomass energy sources like firewood, agricultural waste, and cattle dung, contribute over 27% of the total primary energy consumed in the country (Planning Commission, 2008). Biomass is primarily used for meeting the cooking requirements through traditional stoves having low efficiencies, of the order of 10%. The analysis based on data from latest National Sample Survey results (Table 3) indicate that about 84% of the rural households were using biomass (firewood and agro-waste) and cattle dung as primary cooking fuel in 2005 (NSSO, 2007). Only 10.3% of the rural households use modern carriers like LPG, kerosene, biogas and electricity as primary cooking fuels. In the case of households belonging to low income class, the share of biomass for cooking rises to nearly 93%. The three income classes are derived using the MPCE classes. The use of LPG as a primary cooking fuel is limited to only 33% of the high income rural households.

It is estimated that about 84% of the total rural household cooking energy consumption, including primary, secondary, and tertiary cooking fuels, is derived from biomass with firewood having a dominating share. However, in terms of primary cooking fuel, biomass (including cattle dung) accounts for about 97% of the rural household cooking energy consumption (Table 4). As primary cooking fuels, modern fuels account for only 2.2% share.

Table 3: Number of rural households using a particular energy carrier as a primary fuel for cooking in 2005 (in millions)

	Biomass	LPG	Dung	Kerosene	Coal	Biogas	Electricity	Others	Total
Low income	44.3 (83.4)	0.4 (0.7)	5.0 (9.5)	0.2 (0.3)	0.5 (0.9)	0.0 (0.0)	0.0 (0.0)	2.7 (5.1)	53.1 (100)
Middle income	59.7 (77.2)	5.2 (6.7)	7.3 (9.5)	1.0 (1.3)	0.6 (0.7)	0.2 (0.2)	0.03 (0.05)	3.3 (4.3)	77.3 (100)
High income	10.5 (47.2)	7.5 (33.8)	1.5 (6.9)	0.8 (3.7)	0.2 (0.8)	0.2 (0.9)	0.04 (0.2)	1.5 (6.5)	22.3 (100)
Total	114.5 (75.0)	13.1 (8.6)	13.9 (9.1)	2.0 (1.3)	1.2 (0.8)	0.4 (0.3)	0.1 (0.1)	7.5 (4.9)	152.7 (100)

Note: Figures in brackets give the percentage of households
Source: Balachandra (2011a)

Table 4: Consumption of primary cooking fuels by rural households in 2005

	Biomass (million tonne)	LPG (million tonne)	Dung (million tonne)	Kerosene (million litres)	Coal (million tonne)	Biogas (million M3)	Electricity (GWh)	Total (PJ)
Low income	88.6	0.0	20.2	31.8	0.5	3.8	2.6	1518.9 (37.6)
Middle income	119.3	0.7	29.3	177.9	0.6	51.5	27.9	2095.4 (51.9)
High income	21.1	1.0	6.2	147.6	0.2	56.2	30.7	424.3 (10.5)
Total	229.0	1.7	55.6	357.3	1.2	111.5	61.1	4205.9
Total (PJ)	3435.6 (81.7)	76.5 (1.82)	653.6 (15.5)	13.1 (0.31)	24.4 (0.58)	2.6 (0.06)	0.2 (0.01)	

Note: Figures in brackets give the percentage shares
Source: Balachandra (2011a)

The energy consumption per household estimated using information from Tables 3 and 4 provide additional insights. The estimated household cooking energy consumption in 2005 was nearly 4,206 PJ indicating per household consumption of about 27.5 GJ per year. On an average, the low income households consume about 29.7 GJ of cooking energy per year per household where as they are 28.3 GJ and 19.9 GJ annually for households belonging to middle and high income classes respectively. This indicates the increase in efficiency levels of energy use by higher income households.

4.2 Rural lighting energy

Lighting is an important household energy end-use service as it is directly related to quality of life. Lighting is the energy end-use that is exclusively associated with electricity as it can provide high quality of light at high efficiency compared to a fuel-based light source. The extent of rural electrification in India varies widely from one state to another and from one region to the other, e.g., more than 90 percent of the villages of the states of southern and western part of India are electrified, whereas in states like Uttar Pradesh, Bihar, Jharkhand, Orissa, and in some north eastern states, less than 60 percent villages are electrified. Even in electrified villages many households are not connected to the electricity grid (CEA, 2006).

The analysis based on NSS data (NSSO, 2007) show the current status of rural electricity access to lighting (Table 5). Only 55% of the rural households use electricity for lighting and 44% of the households have access to only low quality kerosene lighting. The situation is worse for the low income households where about 61% of the households were using kerosene for lighting in 2005. The status improves with the rise in income levels.

Table 5: Number of rural households using a particular energy carrier as a primary fuel for lighting in 2005 (in millions)

	Electricity	Kerosene	Others	Total
Low income	19.6 (37.8)	31.8 (61.4)	0.4 (0.8)	51.8 (100)
Middle income	46.8 (59.2)	31.5 (39.9)	0.7 (0.9)	79.0 (100)
High income	17.6 (80.5)	3.8 (17.6)	0.4 (2.0)	21.9 (100)
Total	84.0 (55.0)	67.2 (44.0)	1.5 (1.0)	152.7 (100)

Note: Figures in brackets give the percentage of households
Source: Balachandra (2011a)

It is interesting to note that though 55% of the rural households were using electricity for lighting in 2005, their energy share is just around 30% compared to about 70% in the case of kerosene using households (Table 6). This indicates the low efficiency levels of kerosene lighting. The total lighting energy use in 2005 was nearly 168 PJ indicating per household annual usage of 1.1 GJ. The poor households consume about 1.2 GJ whereas high income households use 1.0 GJ per household for lighting in a year. It is important to note that the estimated electricity consumption of about 13,850 GWh reported here is exclusively for lighting and the fact is that electricity is used for many other types of end-uses even by the rural households, which is estimated at about 25,700 GWh.

Table 6: Consumption of primary lighting fuels by rural households in 2005

	Electricity (GWh)	Kerosene (million litres)	Total (PJ)
Low income	1,637	1,529	61.8 (36.8)
Middle income	7,811	1,512	83.5 (49.7)
High income	4,405	184	22.6 (13.5)
Total	13,853	3,225	167.9
Total (PJ)	49.9 (29.7)	118.0 (70.3)	

Note: Figures in brackets give the percentage shares
Source: Balachandra (2011a)

5. Universal Rural Energy Access: Energy Needs and Cost Implications

The prediction of basic energy needs has been done with an objective of achieving universal access to modern energy services by 2030-31. The approach adopted here is to construct scenarios of rural cooking and lighting energy access with an a priori target of 100% access by 2030. It proposes to meet this goal with a judicious mix of energy supply from centralized energy system (electricity grid and LPG) and decentralized renewable energy-based system (electricity and biogas from distributed biomass energy systems). The modern energy carrier considered for lighting is electricity and that for cooking is either LPG or biogas. We consider 2010 (financial year 2010-11) as the scenario base year and the terminal year as 2030 (2030-31).

