# BIOENERGY IN INDIA

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# Abbreviations and acronyms

| | |
|---|---|
| BET | Biomass energy technologies |
| BGP | Bio-Gas Plants |
| CDM | Clean Development Mechanism |
| CEA | Central Electricity Authority |
| CFA | Central Financial Assistance |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| CRW | Combustible renewables and waste |
| DNES | Department of Non-conventional Energy Sources |
| EIA | Energy Information Administration |
| ESCO | Energy Service Companies |
| ESMAP | Energy Sector Management Assistance Program |
| FAO | Food and Agriculture Organization |
| GDP | Gross Domestic Product |
| GHG | Green House Gas |
| $H_2$ | Hydrogen |
| ICs | Improved Cook stoves |
| IEA | International Energy Agency |
| IIED | International Institute for Environment and Development |
| IIT | Indian Institute of Technology |
| ktoe | kilo ton of oil equivalent |
| KVIC | Village Industries Commission |
| kWe | kilo Watt electric |
| LPG | Liquefied petroleum gas |
| MNRE | Ministry of New and Renewable Energy |
| MoEF | Ministry of Environment and Forests |
| MSP | Minimum Support Price |
| MW | Mega Watt |
| NBMMP | National Biogas and Manure Management Program |
| NGO | Non-Governmental Organization |
| NPBD | National Project on Biogas Development |
| NPIC | National Programme for Improved Cook stoves |
| PHRD | Policy and Human Resource Development Fund |
| PIA | Project Implementation Agency |
| SNA | State Nodal Agencies |
| TERI | The Energy and Resources Institute |
| TFC | Total Final energy Consumption |
| TPES | Total Primary Energy Supply |
| TWh | Tera Watt hour |
| UN | United Nations |
| VER | Voluntary Emission Reductions |
| VESP | Village Energy Security Program |
| WWF | World Wildlife Fund |

# Executive summary

In concurrence with GDP growth, India's projected energy demand is expected to be more than 3 to 4 times the current level in 25 years. Non-commercial bioenergy energy sources, predominantly fuel wood, chips and dung cakes, contribute around 30% of the total primary energy consumption (dominated by coal and imported oil) mainly for cooking and space heating applications in rural areas. 77.6% of India's 159 million rural households used firewood/chips while 9.1% used LPG. Traditionally, use of biomass as energy in India is characterized by low efficiency and environmental degradation. Multiple government programmes to promote bioenergy technologies over the last three decades have been unable to achieve their potential. Dependence on biomass is expected to continue in the foreseeable future, due to the projected increase in rural population in absolute terms and continued lack of access to commercial fuels in rural areas making it worthwhile to explore improved management of bioenergy resources and greater energy efficiency during end use applications.

Instability of oil prices (and in oil producing regions), surging energy demand in developing countries, and greater awareness about climate change threats due to fossil fuel usage have evoked interest regarding bioenergy in policy makers in India and international development agencies in recent years. Recent years have also witnessed development of more efficient and cost-effective bioenergy technologies like forced draft stove technology. Modern bioenergy technologies such as biomass combustion and gasification for power, production of bio-diesel and ethanol as liquid fuels and biogas as gaseous fuel provide opportunities for meeting energy needs in a sustainable manner, improving quality of life and protecting the environment, including addressing climate change. On average, labour intensive biofuels would generate about 100 times more workers per joule of energy content produced in comparison to capital-intensive fossil fuel industry. In some instances, recent advances in BETs are expected to provide locally-produced bioenergy for local agriculture, industrial and household usage at less than the cost of fossil fuels.

On the other hand, researchers have expressed concerns that biomass production could compete with food production on a local/regional scale and lead to regional food supply shortage in developing countries. Further, there is a risk of monetization of hitherto un-monetized fuel depriving access of existing fuel to the poor. If the bioenergy alternative is unaffordable, introduction of bioenergy systems locally can cause a grave impact on access to energy for the economically underprivileged. Also, contrary to conventional wisdom of carbon neutrality of bioenergy, several factors determine the carbon neutrality (or otherwise) of bioenergy vis-à-vis the fossil fuel which is purported to be replaced. It is important to examine inter-linkage and balance between key social, economic and ecological sustainability concerns related to small and large applications of modern biomass energy technologies (BETs) in the context of rising concerns regarding sustainable development in the energy sector.

In the past, biomass was viewed solely as a traditional fuel for meeting rural energy needs. Also, the policies primarily focused on the supply-side push with market instruments having little role in biomass policies. Currently, the new perspective in policy circles in India is that biomass as a competitive energy resource, which can be pulled through energy markets. This policy shift towards market based incentives like tax benefits and institutional support like capacity building has led to introduction of modern biomass technologies such as bagasse-based cogeneration and large-scale adoption of gasification and combustion technologies for electricity generation using a variety of biomass. The bioenergy sector in India is currently primarily driven by Government of India's initiatives. Key government ministries such as the Ministry of New and Renewable Energy (MNRE) and the Ministry of Environment and Forests (MoEF) have had a significant role in promoting bioenergy.

# 1. Introduction

In the past decade, policy makers in central as well as some state governments and international development agencies have shown considerable interest in bioenergy (Francis *et al*., 2005). Instability of oil prices (and in oil producing regions), surging energy demand in developing countries, and greater awareness about climate change threats due to fossil fuel usage have primarily contributed to this renewed interest in bioenergy. Fortunately, alongside this increasing interest, this phase is also marked by the development of more efficient and cost-effective bioenergy technologies (Cushion *et al*., 2010).

India is currently experiencing a surge in energy demand. Growing import dependence and greater consensus at policy level about the need and utility of tapping into national bio-resources for energy supply has created impetus for greater research initiatives, private investment and promotion of bioenergy technologies. In this context, the report primarily deals with five sections:

1. Baseline situation in India in terms of import dependence for transportation energy, deficit in power generation, and rural energy poverty in terms of dependence on biomass-based traditional cooking and unreliable power situation.

2. Scale of current actual biomass usage (by state) as against projected potential for
    a. traditional cooking and heating
    b. biomass based power generation/cogeneration
    c. biogas
    d. biofuels (first generation ethanol and bio-diesel)

3. Current impact of biomass energy usage.

4. Analysis of policies and stakeholders who are part of the bioenergy sector and who can/should be roped into it.

5. Description of the Village Energy Security Program (VESP) project which is being undertaken by Government of India.

6. Conclusion and recommendations.

## India's energy profile

With a population of about 1.2 billion growing at about 1.5% annually, India's economy has been recording growth of over 9% p.a. in 2006-2008 and over 6% even at the time of global recession. In concurrence with Gross Domestic Product (GDP) growth, India's energy demand is also rising rapidly. India's energy demand is expected to be more than three to four times the current level in another 25 years (Ravindranath and Balachandra, 2009). Per capita energy consumption in India has risen by 42.1% in the last two decades (1990-2008), compared to the world average of 9.5%. Yet, in comparison to world average Total Primary Energy Supply (TPES of 1.83 toe/capita), India still lags behind at only 0.54 toe/capita in 2008.

Coal dominates the Indian commercial energy basket followed by oil and gas. India's import dependence for commercial fossil fuels is demonstrated below. In Table 1 below, the import dependence of major fossil fuel types is provided as a percentage of its TPES in India in 2008.

**Table 1: Contribution & import dependence of major fossil fuel types in India in 2008**

| Energy source | TPES (ktoe) | Import dependence |
|---|---|---|
| Coal and peat | 261373 | 14.6% |
| Crude oil | 169313 | 77.3% |
| Natural gas | 35601 | 26.1% |

Source: EIA, 2010

# 2. Bioenergy usage: scale and geographical distribution

In the total energy mix of India (detailed in the above section), biomass fuels play a vital role especially in its rural areas, as it constitutes the major energy source to majority of households in the rural and peri urban India apart from some rural enterprises.

Ravindranath and Balachandran (2009) have reported that non-commercial energy sources, predominantly fuel wood, chips and dung cakes, contribute around 30% of the total primary energy consumed in the country. It has been reported that 46% of households using firewood and chips in rural India obtain these fuels at zero cash outlay; about 21.14% of households depend on home grown stock; and 23.7% make cash purchase. In comparison, two-thirds of urban households using firewood need to purchase the same. Yet, bioenergy does not figure in most energy analyses as they are confined to "non-commercial" energy. Given that most of the biomass used in households is not transacted on the market, bioenergy data is "inadequate and not up-to-date (FAO, 2007). What is clear though, based on studies by TERI and others (NSSO, 2008), is that biomass delivers nearly 90% of energy used in rural households and about 40% of energy used in urban households use.

FAO (2007) reported that in 2005, the contribution of bioenergy was 29.4% of India's TPES. An analysis of India's Energy Balance (IEA, 2009) also substantiates the role of biomass-based energy in India's energy basket. Table 2 below provides the breakup by energy carrier type for India's Total Final energy Consumption (TFC) in 2007, indicating the prominent part played by biomass-based energy in India's energy basket.

**Table 2: Contribution of energy (by type) in India's energy usage**

| Energy type | Contribution to TPES |
|---|---|
| Coal and peat | 42.1% |
| Crude oil | 27.3% |
| Gas | 5.7% |
| Hydro | 1.6% |
| Combustible renewables and waste[1] (CRW) | 26.3% |

Source: EIA, 2010

The existing pattern of usage of CRW (detailed in Table 3 below, based on IEA energy balance estimates) shows that almost 80% of CRW is used for residential energy purposes.

**Table 3: Breakup of sector-wise usage of combustible and renewables in India**

| Sector | Usage pattern |
|---|---|
| Residential | 78.7% |
| Industry | 17.4% |
| Others | 3.9% |

Source: EIA, 2010

Most of CRW for use in the residential sector is consumed for cooking, water heating and space conditioning needs and is produced locally. However, traditionally, use of biomass as energy in India is characterized by low efficiency and environmental degradation. Unprocessed biomass is mostly used in traditional stoves and furnaces that have low efficiencies, of the order of 10% (Ravindranath and Balachandra, 2009).

[1] 97% of which is biomass-both commercial and non-commercial. Source: www.iea.org/papers/2006/renewable_factsheet.pdf

Most programmes to promote bioenergy technologies have not been able to achieve their goals as demonstrated by their cumulative performance in Table 4 (Ravindranath and Balachandra, 2009).

**Table 4: Bioenergy potential and performance in India**

| S.No. | Source/system | Estimated potential | Achieved as on 31st March 2010 |
|---|---|---|---|
| **A** | **Grid Interactive renewable power** | **(MW)** | **(MW)** |
| 1 | Bio power (agro residues and plantations) | 16881 | 861.00 |
| 2 | Bagasse cogeneration | 5000 | 1338.30 |
| **B** | **Captive/combined heat and power/distributed renewable power** | | |
| 1 | Biomass/cogeneration (non bagasse) | - | 232.17 |
| 2 | Biomass gasifier | - | 122.14 |
| 3 | Family type biogas plants | 120 lakh | 41.85 lakh |

Source: Akshay Urja, 2010 Renewable Energy (Akshay Urja), Volume 3, Issue 4, February 2010, published by Ministry of New and Renewable Energy, Government of India

## 2.1 Bioenergy as cooking fuel

Economic development notwithstanding, traditional solid biofuel (such as firewood/chips, agricultural waste, and dried animal manure/dung cake) is still widely used for meeting cooking and space conditioning needs. Solid biofuel has traditionally been used in rural areas as cooking fuel, particularly by the poor (Ravindranath and Balachandra, 2009, Venkataraman *et al.*, 2005).

According to the latest available National Sample Survey (NSS) data (64th round for the year 2007-2008), the primary source of cooking in rural India is firewood, followed by LPG. In the years 2007-08, 77.6% of India's 159 million rural households used firewood/chips while 9.1% used LPG. Dung cake and kerosene is used by 7.4% and 0.6% of households respectively.

In stark contrast, the primary cooking fuel in urban India is LPG with 62% of India's 63 million urban households using it as primary cooking fuel. Firewood and kerosene is used by 20% and 8% of urban households respectively as primary cooking fuel. 1% of urban population use dung cake as primary cooking fuel.

The overall trend in the last decade in primary energy consumption for cooking in rural areas exhibits that the number of households using firewood as primary cooking fuel is increasing steadily, while there is no significant transition with regards to LPG.

LPG and kerosene are currently being projected as alternatives to solid unprocessed biomass due to improved thermal efficiency of 60% in comparison to 15% of biomass-based devices. The number of households using kerosene as primary cooking fuel is decreasing steadily in both urban and rural areas in the reference period (2001-02 to 2007-08).