The 2010 access levels for modern energy carriers have been estimated using the growth rates obtained from the households energy dependency shares during 1999-2000 and 2004-05 (based on NSS data). The number of rural households in 2010 is estimated using data from United Nations Population Division (UNPD) and 2001 Census (Census, 2005, UNPD, 2008). Having derived the current (2010) and decided about the 2030 status of rural household energy access, the next step is to determine the trajectory of the path of the growth in this energy access till 2030-31. Only two aspects become important for this, speed at which the target is to be achieved and willingness to make the investments by the government, public and private sectors. The objective of developing the rural energy access scenarios is to ascertain the implications for energy resources, investments, operating costs and carbon emissions.

Table 7 contains the summarized scenario results of cooking energy needs in 2030-31. Results for two alternatives, LPG-based and biogas-based cooking for all the households, are presented. As per the predictions, there are expected to be about 188.2 million rural households in India. Out of these, about 25 million have access to modern energy carriers for cooking in 2010 and the remaining 163 million requires to be provided access during the next 20 years. Out of these, about 48 million are expected to have LPG connections whereas the remaining 115 million biogas connections. Each rural household is assumed to use 128 kg of LPG or 292 M^3 of biogas per year as primary cooking fuel depending on the type of connection. The total biogas requirement is about 33.6 billion M^3 and for this, the estimated annual soft biomass (dry) requirement is about 67 million tonne and the annual wet dung requirement is about 355 million tonne. The demand for LPG would be about 9.4 million tonne by 2030. The transformation from biomass to modern energy carriers for cooking has enormous cost implications for all the stakeholders involved in this process (Table 7). All the cost estimates are in 2009 Rupees (Rs.). The annualized capital cost is estimated using a discount rate of 10% on the investments made. The cooking energy access scenario has an annual cost implication of about Rs. 336 billion by 2030. The total investment over a period of 20 years is about Rs. 867 billion.

The GHG mitigation benefits of the proposed cooking energy access scenarios are significant. The baseline scenario for 2030 representing no interventions to expand rural energy access is expected to contribute nearly 184 million tCO_{2e} annually. The proposed scenario results in significantly lower emission levels of just 29 million tCO_{2e} per year. There is an additional benefit of mitigation of CH_4 emissions equivalent of 37 million tCO_{2e} per year by avoiding the open exposure of cattle dung. Thus, the proposed scenario, if adopted, can contribute to GHG mitigation of nearly 192 million tCO_{2e} annually. The GHG abatement cost of Rs. 1,756/tonne (US$ 37.4/tonne) is attractive considering related development benefits.

Similar scenario results for 100% electricity lighting access are presented in Table 8. As per the projections made about 105.5 million households are estimated to have access to electricity for lighting in 2010 and the remaining 82.8 million households requires to be provided access during the next 20 years. Out of these rural households, about 49.7 million are expected to have grid-based electricity connections whereas the remaining 33.1 million households are to be connected to the biomass-based distributed electricity systems. Each rural household is assumed to use about 65 kWh of electricity for lighting in a year by adopting efficient lighting devices.

Table 7: Rural cooking energy scenario in 2030-31

Characteristic	**LPG**	**Biogas**
Total households in 2030 (Million)	188.2	
Households with access as on 2010 (Million)	24.7	0.3
Households provided with access during 2010-2030 (Million)	48.4	114.8
Annual fuel usage per household (kg or M^3)	128	292
Annual fuel usage per household in GJ	5.9	6.7
Annual energy requirements (Million Tonne or billion M^3)	9.4	33.6
CO_2 emission factor (kg/GJ)	67.4	0
Baseline CO_2 emissions per year (Million Tonne)	61.3	122.2
Alternative CO_2 emissions per year (Million Tonne)	29.0	0
CO_2e (CH_4) emissions mitigation potential per year (Million Tonne)		36.95
CO_2 emissions mitigation potential per year (Million Tonne)	32.3	159.2
Total annualized capital cost (Rs. Billion)	16.8	93.0
Annual recurring cost (Rs. Billion)	131.0	95.5
Total annual cost (Rs. Billion)	147.8	188.5
Initial investment for stoves (Rs. Billion)	130.6	114.8
Initial investment for biogas plant (Rs. Billion)	0	356.8
Initial investment for distribution system (Rs. Billion)	0	265.2
Total investment (Rs. Billion)	130.6	736.8

Table 8: Rural lighting energy scenario in 2030-31

Characteristic	**Grid**	**Biomass gasifier**
Total households in 2030 (Million)	188.2	
Households with access as on 2010 (Million)	105.5	0.0
Households provided with access during 2010-2030 (Million)	49.7	33.1
Annual electricity usage per household: Efficient (kWh))	65.0	65.0
Annual electricity usage per household: Conventional (kWh)	220	220
Total Annual energy requirements (GWh)	20,627	2,152
CO_2 emission factor (kg/kWh)	0.83	0.0
Baseline CO_2 emissions per year (Million Tonne)	23.4	6.0
Alternative CO_2 emissions per year (Million Tonne)	17.1	0.0
CO_2 emissions mitigation potential per year (Million Tonne)	6.4	6.0
Total annualized capital cost (Rs. Billion)	25.8	15.8
Annual recurring cost (Rs. Billion)	3.8	7.0
Total annual cost (Rs. Billion)	29.6	22.9
Installed capacity required (MW)	4,022	2,500
Initial investment for generation capacity (Rs. Billion)	175.8	81.2
Initial investment for transmission system (Rs. Billion)	128.7	0
Initial investment for distribution system (Rs. Billion)	64.4	40.0
Initial investment for final connection (Rs. Billion)	109.2	72.8
Initial investment for CFLs (Rs. Billion)	14.9	9.9
Total investment (Rs. Billion)	493	204

The results indicate that by 2030, the centralized grid is expected to supply about 90% (20,627 GWh) of the electricity needs of the rural households for lighting and the remaining 10% (2,152 GWh) to be contributed by the distributed electricity. The installed capacity required to provide lighting access for the incremental households is approximately 6,500 MW with 4,000 MW from the grid and 2,500 MW from distributed biomass power. From Table 8, it may be observed that the total investment over a period of 20 years is about Rs. 697 billion with grid supply accounting for Rs. 493 billion and biomass gasifier power for Rs. 204 billion. On the other hand, the total annual cost (including annualized capital cost and recurring cost) of biomass gasifier-based electricity access is at Rs. 22.9 billion compared to grid-based access at Rs. 29.6 billion. The annual GHG mitigation potential is expected to be 12.4 million tonne. The GHG abatement cost of about Rs. 4,233/tonne (US$ 90.1/tonne) is relatively high in the present context.