Government endeavours have had limited success as LPG penetration in rural India is limited with only economically affluent rural households (Nautiyal and Kaechele, 2008). In spite of government efforts, past trend of LPG penetration in rural areas in the same reference period indicates a mere 1% increase in terms of percentage of households (as compared to 12% increase in urban areas in same reference period) utilizing LPG as primary cooking fuel. In spite of subsidized prices in India, high up-front costs associated with the equipment needed to use LPG (stoves and cylinders) and lack of supply security have acted as a hindrance to its wider adoption among rural households (Pachauri and Jiang, 2008). Further, low population density, poor road infrastructure and low economies of scale in rural areas pose challenges to commercial viability of LPG distribution network at current prices (ESMAP, 2003).

It can be safely assumed that additional government support for further subsidizing LPG/kerosene to enable 149 million rural households (NSS, 2010), currently dependent on biofuel, to switch over is neither economically feasible nor desirable from an energy security perspective in the long run. Hence, considered in its entirety, the adoption of LPG or kerosene based cooking as an alternative to biomass-fuelled cooking on a mass scale is not feasible in the foreseeable future. It is therefore widely believed that dependence of the population on unprocessed solid biofuels is expected to not only continue but also increase (to keep pace with India's burgeoning population) in the foreseeable future (Ramachandra *et al*., 2003, IEA, 2007). As per a study by the International Energy Agency (IEA), 585 million Indians were dependent on biomass for cooking and heating in 2000 and this is projected to increase to 632 million by 2030.

Dependence on biomass is expected to continue in India, due to the projected increase in rural population in absolute terms and continued lack of access to commercial fuels in rural areas particularly for cooking.

**Table 5: Current and expected future energy consumption in households**

| Source | Consumption 2003-2004 MTOE (%) | Projections 2031-2032 MTOE (%) |
|---|---|---|
| Fuel wood | 92.57 (57.82) | 106.39 (37.44) |
| Agro waste | 17.12 (10.69) | - |
| Dung cake | 22.62 (14.13) | 40.47 (14.24) |
| Biogas | 0.71 (0.44) | - |
| Kerosene | 10.69 (6.68) | 15.12 (5.32) |
| Electricity | 7.72 (4.82) | 69.72 (24.53) |
| LPG | 8.68 (5.42) | 52.49 (18.47) |
| **Total** | **160.11** | **284.19** |

Source: Ravindranath N.H. and Balachandra P. Sustainable bioenergy for India: Technical, economic and policy analysis; Energy (2009). doi10.1016/jenergy.2008.12.012

To summarize, 84.9% of rural households and 21.5% of urban households use biomass (firewood/dung cake etc.) based fuel which is traditionally used in thermally inefficient and polluting mud stoves. While 66.9% i.e. more than two-third of India's 222.5 million households use solid biomass presently, no major change in the trend of India's dependence on household level biomass-based cooking is envisaged in the near future. Hence though per capita usage of cooking biofuels has declined in the last decade and is expected to further decline in the near future (Parashar *et al*., 2005, Ravindranath and Balachandra, 2009), solid unprocessed biomass is expected to remain the largest source of cooking fuel, especially in rural India.

## 2.2 Bioenergy as biogas

Biogas is produced when organic materials, such as cattle dung, are digested in the absence of air. It is an excellent energy source for individuals/institutions with cattle ownership. Biogas can be used in a specially designed burner for clean cooking without indoor air pollution. A biogas plant of 2 $m^3$ capacity is sufficient for providing cooking fuel to a family of five persons (standard family size in India as per Census of India, 2001). It can also power gas lamps. For example, a gas lamp with equivalent power of 60W needs 0.13 $m^3$ of gas every hour (MNRE, 2010).

**Table 6: State-wise estimated potential and cumulative achievements for family type biogas plants up to 31.12.2009 under National Biogas and Manure Management Programme (NBMMP)**

| State/Union Territories | Estimated potential (nos. of biogas plants) | Cumulative achievements as on 31/12/2009 |
|---|---|---|
| Andhra Pradesh | 1065000 | 452499 |
| Arunachal Pradesh | 7500 | 2818 |
| Assam | 307000 | 74187 |
| Bihar | 733000 | 125688 |
| Chattisgarh | 400000 | 30576 |
| Goa | 8000 | 3878 |
| Gujarat | 554000 | 404973 |
| Haryana | 300000 | 53345 |
| Himachal Pradesh | 125000 | 45488 |
| Jammu & Kashmir | 128000 | 2352 |
| Jharkhand | 100000 | 4408 |
| Karnataka | 680000 | 411241 |
| Kerala | 150000 | 124202 |
| Madhya Pradesh | 1491000 | 287549 |
| Maharashtra | 897000 | 773410 |
| Manipur | 38000 | 2128 |
| Meghalaya | 24000 | 6058 |
| Mizoram | 5000 | 3770 |
| Nagaland | 6700 | 3743 |
| Orissa | 605000 | 235393 |
| Punjab | 411000 | 101705 |
| Rajasthan | 915000 | 67172 |
| Sikkim | 7300 | 6926 |
| Tamilnadu | 615000 | 215033 |
| Tripura | 28000 | 2771 |
| Uttar Pradesh | 1938000 | 419516 |
| Uttarakhand | 83000 | 9590 |
| West Bengal | 695000 | 305760 |
| A&N Islands | 2200 | 137 |
| Chandigarh | 1400 | 97 |
| Dadra & Nagar Haveli | 2000 | 169 |
| Delhi | 12900 | 679 |
| Pondicherry | 4300 | 573 |
| KVIC and others | - | 7608 |
| **Total** | **12339300** | **4185442** |

Source: MNRE, 2010

It is important to note that a significant percentage of these 4.2 million biogas plants are not functional. A study by IIT (2002) indicates that only 77% of total installed plants were fully functional.

## 2.3 Bioenergy as power and heat through biomass gasification and cogeneration

Biomass gasification involves incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen ($H_2$) and traces of Methane ($CH_4$). This mixture, known as producer gas, is used to run internal combustion engines generating power.

In sugar growing areas, there is possibility of cogeneration (heat and power) from bagasse, a by-product of sugarcane processing.