6. Mechanism of implementation

The main goal of the proposed implementation framework is to facilitate easy and affordable access to energy services for all rural households. Like their counterparts in urban India, the rural households would remain buyers of modern carriers or services to perform their preferred end-uses. The rural households too are expected to be delinked from the complexities of programmes, technologies and processes. It is not aimed at proposing a radically new approach for implementation rather the proposal is to adopt existing mechanisms that are available and already in practice with certain incremental modifications and innovations.

6.1 The framework

The proposed approach is a public-private-partnership-driven ‘business model’ with innovative institutional, regulatory, financing, and delivery mechanisms. Some of the innovations recommended for adoption are (Balachandra, 2011b):

(i) Creation of exclusive **rural energy access authorities (REAAs)** within the government system as leadership institutions;

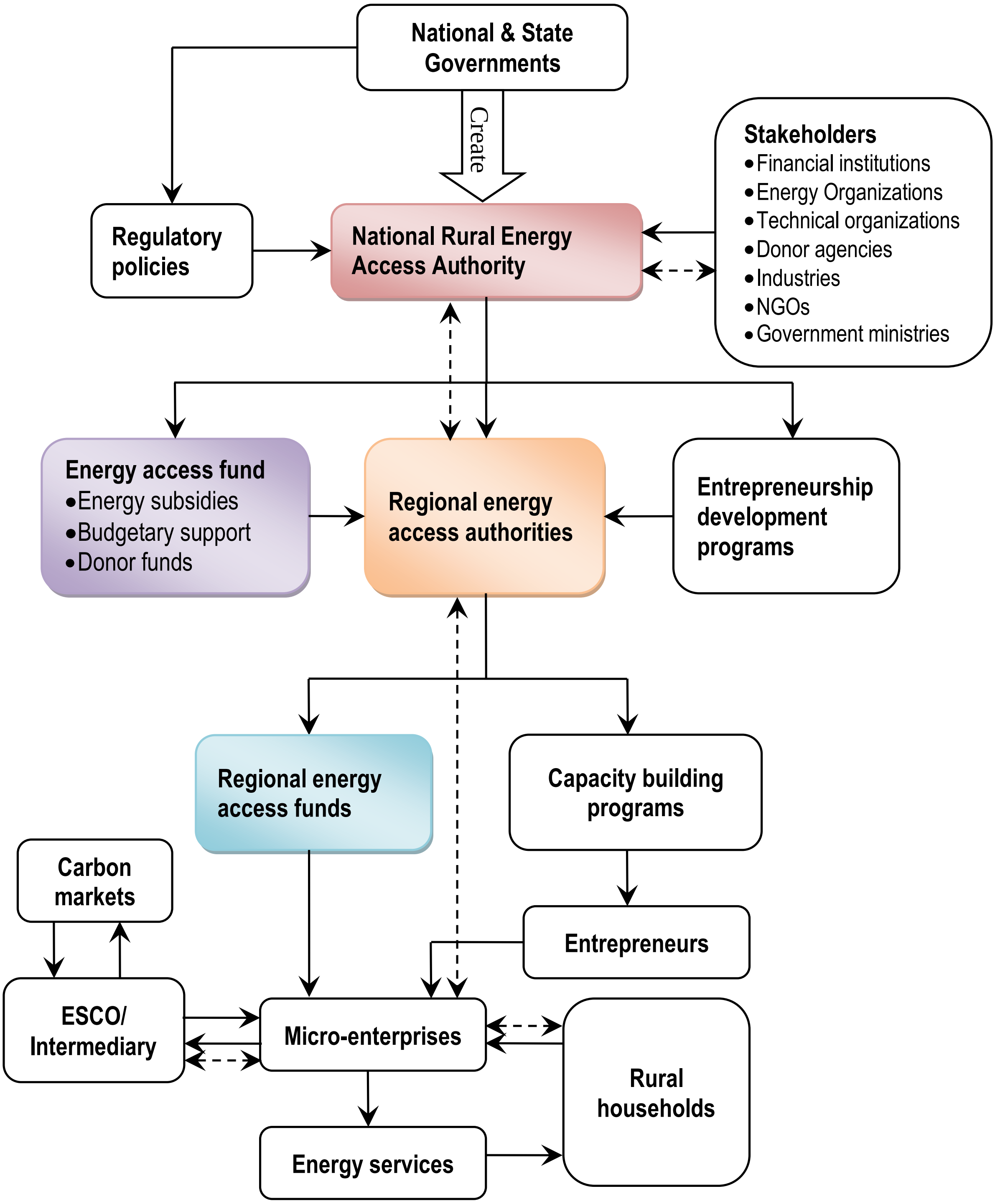
(ii) Establishment of **energy access funds (EAFs)** to enable transitions from the regime of “investment/fuel subsidies” to “incentive-linked” delivery of energy services;

(iii) **Integration of business principles** to facilitate affordable and equitable energy sales to households and carbon trade; and

(iv) Treatment of **entrepreneurs as implementation targets** and not millions of rural households.

The proposed implementation framework under which this process can happen is presented in Figure 1 (Balachandra, 2011b). The framework represents a top-down approach with the government/s represented by the appropriate ministries at the top and the rural households, at the other end reaping the benefits. Considering the scale of problem of expanding access, bottom-up approaches resulting in independent small-scale initiatives would not be able to achieve the desired success levels. The past experiences too suggest failure of a large number of NGO and private sector initiated projects.