The cumulative spread of bioenergy for power and heat across major states is provided below:

**Table 7: State-wise/year-wise list of commissioned biomass power/cogeneration projects (as on 30.06.2010)**

| S.No. | State | Total |
|---|---|---|
| 1 | Andhra Pradesh | 363.25 |
| 2 | Bihar | 9.5 |
| 3 | Chattisgarh | 199.9 |
| 4 | Gujarat | 0.5 |
| 5 | Haryana | 35.8 |
| 6 | Karnataka | 336.18 |
| 7 | Madhya Pradesh | 1 |
| 8 | Maharashtra | 288.5 |
| 9 | Punjab | 62.5 |
| 10 | Rajasthan | 59.3 |
| 11 | Tamil Nadu | 419.2 |
| 12 | Uttar Pradesh | 581 |
| 13 | West Bengal | 16 |
| **Total** | | **2312.63** |

Source: MNRE

The potential for bioenergy based power generation is almost 12% of India's existing installed capacity of 160,000 MW.

## 2.4 Biomass crop yield

India's total land area is 328.7 Mha out of which 42.5 Mha is not available for cultivation. The existing land usage in India is provided in table 8 below.

**Table 8: Potential land areas in India with biomass potential (based on 2004 field data)**

| Land details | Area (kha) | Percentage of India's total land area |
|---|---|---|
| Forest | 69.8 | 22.9% |
| Net sown area | 141.9 | 46.5% |
| Uncultivated land excluding fallow land | 26.9 | 8.8% |
| Fallow land | 24.2 | 7.9% |
| Not available for cultivation | 42.5 | 13.9% |
| **Total** | **328.7** | **100%** |

The classification of biomass yield through the three main sources of forestry, agriculture and wasteland is provided in table 9.

**Table 9: Potential of biomass yield by source**

| Type of resource | Area (kha) | Biomass generation (kt/yr) | Biomass surplus (kt/yr) |
|---|---|---|---|
| Agri-residue | 16423 | 95512 | 43162 |
| Forestland | 64570 | 89119 | 59678 |
| Wasteland | 54253 | 66355 | 44369 |
| **Total** | **135246** | **250986** | **147210** |

Source: Biomass Atlas of India, Version 2.0

In conclusion, modern bioenergy technologies such as biomass combustion and gasification for power, production of bio-diesel and ethanol as liquid fuels and biogas as gaseous fuel provide opportunities for meeting energy needs in a sustainable manner, improving quality of life and protecting environment, including addressing climate change. It is expected that cleaner sources of bioenergy will contribute to the sustainable development of the rural areas through agricultural modernisation, rural electrification, provision of cleaner cooking fuels, employment generation and opportunities for small entrepreneurial activities, etc.

# 3. Impact of bioenergy technologies

It is important to examine inter-linkage and balance between key social, economic and ecological sustainability concerns related to small and large applications of modern biomass energy technologies (BETs) in the context of rising concerns regarding sustainable development in the energy sector (Demirbas, 2009).

**Promotion of energy security**

Exposure of the Indian economy to increasingly unstable international energy markets is high. In some instances, recent advances in BETs are expected to provide locally produced bioenergy for local agriculture, industrial and household usage at less than the cost of fossil fuels (UN, 2007). Instead of directing scarce resources to foreign countries to pay for oil, it makes business sense to invest in local agriculture and manufacturing sectors with additional benefits of strengthening local economies and rise in livelihood opportunities. In terms of plant capacity, the potential of biomass gasification projects could reach 31 GW that can generate more than 67 TWh electricity annually (Purohit, 2009) which would directly contribute to energy self-sufficiency.

## 3.1 Poverty reduction

**Livelihood benefits**

As in any development project, the essence of sustainability of bioenergy projects lies in how the community benefits from the project activity. The primary driving force for acceptance of such project activity from the community point of view will most probably be employment or job creation, contribution to regional economy and income improvement. Other “big issues” such as carbon emissions, environment protection, security of energy supply on a national level are an “added bonus” (Domac *et al.*, 2005).

Bioenergy-related employment opportunities include direct employment, comprising jobs involved in fuel or crop production, in the construction, operation and maintenance of conversion plants and in the transport of biomass; and indirect employment, comprising jobs generated within the economy as a result of expenditures related to biofuel cycles (Faaij, 1997).

Bioenergy is possibly the most labour intensive energy source and there is little doubt that bioenergy development will bring about significant job creation in unskilled and semi-skilled labour in India depending on the scale of production (large scale plantations, or medium and small scale operations) and on the degree of mechanisation – new employment opportunities arise for unskilled workers (FAO, 2007). On average, labour intensive biofuels would generate about 100 times more workers per joule of energy content produced in comparison to capital-intensive fossil fuel industry (UNDP, 2009).

However, actual direct and indirect employment opportunities for biomass gasification and biogas vary considerably due to local factors such as physical infrastructure, density of plants, feedstock type, soil quality, etc. For example, TERI experience suggests that installation of a 2 $m^3$ biogas plant requires 10 skilled and 40 semi-skilled person days. However, the job generation for servicing and maintenance will vary depending on the number of biogas plants installed in adjoining areas. Say, if 10 biogas plants are installed, 10 skilled person days will be generated for periodic visits to the installed plants every week. However, the presence of 100 plants would lead to a full time direct employment for 1 skilled worker deputed for service and maintenance. In the case of biomass gasifier technology, there is potential of regular employment generation. One skilled and one semi-skilled person are required for daily maintenance and operation for a 20 kWe biomass gasification system. Job creation for fabrication of one plant is difficult to calculate. Staff on permanent company payroll deal with fabrication and person days/unit of plant would depend on the number of orders executed by the company in a month.

The potential for generating employment opportunities in modern bioenergy applications among developing countries is a topic worthy of serious study and a country and technology specific study should be commissioned to understand the direct, indirect and induced benefits from selected case studies.

**Lower Energy Cost**

Biomass gasifier is reported to outperform conventional fossil fuel (mostly coal) based grid power for electricity generation in economic terms (Ravindranath and Balachandra, 2009). Life Cycle cost Analysis (LCA) of power generation in Indian condition (Table 10) clearly indicates that although biomass gasification technology is marginally more costly compared to grid based power generation, it is environmentally benign and creates local livelihood opportunities.

**Table 10: LCA estimates bioenergy technologies for power generation**

| Power generation technology | Total life cycle cost (Rs./kW) | Unit cost of energy (Rs./kWh) |
|---|---|---|
| Grid electricity (coal based) | 174310 | 3.25 |
| Biomass gasifier | 149150 | 4.17 |

Source: Ravindranath and Balachandra, 2009

Comparison of life cycle analysis of traditional fuel wood technology with improved stove and biogas for cooking is provided in Table 11, indicating the efficacy of improved cooking stoves. Though unit cost of biogas is slightly higher it has significant environmental and health benefits for which monetization is difficult.

**Table 11: LCA estimates bioenergy technologies for cooking energy**

| Technology details | Total life cycle cost (Rs./GJ of heat output) | Unit cost of energy (Rs./GJ of heat output) |
|---|---|---|
| Traditional fuel wood stove | 674.27 | 271.13 |
| Efficient fuel wood stove | 713.78 | 163.89 |
| Dung based biogas | 3572.4 | 393.56 |

Source: Ravindranath and Balachandra, 2009

However, as bioenergy production costs can vary widely by feedstock, conversion process, scale of production and region (Demirbas, 2009), the life cycle and unit energy cost can significantly vary with project location and management efficiency.

**Fuel savings**

An average household dependant on fuel wood consumes 1800 kg of fuel in a year (Ravindranath *et al.*, 2005). Ravindranath and Balachandra (2009) have reported that 40% of fuel wood extraction in India is non-sustainable in nature. Improved cook stoves have potential of reducing fuel consumption by almost 30% to 45% (TERI, 2010) thereby reducing dependence on non-sustainable fuel. Hence, such initiative can promote forest conservation.

**Distributed power (In situ power generation and consumption)**

Power demand has out-stripped supply by more than 10% (CEA, 2010) and the brunt of power cuts fell upon rural consumers. Hence, it has been reported that provision of reliable energy for small-scale household or “cottage” industries, agricultural enterprises and other productive use applications (requiring light or motive power) is one of the biggest challenges facing Indian development planners (UN, 2007). Distributed generation of electricity through biomass gasification can improve the existing situation significantly.

**Food security**

FAO (2007) has raised concern that rapid biofuel growth, mono-cropping practices and assured buyback of preferred energy crop varieties may lead to a reduction in agricultural biodiversity with negative repercussions on food security. While globally there is sufficient food production but unequal access, local bioenergy production and usage can be a means of alleviating poverty and improving food security through income generation (WWF, 2007). However, Lewandowski and Faaij (2006)[2] have expressed concern that biomass production could compete with food production on a local/regional scale and lead to regional food supply shortage in developing countries.

There are growing doubts on the efficacy of biofuels in reducing carbon emissions, largely because of the impacts of large-scale land use change particularly relevant for large-scale commercial biofuel production, which tends to take place on lands that would be suitable for food production (FAO, 2008). Even the concept of “biofuel cultivation in wasteland” has been questioned in India because of the heavy reliance of rural people on these lands for collecting fuel wood, food, fodder, timber and thatch (Rajagopal, 2007). However, in the context of biogas and biomass gasifier technology dissemination such concerns are not applicable.

**Competing local usage of bio-resources**

Local level production of agri-residue based processed solid fuel (briquettes/pellets) is likely to spike the demand for agricultural residues which are currently used for cattle fodder and manure. Poor population runs the risk of compromising on usage of agricultural residue for short term monetary gains. Such competition with local bioenergy system may in the long run negatively impact cattle rearing and soil quality for villagers without access (due to disparity between purchasing power and cost) to commercial alternatives. Hence, detailed, location specific and participatory resource assessment should be carried out before executing BETs based on local biomass resources.

**Monetization of local biomass**

Often, economic constraints (disposable surplus cash) force population to rely on (often) non-monetized fuel from own land, public/open access lands or engage in informally traded fuel. There is a risk of monetization of hitherto un-monetized fuel depriving access of existing fuel to the poor. If the bioenergy alternative is unaffordable, introduction of bioenergy systems locally can cause grave impact on access to energy for the economically underprivileged. Hence, introduction of any BETs should consider the access issues related to local population.

[2] Steps towards the development of a certification system for sustainable bioenergy trade; I. Lewandowski, A.P.C. Faaij; Biomass and Bioenergy 30 84 (2006) 83–104.

## 3.2 Carbon sequestration

In the era of increasing climate change awareness, environmental benefits produce a strong case for bioenergy (Demirbas, 2009). It is a common notion that burning biomass merely returns the $CO_2$ that was absorbed as the plants grew and as long as the cycle of growth and harvest is sustained, biomass burning is carbon-neutral (Ravindranath and Balachandra, 2009). But this is not applicable as the universal truth for all forms of bioenergy and its varied production and usage mechanisms. Schubert and Blasch (2010) list several factors which determine the carbon-neutrality (or otherwise) of bioenergy vis-à-vis the fossil fuel which is purported to be replaced. The life-cycle carbon balance critically depends on the choice of feedstock, the management of land resources when growing the feedstock, the kind of land-use changes induced by cultivation, conversion and processing methods used in bioenergy production, the type of fossil energy carrier which is replaced by biomass and the efficiency of energy end-use. The efficiency in harvesting and combustion – both play a role in determining the carbon implications of biomass burning. For example, 40% of fuel wood usage in India is from unsustainable extraction (Ravindranath and Balachandra, 2009).

Feedstock production is arguably the most important factor in determining the sustainability of bioenergy production. Hence, potential impacts of efficient (often translated to “intensive”) land usage will have direct impact on biodiversity, greenhouse gas emission, and degradation of soil and water bodies (WWF, 2007). Land usage has very high impact on Green House Gas (GHG) emissions. Conversion of forest land, pastures and savannah type land for bioenergy cultivation can cause higher GHG emission than what is abated by GHG emissions (WWF, 2007).

Table 12 below details the theoretical possibility of greenhouse gas abatement through bioenergy technologies (Ravindranath and Balachandra, 2009).

**Table 12: BETs greenhouse gas reduction potential in India**

| BET detail | Technical potential | Annual abatement (million TC/year) |
|---|---|---|
| Biogas | 17 million | 5 |
| Community biogas | 150,000 | 10.8 |
| Improved stove | 120 million | 4 |
| Biomass based power generation | 57000 MW | 89 |

Source: Ravindranath and Balachandra, 2009

## 3.3 Loss of biodiversity

Depending on land type, cultivation forms (rotation scheme, plantation management plan, etc.) there are threats of biodiversity loss. Conversion of forest land for bioenergy usage would lead to severe loss of biodiversity (WWF, 2007). Apart from strict land use policy there should also be more stress on perennial bioenergy plantations rather than annual rotation harvests as it may create more favourable habitats for biodiversity compared to conventional crop production (FAO, 2007). However, there is lack of country specific data for the same.