Figure 1: Implementation framework



The framework (Figure 1) entails establishment of the rural energy access authorities (REAAs) both at the national and regional levels to be empowered with enabling regulatory policies and supported by the multi-stakeholder partnership. The stakeholders are expected to be from the relevant public as well as private sector organizations. These REAAs need to be empowered with exclusive powers to initiate, establish, manage, support, and supervise programmes for expanding energy access. The national REAA is expected to establish the national energy access fund (EAF), support the creation of and coordinate with the regional REAAs, and develop a comprehensive entrepreneurship development programme with inputs from stakeholders. The regional REAAs are expected to manage the regional EAFs and facilitate the conduct of intensive capacity building programmes for the prospective entrepreneurs. The national REAA would support the regional authorities in these endeavors. The EAF should be established with contributions from the diverted fossil fuel subsidies, allocations from the national budget, plan grants, and donor funding. These funds should be used to provide incentives for the energy enterprises. The regional REAAs are expected to manage the regional EAFs and facilitate the conduct of intensive capacity building programmes for the prospective entrepreneurs. At the other end, the trained entrepreneurs are envisaged to establish village-level energy micro-enterprises to produce and distribute energy carriers to the rural households at affordable cost. The Energy service companies (ESCOs) would function as intermediaries between these enterprises and the international carbon market in aggregating the certified emission reductions (CERs) and trading them under the clean development mechanism (CDM) or similar mechanisms. As per the proposal, the ESCOs would share carbon trade proceeds with energy enterprises at pre-determined rates. The financial institutions are expected to lend to these energy enterprises as well as ESCOs at soft interest rates under priority lending schemes.

In the figure, the unidirectional dark lines with arrows represent various types of flows and they represent flow of authority, inputs, services, payments, etc. The dotted lines with arrows represent flow of communication and they are bi-directional. These represent flow of information, guidance, feedback, etc. These flows have been designed to reduce complexities, to eliminate overlapping of authorities and interference, to keep the communication and monitoring hierarchical and simple. This we believe can make the whole process very effective. Though the implementation framework appears to be a top-down approach, there is every chance that the actual process would be a bottom-up one. If the whole programme needs to be successful, then the energy-enterprises need to perform very well. For this to happen, the inputs from the top should be timely and effective. Here, the presumption is that the successful energy-enterprises will demand contributions from the entities above them. In other words, it is the "pull" factor from the bottom will make the whole programme successful rather than the "push" factor from the top. Thus, the main responsibility of the energy access authorities would be to ensure smooth flows of required inputs to the enterprises.

6.2 Integrated Rural Energy Policy (IREP)

In India, policy making with respect to energy systems are fragmented. The policy frameworks predominantly focus on the type of energy sources. For example, there are policies exclusively focusing on electricity, coal, oil & natural gas, renewable energy, etc. There was no all encompassing energy policy until the government's acceptance of Integrated Energy Policy (IEP) in 2008 (Planning Commission, 2006). Realization of the serious inadequacies with respect to rural electrification influenced the government of India to adopt rural electrification policy in 2006. However, rural energy problems are not limited to lack of electricity access alone, the more critical issue is with respect to lack of cooking energy access. Though IEP has recommendations for expanding rural cooking energy access, it is very likely that these aspects would get ignored among the many so-called "critical recommendations" for the energy sector as a whole. Therefore the need is to have an exclusive policy focusing only on rural energy in an integrated manner. Thus, this proposal recommends introduction of an integrated rural energy policy (IREP). The advantage is that most of the components of this proposed policy framework already exist in various energy policy documents. Therefore the recommendation is to extract relevant policies from these and include them into the proposed IREP. However, some of the existing policy recommendations would need some minor adjustments to address the rural energy access issues in totality. In addition, IREP also needs to include some new policy guidelines to facilitate establishment of new institutions and to expand the scope of currently pursued initiatives (Balachandra, 2011b).

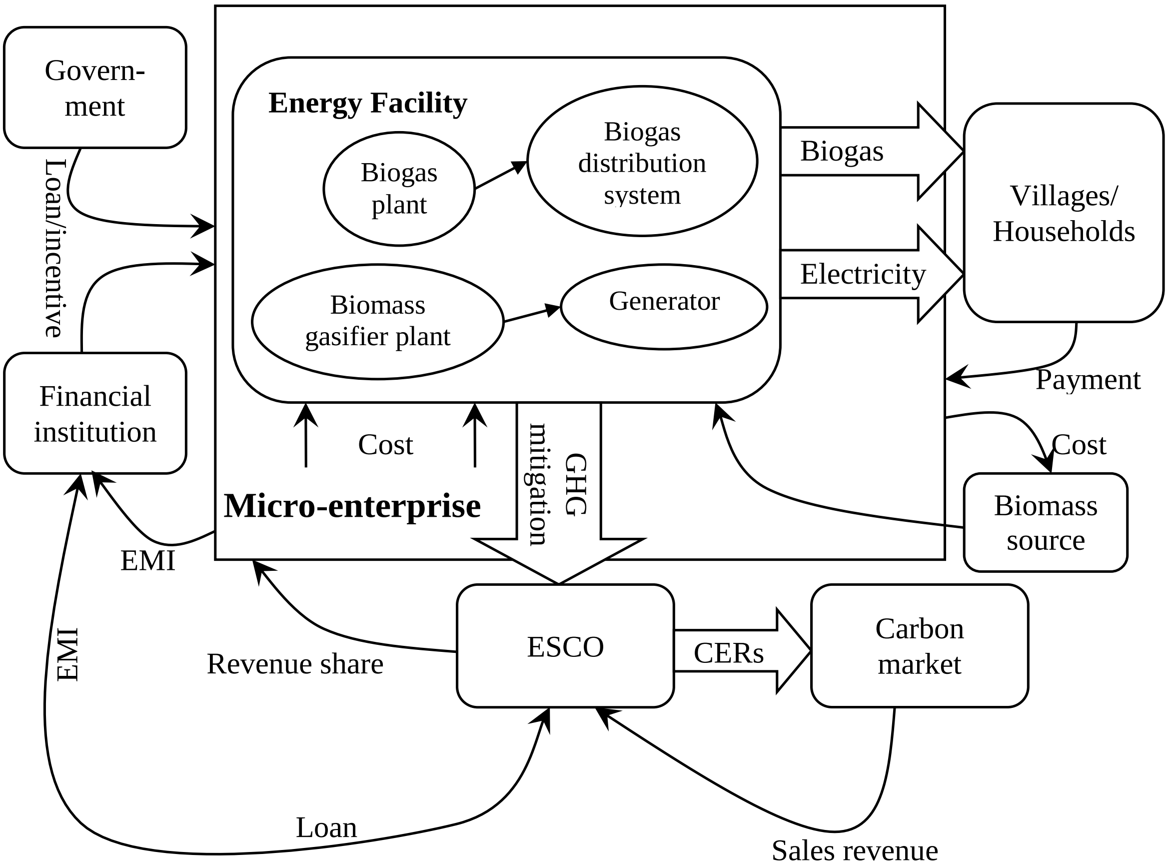
It is proposed that the IREP need to include policies to enable setting-up of exclusive rural energy access authorities (REAAs) both at the national and regional (states) level as nodal agencies. These authorities need to be empowered with exclusive powers to initiate, establish, manage, support and supervise programmes for expanding energy access. It is also required to establish energy access funds (EAFs) both at the national and regional level to support implementation and sustainable operation of the programme. The fund should be established with contributions from the diverted fossil fuel subsidies, budgetary allocations, plan grants and donor funding. The proposed IREP should have policy guidelines to enable the existing rural electricity franchisees be transformed into independently functioning rural energy enterprises and facilitate establishment of a large number of such rural energy enterprises. They should be enabled to carry out the business of all-inclusive energy service providers including production of energy carriers. The scope of these enterprises should be enlarged to include electricity generation from distributed power generation systems, performing existing transactions between the distributing utilities and the rural households, LPG distribution, usage of the infrastructure created by the government and establishment of biogas supply systems for supplying cooking gas. All the policies and rules related to licensing, pricing, taxation, depreciation, exemptions, etc., that have been notified for rural electrification should be part of IREP.