# 4. Review of policies related to bioenergy sources and stakeholders

## 4.1 Policies and programmes

India has a long history of bioenergy planning and programme interventions. The national biomass policy originated in the decade of 1970s as a component of rural and renewable energy policies. The biomass policy followed a multi-pronged strategy: i) improving efficiency of the traditional biomass use (e.g. improved cook-stove programme), ii) improving the supply of biomass (e.g. social forestry, wasteland development), iii) technologies for improving the quality of biomass use (e.g. biogas, improved cook-stoves), iv) introduction of biomass based technologies (wood gasifiers for irrigation and biomass electricity generation) to deliver services provided by conventional energy sources, and v) establishing institutional support for programme formulation and implementation.

Two deficiencies in past policy perspectives contributed to the slow progress in the penetration of biomass technology. Firstly, the biomass was viewed solely as a traditional fuel for meeting rural energy needs. Secondly, the policies primarily focused on the supply-side push with market instruments having little role in biomass policies.[3] Under the circumstance, neither the modern plantation practices for augmenting the biomass supply nor the growing pool of advanced biomass energy conversion technologies could penetrate the Indian energy market.

Currently, the new perspective views biomass as a competitive energy resource, which can be pulled through energy markets. The timing of the change in the perspective coincided with the development of several advanced biomass technologies. As a result, the Ministry of New and Renewable Energy (MNRE, erstwhile DNES) policy shift towards market based incentives and institutional support has led to the introduction of modern biomass technologies such as bagasse-based cogeneration and large-scale gasification and combustion technologies for electricity generation using a variety of biomass. The current bioenergy programs and policies in India with respect to modern usage of bioenergy (solid and gaseous forms) are described below:

**Direct combustion and cogeneration**

The biomass power and cogeneration program is being implemented in the country with the objective to promote technologies for optimum use of the country's biomass resources for power generation. MNRE has been supporting the promotion of biomass power/cogeneration programme since the mid 1990s. MNRE has estimated that surplus agricultural residues can generate about 16,000 MW of grid quality power with the present available technologies. The biomass power projects in the country are all private sector driven. In the cogeneration projects, which largely exist in sugar industries, the generated power is used in the sugar mill and the balance is exported to the grid.

Central Financial Assistance (CFA) in the form of capital subsidy or interest subsidy has always been instrumental in building promoters' interest for bringing investments in the sector. Besides the CFA, fiscal incentives such as 80% accelerated depreciation, concession in import duty and excise duty exception on equipments, tax holiday etc. are also available for biomass power projects. At the state sector, different State Governments have also taken initiatives and declared their policies for attracting private investment in biomass

[3] Shukla P R; Biomass Energy In India: Transition From Traditional To Modern; The Social Engineer, Vol. 6, No. 2; < http://www.e2analytics.com>

power projects. Preferential feed in tariffs along with renewable purchase obligation declared by the State Electricity Regulatory Commissions is also assisting the growth of the sector.

**Biomass gasifier**

MNRE is promoting the biomass gasifier programme with the following key objectives:

- to deploy biomass gasifier systems for meeting unmet demand of electricity in villages;
- to take up demonstration projects for 100% producer gas engine, coupled with gasifier for off grid and grid power operation;
- to meet electricity needs for water pumping and other electrical applications on decentralized basis from various types of woody and non-woody biomass available in villages.

The biomass gasifier projects can be taken up by village level organization, Panchayats, institution, private entrepreneurs and industries, in rural areas. The programme is implemented through the state nodal agencies with the involvement of energy service companies (ESCOs), co-operative, panchayats, NGOs, and manufacturers or entrepreneurs etc. The total installed capacity of biomass gasifier systems as of January 2009 is nearly 160.31 MWe.[4]

**Biogas based distributed/grid power**

In addition to the biomass combustion and gasifier program, MNRE also started a scheme called biogas based distributed/grid power generation programme from 2005-06 onwards with a view to promote biogas based power generation, specially in the small capacity range, based on the availability of large quantity of animal wastes and wastes from forestry, rural based industries (agro-/food-processing), kitchen wastes, etc. Under the program, MNRE provides CFA to a maximum of Rs.30000 to 40000 per kW depending upon capacity of the power generating projects in the range of 3 kW to 250 kW of different rating limited to 40% of the plant cost. The projects could be taken up by any village level organization, institution, private entrepreneurs etc in rural areas.

**Improved cook stoves**

The National Programme for Improved Cook stoves (NPIC) was launched in 1983 with the aim to disseminate mud based improved cook stoves (ICs), equipped with chimneys, and portable metallic stoves to increase the fuel use efficiency and to reduce indoor air pollution. Under NPIC, three types of IC were promoted, which included fixed-type cook stoves, portable cook stoves and high-altitude metallic cook stoves, with an efficiency of over 20% for fixed cook stoves and over 25% for portable ones. The aggregate number of IC disseminated by 2003 was around 35.2 million. However, the NPIC was found to be ineffective over the long term and MNRE discontinued the programme in 2002. Currently, the responsibility of promoting IC lies on state and local governance institutions and NGOs. However, with the lack of central government support and limited funding, the success rates are negligible. In December 2009, Government of India relaunched the stove programme as National Biomass Cook-stoves Initiative where a series of pilot projects which aims to explore a range of technology deployment, biomass processing, and delivery models leveraging public-private partnerships apart from endeavouring to develop next-generation cleaner biomass cook stoves.

[4] www.mnes.nic.in

**Biofuels**

The national biofuel policy of India adopted in December 2009 aims at facilitating development of indigenous biomass feedstock for production of biofuels. The Indian approach to biofuels is "based solely on non-food feedstock to be raised on degraded/waste lands that are not suitable for agriculture, thus avoiding a possible conflict of fuel versus food security" (MNRE, 2009). The new biofuels policy will incentivize plantation of non-edible oilseeds, such as jatropha and karanjia over about 11.2 million hectares of land, which is 30 times of present cultivation, resulting in 13.38 million tons of biofuel to meet its policy target of 20% blending of biofuels in transportation fuel by 2020. The new policy offers financial incentives such as subsidies and grants for biofuels production apart from declaring Minimum Support Price (MSP) for non-edible oil seeds. The policy also envisages setting up of a National Biofuel Fund.