7. Micro-enterprises for rural energy services

The final delivery of energy services to the rural households is to be performed by the micro-enterprises. As suggested earlier this could be done either through producing energy carriers by establishing bioenergy-based distributed energy systems or by purchasing these carriers from the centralized energy systems or both. Financial cost and benefits should be the influencing factor for selecting the best among these options for the individual entrepreneurs.

The overall structure of the micro-enterprise would be as shown in Figure 2 (Balachandra, 2011b). The enterprise would own an energy facility consisting of biogas plants, either based on biomass or cattle dung or both types, for producing biogas and biomass gasifier plants for generating electricity. The energy facility would also include biogas distribution system connecting every household in the village/s. This would ensure piped biogas supply to the households. Further, the electricity distribution infrastructure would be accessed under lease from the government utilities at pre-determined leasing rates. The entrepreneurs are also can directly purchase electricity from the grid and perform only the distribution of it to the rural customers. Similarly, LPG also can be procured from the government agencies and distributed to the households. A mixed strategy with purchased quantity complementing own production, especially for electricity, could be the preferred choice. However, own production with renewable energy sources can earn CER revenue which is not available in the case of purchased energy carriers. Further, if the centralized energy supply is unreliable and of low quality then again own production is a better option. If the prohibitively high investments and difficulty in accessing loans are preventing new distributed capacity additions then it may be advisable to opt for purchased energy.

Figure 2: Micro-enterprise for rural energy services



As explained earlier, the financial institutions are expected to support the enterprise with loans at favorable terms and government entities to support with incentives to enhance profitability. In addition, the entrepreneur is expected to invest in the enterprise as his or her equity contribution. For the entrepreneur, the financial inflow is in the form of payments received from the households, revenue share from the ESCO due to CER sales and operational incentives from the government. The enterprise could enhance inflows by selling the surplus energy carriers at higher prices to other sectors of the rural economy and to households for other than basic end-uses (lighting and cooking). The financial outflow for the entrepreneur would be for equated monthly installments (EMI) for loan repayment, and expenses related to O&M and purchase of biomass.

An ESCO would bundle many such enterprises and present a single potential small-scale CDM project to the international carbon market. It will transform the GHG emissions mitigated into CERs and trade them in the carbon market. In this process, the ESCO need to bear both the fixed and variable transaction costs and again it would seek loans from the financial institutions. The revenue from CER sales would be shared with the entrepreneurs. Thus, financial inflow for the ESCO would be revenue from CER sales and the outflow would be the EMI for loan repayment and the revenue shared with the entrepreneurs.

The enterprise could be providing energy access to a single village or multiple villages. This depends on the size of the village, geographical clustering of villages, availability of biomass and financial resources, installed capacity, financial and operational feasibility, potential growth opportunities, demand from other sectors of the rural economy, etc. Even it is possible for a single enterprise to have multiple energy facilities at different villages. These depend on the ability of the entrepreneur to expand his or her enterprises. There is no size restrictions proposed on the enterprises. Further, the households are not expected to pay for the connection costs for the basic energy services. Thus, it is proposed that each household would be getting the basic electricity connection for lighting and biogas connection for cooking including the end-use devices (lighting lamps and biogas stove) for free of cost. These costs have been proposed to be built into cost of the enterprise and may be recovered through monthly payments made by the households. It is important to remember that these monthly payments cannot be high considering the fact these households are being made to shift from free or low cost conventional energy carriers to relatively expensive modern energy carriers.

8. Micro-enterprises for expanding rural energy access: A financial feasibility analysis

The success of any business is dependent on the level of profits it could earn. Thus, a financial feasibility analysis of a business proposition is very much critical to assess its profitability potential. The estimates of net present value (NPV) and internal rate of return (IRR) are excellent indicators of profitability of a business. The financial feasibility assessment of two possible rural energy enterprises is performed. The first one is adopting biogas technology for producing biogas for cooking by either using cattle dung or soft biomass. The second enterprise is with biomass gasifier technology for generating electricity for lighting and other end-uses. In the second example, energy efficiency is integrated with the inclusion of compact fluorescent lamps (CFL) for household lighting. As discussed previously, the ESCOs are expected to exploit the potential of large emissions reductions through small-scale CDM projects.

8.1 Micro-energy enterprise for producing biogas for cooking: Financial feasibility

As proposed, the entrepreneurs will establish and run the bio-methanation (or biogas) enterprise and the energy service companies (ESCOs) will bundle these into a small-scale CDM project. It is assumed that the ESCO will bear the transaction costs and earn the revenue from carbon trading while sharing agreed parts of the benefits with the entrepreneurs to enhance their profitability. While performing the financial feasibility study of the bio-methanation enterprise, the following assumptions have been used:

- The baseline is biomass cookstove-based cooking and the two possible alternatives are cattle dung-based and soft biomass-based biogas plants for supplying biogas for cooking. The cost implications of both the alternatives are assumed to be equal considering the large scale implementation possibilities.
- The average number of households in a village is 200. This assumption is based on the 2001 census data related to number of inhabited villages of about 593,732 and the number of rural households of 137.75 million. This gives an average village size of 232 households per village and as an approximation we have used 200 households per village. The number of biogas using households will be zero in the baseline scenario and it is 200 in the alternative scenario.
- The estimated biogas requirement is 1 m^3 per day per household. It is assumed that the village will have 10 biogas plants of 20m^3 capacity. Each biogas plant will have a life of 25 years (200 families will need 200m^3/d).

- An equity contribution of 20% of the total investment required for the project will be contributed by the entrepreneur. Remaining 80% will be obtained by the entrepreneur as a loan from the financial institutions.
- A discount rate of 10% is used for estimating the present values of cash flows happening in different years.
- An interest rate of 6%, a subsidized rate, is used for the repayment of the loan. Because of the developmental benefits of such enterprises, the government can be pursued to provide interest subsidy for the loans given to the entrepreneur. These loans can be made part of the priority sector lending schemes of the banks. In addition, a loan repayment period of 5 years is assumed.
- A price for Certified Emissions Reduction (CER) of US \$20/tCO_2 and a conversion rate of Rs. 47/US\$.
- The benefits/revenue for the households are on account of cost and efforts saved due to non-usage of biomass and the cost is the monthly payment to be made to the entrepreneur. All the costs related to distribution infrastructure, operations and maintenance (O&M) and biogas stoves are expected to be borne by the entrepreneur.
- The net cost of energy resources (cattle dung and soft biomass) is assumed to be zero since equivalent value can be obtained from the organic fertilizer, which is a by-product from the biogas plant.
- For the entrepreneur, the revenue streams are from the payments made by the households, and the share from the CDM benefits given by the ESCO. The entrepreneurs' cost streams are equity contribution, equated monthly installments (EMI's) to be paid to the financial institutions and O&M costs. The proposed operational incentives from EAFs are not included in these estimates.
- For the bundling intermediary (ESCO), the benefits are the remainder share of the CDM benefits and the cost are the EMIs towards loan taken for paying the CDM transaction costs and monitoring costs.

The feasibility assessment of the biogas enterprise involves estimation of the cost and benefits of shifting from traditional inefficient firewood stove-based cooking to high quality biogas-based cooking. As discussed in the previous section, considering the investment capabilities of small scale entrepreneurs, we have assumed that a typical project can include a village consisting of 200 households (Table 9). The baseline has two types of emissions, (i) CO_2 emissions of 214 tonne per year due to combustion of 40% of the biomass, which is sourced from unsustainable sources (Parikh and Reddy, 1997), and (ii) CO_2 equivalent (CH_4) emissions of 201 tonne per year due to exposed cattle dung stored open ground. Thus, the annual CO_2 emission mitigation potential of dung-based biogas plant is 415 tonne and that of soft biomass-based biogas plant is 214 tonne. The total investment required for 10 biogas plants is Rs. 1.6 million.

Thus, two possible biogas enterprise cases, one with cattle dung and the other with soft biomass as feedstock are assessed. The results of the assessment of financial viability from the entrepreneur's perspective are presented in Table 10, which indicate the profitability nature of this enterprise. We feel that the equity contribution Rs. 0.32 million will ensure continuous involvement of the entrepreneur in the project and with a stake in the project he/she is sure of striving for its success. With the estimated equated monthly installment

(EMI) of Rs. 25,322 (Table 10) and cost of operation and maintenance of Rs. 17,333, the monthly cost implication for both types of enterprises is likely to be Rs. 42,656.

Table 9: Data and assumptions used for bio-methanation-based enterprise

Characteristic	Baseline (biomass)	Alternative (biogas)
Number of households per enterprise	200	200
Energy consumption/household/year	2000 kg	365 m^3
Annual energy consumption for all households (GJ)	6,000	1,679
Total new investment (Rs. million)	0	1.6
Annualized capital cost (Rs. million)	0	0.19
Annual O&M cost	0	0.21
Annual energy cost (Rs. million)	0	0.00
Annual cost (Rs. million)	0	0.40
Annual CO_2 emission (tonne)	214	0
Annual CO_2 equivalent emission due to open storage of cattle dung (tonne)	201	
Price of CERs (US$)	20	20
Rs./US$	47	47
Soft loan interest rate (%)	6	6

The CDM revenues received from ESCO per month will be Rs. 29,583 for dung-based and Rs. 14,678 for biomass-based biogas enterprises. This revenue is the entrepreneur's share in the total earnings from the CER sales after accounting for the costs incurred by the ESCO and its profits. It may be observed from the results that the CDM benefits are not adequate to cover the monthly costs. Especially, the situation is worse for the biomass-based enterprise. The entrepreneur's revenues are further enhanced by the monthly payment of Rs. 20,000 from the households as nominal cost of biogas (at Rs. 100/household/month). With this, the net profit for the first five years will be about Rs. 6,928 per month for the dung-based biogas enterprise and it is a loss of Rs. 7,978 per month for the biomass-based biogas enterprise. This would be a serious discouragement for the prospective entrepreneurs and the proposed EAFs must contribute to overcome such situations. However, the situation changes after the completion of EMI payments, when both enterprises would start making profits (Table 10). The post-EMI profit is Rs. 32,250 for dung-based enterprise and it is Rs. 17,344 for biomass-based enterprise and these are expected to continue for the next 20 years. The Net Present Value (NPV) for the entrepreneur from the dung-biogas enterprise is about Rs. 1.85 million and that for biomass-biogas enterprise is nearly Rs. 0.38 million. The internal rate of returns (IRRs) of 42% and 15% show the benefits are significantly higher than the costs. The profitability analysis shows that the financial performance of dung-biogas enterprise is extremely high and can be attractive even without government incentives. The avoided methane emissions are mainly responsible for such an outcome. However, this is not the case with biomass-biogas enterprise and these enterprises could survive only with the support of government incentives through EAFs. However, these limitations could also be overcome by integrating other energy services and procurement options proposed in this study.