**Biogas**

The National Project on Biogas Development (NPBD), which mainly caters to setting up of family type biogas plants, has been under implementation since 1981-82. The NPBD was broadened and rechristened as National Biogas and Manure Management Program (NBMMP). The key objectives of the programme are:

- to provide fuel for cooking purposes and organic manure to rural households through family type biogas plants;
- to mitigate drudgery of rural women, reduce pressure on forests and accentuate social benefits;
- to improve sanitation in villages by linking sanitary toilets with biogas plants.

The programme is implemented by the SNAs, Khadi and Village Industries Commission (KVIC) and NGOs. MNRE provides central subsidy in fixed amounts, turn-key job fee linked with three years' free maintenance warranty; financial support for repair of old-non functional plants; training of users, masons, entrepreneurs, etc. At the household level, the cumulative number of biogas plants built from 1982 to 2006 is estimated to be 4.09 million against a potential of 12 million. Some selected NGOs such as SKG Sangha, Gram Vikas etc. have attained good success in implementing the biogas program in India.

**Village Energy Security Programme**

The Village Energy Security Programme (VESP) was started by the MNRE in the 10$^{th}$ five-year plan with an objective beyond electrification to provide total energy requirement of villages including lighting, cooking, and motive power with the involvement of local community. VESP aims to transform the locally available biomass energy use in rural remote areas from traditional biomass that is currently in use, mostly in unsustainable manner to innovative modern biomass energy use in sustained manner. Clear emphasis of VESP is thus on energy security; with a further thrust on productive micro enterprise development linked to existing rural credit facilities and local employment generation to enhance the income of rural households. The program is quite innovative as it tries to solve an emerging 3E-trilemma of maintaining Energy resources; sustaining Economic development and preventing Environment degradation through a pragmatic approach.

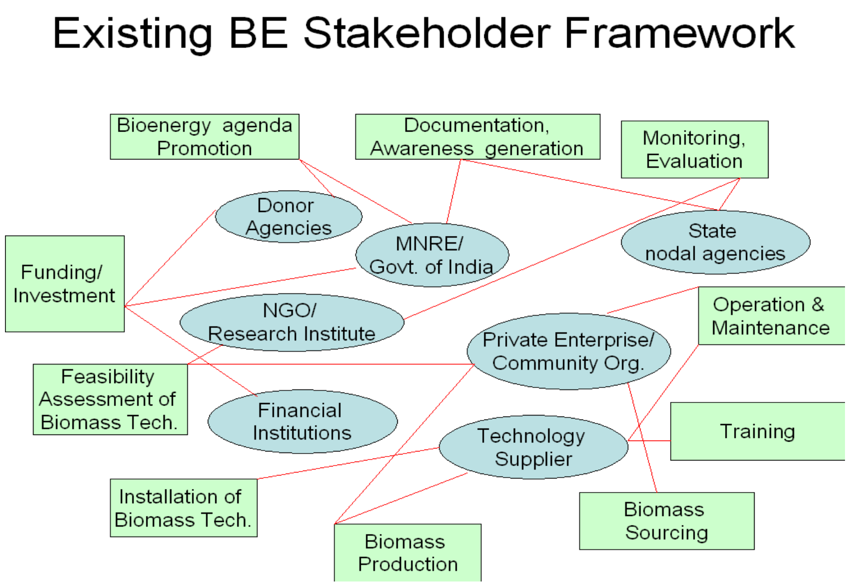
Test projects on village energy security are being taken up to demonstrate the techno-economic parameters, provide operational experience, mobilize local communities and firm up the institutional arrangements to operate and maintain the energy production system. The energy production systems comprises improved cook stoves, biogas plants based on dung/ oil cakes or leafy biomass; biomass gasifiers coupled with 100% producer gas engines; and biofuel based engines running on 100% straight vegetable oils.

Under the program, 90% of capital cost is provided as grant by MNRE and the remaining 10% is mobilised by the community/Project Implementation Agency (PIA) and/or SNA (State Nodal Agencies). Further, support is also provided towards professional charges to implementing agencies and administrative charges to SNA towards operation and maintenance charges.

The World Bank under its Policy and Human Resource Development Fund (PHRD) grant project on 'Biomass for Sustainable Development' is also supporting the pilot phase of VESP for the period of 2006-2009. The purpose of the grant is to identify and test scaleable models for designing and implementing community-driven programs for meeting comprehensive village energy needs. The focus is on business models for small-scale biomass based applications that can meet energy needs related to productive uses, cooking and lighting. A total of 95 test projects, including 56 ongoing projects and 39 new projects in 8 States are covered under this World Bank supported program.

## 4.2 Stakeholder analysis

The bioenergy sector in India is currently driven by Government of India's initiatives. Key government ministries such as Ministry of New and Renewable Energy (MNRE), Ministry of Environment and Forests (MoEF) have had a significant role in promotion of bioenergy. Bioenergy plantation is currently being experimented as an approved task under India's flagship programme of national employment generation scheme. The Planning Commission of India has taken active interest in promotion of bioenergy in its Integrated Energy Policy 2003. A diagrammatic overview of the role of stakeholders is presented in the figure below.



# 5. Innovative business model: SKG Sangha

SKG Sangha is a non profit voluntary organization, engaged in a variety of economic, agricultural, social and environmental empowerment activities in rural India. Founded in 1993, the organisation's core focus areas include Sustainable Energy, Sustainable Agriculture, Rural Industrialization, Solid Waste Management and optimizing natural resources.[5] The group has developed a unique and sustainable model for using biogas plants (BGPs) as a source for meeting cooking and lighting loads in rural households. At present it has its presence in 4 southern states including Karnataka, Andhra Pradesh, Tamil Nadu and Kerela and other states include West Bengal, Meghalaya and Manipur. It is also implementing similar initiatives outside India in countries such as Nepal and Africa (particularly Kenya, Uganda and Ghana) and is considering working in Sudan, Morocco, Liberia and Tanzania.

The following case study discusses in detail the business model used for setting up BGPs, the objective of the program, the beneficiaries identified, the implementation strategy and modes of finance used in detail. It also summarizes the achievements and benefits accrued by the project so far.

| S.No. | Factors | SKG Sangha's Initiative |
|---|---|---|
| 1 | Type and size of biogas plants installed | • Deenbandhu model – cost effective, reliable, local network for construction and repair, and sustainability<br>• Size – 2m$^3$ – suitable for family size of 4-6 people, owning 3-4 cows (adequate for average family size in the project region) |
| 2 | Target beneficiaries | • Rural households, especially women, who own cattle and have sufficient space for the installation of the biogas plant unit |
| 3 | Implementation strategy | • Bottom up approach – priority to community needs<br>• Employ grassroots level supervisors and masons (unemployed youth, both men and women) – key for adequate repair, maintenance and easily available to beneficiary users<br>• Each supervisor provided with a mobile phone and vehicle (motor bike) – easily approachable by users<br>• Prompt problem rectification – adequate training to local personal for rectification, easy accessibility and accountability<br>• After sale services – 100% guarantee for all plants for 5 years; all service costs borne by SKGS for life of plant; 100% replacement for technical faults<br>• Adequate training of implementation staff – skill development, linking with broader issues of environment and community development<br>• Awareness and capacity building of beneficiaries (workshops at beginning of project, and after 6 months) – ensures proper utilization and maintenance of BGPs<br>• Quality control – quality of material used (purchase material directly from factories – cheaper & better quality)<br>• Demand driven approach (no marketing strategy) for replication – demonstration through successful BGPs |
| 4 | Functionality rate | • Functionality of 95% after 5 years of operation<br>• National average in India – 42% |

[5] http://www.skgsangha.org/index01.html

| | | |
|---|---|---|
| 5 | Financial aspects | • SKGS generally installs $2m^3$ size costing between Rs.18,000-19,000<br>• Cost covered by contribution from Central subsidy, State subsidy and beneficiary contribution (in cash or kind)<br>• Beneficiary contribution – households stake in success of project (labour or material costs)<br>• Due to high demand for BGPs and shortage of government subsidy, alternative funding sought by SKGS – CDM, VER and vermin-composting |
| 6 | Innovation and linkages | • Linking vermin-composting with BGPs – more government subsidy, income generating opportunity especially for women, organic fertilizers to improve soil fertility<br>• SKGS ensures that only half of compost produced is sold in the market, other half utilized on beneficiary fields – demonstrate benefits of organic fertilizers and enhance yields |
| 7 | Project benefits | **Economic**<br>• Generation of employment – local youth (men and women) – supervisors, technicians and masons<br>• Additional income from vermin-composting<br>• Indirect benefits – time saved (3-4 hrs in fuel collection and cooking time), improvement in indoor air quality, reduction in expenditure on health, reduced expenditure on firewood and kerosene for cooking etc. These however need to be quantified in the project villages<br>**Environmental**<br>• Reduction in fuel wood consumption: 3.56 tonnes and 31.2 liters of kerosene per family per year<br>• Emissions reduction – with SKGS installed $2m^3$ system, is expected to be 3.56 tCO2e reductions per household<br>• Improvement in soil fertility – organic fertilizers<br>• Improvement in indoor air quality and reduced smoke in kitchens<br>**Social**<br>• Capacity building of local manpower especially youth<br>• Reduced drudgery of women and children – 2-4 hours travelling 2-3 kilometres a day to collect firewood<br>• Women empowerment – income generation through vermin-composting, health benefits, awareness and capacity building |
| 8 | Awards and achievements | National and international recognition:<br>• Mother Teresa Excellence Award – 2008<br>• International Ashden Award for Sustainable Energy – 2007 under Food Security Category<br>• Social Entrepreneur Award – by Entrepreneurs forum<br>• Sustainable Energy Association Award – 2006 |
| 9 | Areas that need to be strengthened from documentation and research perspective | • Book keeping of problems faced by users needs to be emphasized<br>• Possibly maintain a member card – date and type of problem faced, date and rectification measure, person undertaking rectification – help illustrate prompt problem rectification and analysis of types of problems faced in the SKGS biogas initiative |

# 6. Conclusion

The sustainability of bioenergy depends largely on how the risks associated with its development – especially pertaining to the land use and climate implications of large-scale feedstock production and potential social inequity – are managed. Hence, while the much touted positive impacts related to bioenergy activities are well accepted, it is also important to be cautious about safeguard mechanisms against possible negative impacts.

BETs have significant benefits from energy security and green house gas (GHG) mitigation potential. However, for all practical purposes, it is vital to clearly define land use policies to ensure restriction of bioenergy cultivation to areas that are not in competition with other uses like agriculture, biodiversity etc. Also, during GHG calculations of bioenergy, fossil fuel/fertilizer inputs in bioenergy production and downstream processing should also be taken into account like GHG benefits from by-product utilization which varies significantly with local conditions. At project approval stage, a relatively simple yet verifiable estimation of GHG life cycle crops must be submitted before appropriate authorities which can indicate reduction vis-à-vis life cycle GHG emission of unprocessed crude oil combustion of approximately 90 kg/GJ (WWF, 2007).

## Recommendations

**Dovetailing with existing programmes**
There are several government funded programmes which can be dovetailed with bioenergy programmes to improve resource efficiency which leads to economic competitiveness vis-à-vis fossil fuel based energy technologies. The possible dovetailing opportunities are:

- NREGA and energy plantation
- Dairy and biogas
- Afforestation with biomass gasification

**Institutional financing mechanism**
It has been reported that financial institutions in developing countries have less favourable risk rating for small scale BETs compared to better established energy technologies like grid access and solar power (UN, 2007). This risk perception should be addressed by sensitizing concerned stakeholders through policy initiatives such as crop insurance and technological measures like demonstration projects and access to best cropping technologies and knowledge for the farmers engaged in bioenergy feedstock. Financial instruments such a price support mechanism, micro-credit, tax breaks etc. are often necessary for commercial viability of BETs till they reach economies of scale.

**Community-based bioenergy production**
Considering the disadvantages of large scale private investment in biofuels mono-culture, it is advisable to encourage small-scale community based Jatropha initiatives like Jatropha intercropping with existing crops. Oil from such plantations can be extracted through low cost expellers, which have in-situ usage like lighting fuel or as fuel for running water pumps.

**Technology Transfer**
There are several technology initiatives across the globe which need to be shared and assessed under a common technology platform. It will help to ensure that scientific and technological developments in bioenergy technologies are accessible to other development stakeholders who can then further develop and exploit these technologies into new products, processes, applications, materials or services in local conditions which vary considerably across India.