Table 10: Financial feasibility of biogas enterprise from entrepreneur's perspective

Characteristic	Biogas-Dung	Biogas-Biomass
Contribution by entrepreneur @ 20% equity (Rs. million)	0.32	0.32
Life of the device (years)	25	25
Loan amount (Rs. million)	1.28	1.28
Loan repayment period (years)	5	5
Equated monthly installment, EMI (Rs.)	25,322	25,322
O&M cost (Rs./month)	17,333	17,333
Total cost (Rs./Month)	42,656	42,656
Annual CO_2 emissions reduction (tonne)	415	214
CDM revenue from intermediary (Rs. million/year)	0.35	0.18
CDM revenue from intermediary (Rs./month)	29,583	14,678
Household repayment (Rs./month)	20,000	20,000
Total revenue (Rs./month)	49,583	34,678
Profit per month for the first 5 years (Rs)	6,928	-7,978
Profit per month for the remaining 20 years (Rs)	32,250	17,344
Internal rate of return (IRR) - %	42%	15%
Net present value (Rs)	1,855,364	379,380

For a bundling intermediary (ESCO), the profit margins are significantly higher than the biogas enterprises (Table 11). It is assumed that a bundle of either 125 biogas-dung or 225 biogas-biomass enterprises of would be feasible from the point of view of cost implications and the need for retaining the status of small-scale bundled CDM project. These could be part of small-scale CDM Type III project activities limited to those that result in emission reductions of less than or equal to 60,000 tCO_2 equivalent annually (UNFCCC, 2007). The estimated CERs and the revenue from the sale of CERs are given in Table 11. The one-time transactions costs are expected to be Rs. 7.5 million and Rs. 12 million respectively for the biogas-dung and biogas-biomass projects respectively. The annual verification costs are likely to be Rs. 1.5 million each for both types. The total annual costs for the first five years would be Rs. 3.5 million and Rs. 4.9 million respectively for dung- and biomass-based projects. It is assumed that the ESCO will retain 2% of the net profits from the sale of CERs and the remaining amount will be distributed to the entrepreneurs. This will be the situation for the first five years and in the next 20 years; the annual earnings of the ESCO will be enhanced by the savings due to the stoppage of EMI payments (Table 11). It may be observed from the table that the financial returns with NPVs of about Rs. 12.9 million and Rs. 15.4 million, and the IRRs of 68% and 47% respectively for the two project cases seem to be very attractive for the entrepreneurs to have a serious look at these opportunities.

Table 11: Financial feasibility of bio-methanation enterprises from ESCOs perspective

Characteristic	Biogas-dung	Biogas-biomass
No. of enterprises	125	225
Annual CERs available for sale	51920	48189
Revenue from CERs (Rs. million)	48.80	45.30
Transaction cost (Rs. million) - One time	7.5	12
Transaction cost (Rs. million) - Annual	1.5	1.5
Intermediary's contribution @ 20% equity (Rs. million)	1.5	2.4
Loan amount (Rs.)	6	9.6
Loan repayment period (years)	5	5
Equated monthly installment, EMI (Rs.)	118,698	189,917
O&M cost (Rs./month)	50,000	90,000
Total cost (Rs./Month)	168,698	279,917
Annual cost of loan and O&M (Rs. million)	2.0	3.4
Total annual cost (Rs. million)	3.5	4.9
Net profit from CER sales (Rs. million)	45.28	40.44
Share of profits @2% for the first 5 years (Rs. Million)	0.9	0.8
Share of profits for the remaining 20 years (Rs. Million)	2.3	3.1
Share of profit for entrepreneurs (Rs. million)	44.37	39.63
Internal rate of return (IRR) - %	68%	47%
Net present value (Rs)	12,954,417	15,444,178

8.2 Micro-energy enterprise for distributed electricity generation and efficient lighting: Financial feasibility

The method of establishing this enterprise, cost and revenue structure and bundling several such enterprises into single CDM project is similar to that adopted for the biogas enterprises. Thus, entrepreneurs will establish and run the distributed electricity generation/efficient lighting enterprise and the ESCOs will bundle these into a small-scale CDM project. While developing this enterprise, the following assumptions have been used:

- The baseline is centralized grid-based electricity and incandescent bulbs (IB) as lighting devices and the possible alternative is distributed electricity generation using biomass gasifier plants and compact fluorescent lamps (CFL) as efficient lighting alternatives.
- The number of households per enterprise is assumed to be equal to 1000. The number of biomass gasifier-based electricity and CFL using households will be zero in the baseline scenario and it is 1000 in the alternative scenario.
- For financial feasibility, five villages (each with 200 households) will be under single enterprise and the total of 1000 households will be served by one biomass gasifier-based electricity generation plant of 100 kW with a life of 25 years. The plant is expected to run for 16 hours per day and 5840 hours per year. The annual generation is expected to be 584,000 kWh for a possible net saleable quantity of 543,700 kWh after accounting for auxiliary consumption and distribution losses.

- The households using incandescent bulbs (IB) are estimated to consume 220 kWh per year per household with an assumption that each household will be having three IBs of 40 watt used for an average of 5 hours per day for 365 days.
- The households using compact fluorescent lamps (CFL) are estimated to consume 65 kWh per year per household with an assumption that each household will be having three CFLs of 11 watt (total of 12 watt including one watt for choke) used for an average of 5 hours per day for 365 days.
- Thus, out of the electricity available for sale, 65,000 kWh would be for lighting, the next 300,000 kWh for other household electricity end-uses (lifeline consumption) and remaining 178,700 kWh to other sectors of the rural economy (agriculture, rural industries) and to households for other luxury end-uses at higher prices.
- The electricity price for household lighting is Rs. 2.0/kWh and for lifeline end-uses Rs. 4.0/kWh and for other sectors it is Rs. 6.0/kWh.
- The benefits/revenue for the households are on account of excellent lighting at nominal price and the cost is the monthly payment to be made to the entrepreneur. All the costs related to distribution infrastructure, O&M and lighting devices are expected to be borne by the entrepreneur.
- For the entrepreneur, the revenue streams are from the payments made by the households, proceeds from the sale of surplus electricity, and the share from the CDM benefits given by the ESCO. The entrepreneurs' cost streams are equity contribution, EMI's to be paid to the financial institutions, O&M and fuel costs. The current calculations do not include incentives from EAFs.

The financial feasibility assessment of the distributed electricity generation and efficient lighting enterprise involves estimation of the cost and benefits of shifting from grid-based electricity to biomass gasifier-based electricity in the first stage and shifting from standard to efficient lighting packages in the in the second stage. Table 12 contains the details of the data inputs used for comparing the grid-based and biomass gasifier-based electricity systems. As explained above, the standard package of lighting is assumed to be dominated by IBs and the efficient lighting package consists of only CFLs (Table 13). The packages are developed based on the typical lighting pattern in the middle income rural households (Reddy and Balachandra, 2006). The baseline has two types of emissions, (i) CO_2 emissions of 483 tonne per year from the grid-based electricity, and (ii) CO_2 emissions of 128 tonne per year due to additional electricity consumed by the inefficient standard lighting package. Thus, the total annual CO_2 emission mitigation potential is 611 tonne. The total investment required for this enterprise is Rs. 5.4 million.

Table 12: Data and assumptions used for biomass gasifier-based enterprise

Characteristic	Baseline (Grid)	Alternative (Biomass gasifier)
Number of households per Enterprise	1000	1000
Energy demand (kWh)	365,000	365,000
Total new investment (Rs. million)	0	4.70
Annualized capital Cost (Rs. million)	0	0.52
Annual O&M cost	0	0.32
Annual energy cost (Rs. millions)	0	1.69
Annual cost (Rs. million)	0	2.53
Annual CO_2 emission (tonne)	483	0
Price of CERs (US$)	20	20
Rs./US$	47	47
Soft loan interest rate (%)	6	6

Table 13: Data and assumptions used for shifting from IB to CFL

Characteristic	IB	CFL
Number of households/enterprise	1000	1000
Energy consumption/household/year (kWh)	220	65
Energy consumption/enterprise/year (kWh)	220,000	65,000
Total new investment (Rs. million)	0	0.65
Annualised capital cost (Rs. million)	0	0.07
Annual O&M cost	0	0.00
Annual energy cost (Rs. million)	0	0.00
Annual cost (Rs. million)	0	0.07
Annual CO_2 emission (tonne)	128	0
Price of CERs (US$)	20	20
Rs./US$	47	47
Soft loan interest rate (%)	6	6

The assessment of financial profitability for the energy enterprise is presented in Table 14. At 20% equity, the entrepreneur's contribution will be Rs. 1.1 million and the remaining amount of Rs. 4.3 million is through a loan. For the first five years of the enterprise, the total cost per month is expected to be Rs. 252,070. The O&M and the fuel costs account for major share at about Rs. 167,400 and this would be the only monthly cost for the entrepreneur after five years when the payment of EMI stops. The revenue for the enterprise during the first five years is estimated at Rs. 244,276 resulting in a loss of Rs. 7,794. After the EMI period, the monthly profits are expected to increase to Rs. 76,866. The CDM revenues received from the ESCO of Rs. 44,091 is not significant considering the high operating costs involved in running the enterprise. The financial margins clearly indicate the profitability nature of the enterprise. The NPV for the entrepreneur from this enterprise is about Rs. 3.1 million, which are significantly higher than his original equity contribution of Rs. 1.1 million. The IRR of 24% is typically considered adequate for conventional enterprises which are perceived to encounter lower risk levels but may be considered inadequate for such a novel rural energy enterprise. The operating incentives from the EAFs should enable obtaining higher IRR levels. The negative profits during the first five years are also a discouraging factor and the operational incentives should be used to ensure reasonable surplus for the entrepreneur. Any increase in CER as well as electricity selling prices also can result in enhanced profits for the entrepreneur.

Table 14: Financial feasibility of distributed generation and energy efficient lighting enterprise from entrepreneur's perspective

Characteristic	Biomass Gasifier/ Efficient Lighting
Contribution by entrepreneur @ 20% equity (Rs. million)	1.07
Life of the device (years)	25
Loan amount (Rs. million)	4.28
Loan repayment period (years)	5
Equated monthly installment, EMI (Rs.)	84,660
O&M and fuel cost (Rs./month)	167,411
Total cost (Rs./Month)	252,070
Annual CO_2 emissions reduction (tonne)	611
CDM revenue from intermediary (Rs. million/year)	0.53
CDM revenue from intermediary (Rs./month)	44,091
Household repayment (Rs./month)	110,833
Revenue from sale of electricity to other users (Rs./month)	89,352
Total revenue (Rs./month)	244,276
Profit per month for the first 5 years (Rs)	-7,794
Profit per month for the remaining 20 years (Rs)	76,866
Internal rate of return (IRR) - %	24%
Net present value (Rs)	3,137,795

The business is expected to be more attractive for the ESCO compared to the entrepreneur (Table 15). It is assumed that a bundle of 75 enterprises would be feasible from the point of view of business profitability and the need for retaining the status of small-scale CDM project. The estimated CERs and the revenue from their sales are given in Table 15. The one-time and the annual recurring transactions costs are expected to be Rs. 4.5 million and Rs. 1.5 million respectively. The total annual costs, including the cost of EMIs, for the first five years would be Rs. 2.6 million. As earlier, it is assumed that the ESCO will retain 2% of the net profits from the sale of CERs and the remaining amount will be distributed among the entrepreneurs. This is the situation for the first five years and it will change for the subsequent 20 years with the stoppage of EMI payments (Table 15). For the intermediary, the financial returns are high with an NPV of nearly Rs. 10 million and IRR of 93%.

The above assessments establish the fact that with the adoption of sustainable technologies, rational payments from the end-users, strategic support from the government and CDM revenue can make both the modern fuel-based cooking and electricity lighting access business financially profitable.

Table 15: Financial feasibility of distributed generation enterprises from ESCOs perspective

Characteristic	Biomass Gasifier/ Efficient Lighting
No. of enterprises	75
Annual CERs available for sale	45836
Revenue from CERs (Rs. million)	43.09
Transaction cost (Rs. million) - One time	4.5
Transaction cost (Rs. million) - Annual	1.5
Intermediary's contribution @ 20% equity (Rs. million)	0.9
Loan amount (Rs.)	3.6
Loan repayment period (years)	5
Equated monthly installment, EMI (Rs.)	71,219
O&M cost (Rs./month)	20,000
Total cost (Rs./Month)	91,219
Annual cost of loan and O&M (Rs. million)	1.1
Total annual cost (Rs. million)	2.6
Net profit from CER sales (Rs. million)	40.49
Share of profits @2% for the first 5 years (Rs. million)	0.8
Share of profits for the remaining 20 years (Rs. million)	1.7
Share of profit for entrepreneurs (Rs. million)	39.68
Internal rate of return (IRR) - %	93%
Net present value (Rs)	9,971,512

9. Conclusion

The paper discusses an innovative business approach to simultaneously address the challenges of rural energy empowerment by creating access to modern energy carriers for cooking and lighting, and global climate change mitigation. The results of the analysis establish the fact that such a model if implemented will result in a win-win situation for all the participating stakeholders. The households can enjoy the benefits of modern energy carriers at affordable cost; the rural entrepreneurs can run the profitable energy enterprises; carbon markets can have access to large quantity of carbon credits; the government can have the satisfaction of securing energy access to a large section of the rural population; and globally, there is a benefit of climate change mitigation. The outputs also falsify the notion that the social enterprises are always bound to make losses. It has been proved in this paper that the enterprises created to maximize the social benefits can also maximize the private benefits. By adopting a proper business model integrated with efficient incentive schemes can simultaneously provide economic/livelihood benefits to the rural population while earning handsome profits to the entrepreneurs.

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