Low-carbon South Asia: **India**

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Photo above: Transmission and distribution losses are much higher in South Asia than other regions.
Photo credit: Vasudha Gulati

Cover photo: Members of a study group do their homework by the light of a D-light solar panel lamp.
Photo credit: Christian Aid/Elizabeth Dalziel

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Contents

1. Country context

India is the largest country in South Asia, with an area of 3.29 million km^2. The subcontinent shares its northern borders with Afghanistan, Pakistan, China, Nepal, Bhutan and Bangladesh. Its southern, or peninsular, boundary is surrounded by the Arabian Sea on the west, the Bay of Bengal on the east and the Indian Ocean on the south. Sri Lanka is India's closest neighbour in the south/south-east, while the Maldives is located around 1,000km to the south-west.

India is the most populous country in the region. It is home to 1.237 billion people, with a density of 416 people per km^2, which is among the highest in the world. Rich in biodiversity, India has five distinct geographical regions: the Northern Mountains; Indo-Gangetic Plains (central India); the Peninsular Plateau (southern); the Thar Desert (north-west); and the Coastal Plains.

A great arc of mountains, consisting of the Himalayas, Hindu Kush, and Patkai ranges define the northern Indian subcontinent. These mountains facilitate the monsoon winds, which in turn influence the Indian climate. Rivers originating in these mountains flow through the fertile Indo-Gangetic Plains. These large alluvial plains, also known as the Great Plains, cover 700,000 km^2. The Thar Desert forms a significant portion of western India, covering an area of 200,000-238,700km^2.

The Indian economy

India is a young country with more than half of its population below the age of 25 and more than 65% below the age of 35. Approximately 69% of its population lives in rural areas and depends on the agriculture sector for its livelihood.

India has a 6.4% share of global gross domestic product (GDP) in terms of purchasing power parity (PPP) and is the third biggest economy in the world in terms of PPP.

As Figure 1 shows, the primary sector (agriculture, forests and fisheries) contributes around 20% to the economy, though around 69% of households are dependent on it and about half of the labour force is still employed in the sector.

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>
> However, the growth over the decade 2000-2010 has helped reduce poverty by 7.4%, much faster than India managed in the first 50 years of independence.

This has implications for incomes and poverty levels. The contribution of the secondary sector (manufacturing) is only around a quarter of the aggregate GDP.

The biggest contributor to the economy is the tertiary sector (services), with 56%. However, if one looks at employment patterns, the primary sector still dominates with 48.9% of the workforce, while both the secondary and tertiary sectors are far behind with 24.3% and 26.8% respectively. The big challenge is that the service sector is not employment intensive and, hence, its growth does not address the key development issue of generating employment.

India has a significant share of world trade. Primary sector exports such as rice (16.8%), tea (11%) and spices (18.1%), and secondary sector exports such as jewellery (19.6%) and textiles and leather (32%) are key export commodities. India's share of global manufacturing output is only 2.2%, which is small when compared with China (18.9%), US (8.2%), Japan (7%) and Germany (6%).

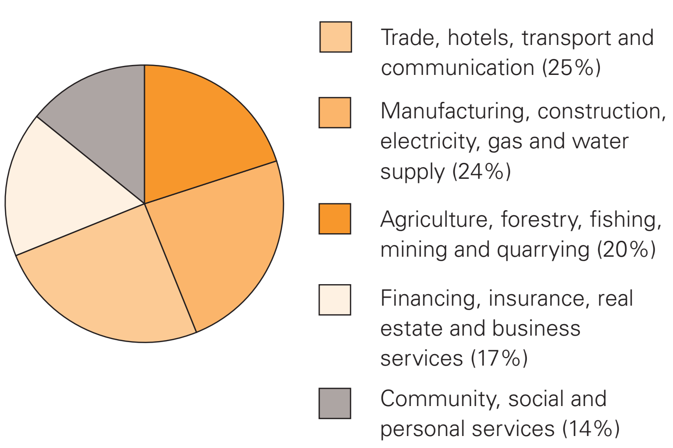
Development challenges

A key development challenge for India is addressing poverty and deprivation through inclusive sustainable development. One-third of the global poor, living on less than $1.25 a day, are in India – the highest in any country. In 2009/10, the number of people living below the official Indian poverty line was 354.7 million – 29.8 per cent of India's population.

The growth over the decade 2000-2010 has helped reduce poverty by 7.4%, much faster than India managed in the first 50 years of independence. This decrease is also partly a result of several policy measures initiated by the government specifically for poverty reduction and better implementation of ongoing poverty reduction programmes.

Poverty is just one dimension; the challenge is also to provide basic living amenities such as health, safe water, sanitation and education. The infant mortality rate, although declining significantly, remains unacceptably high at 44 per 1,000. Only 40.8% of Indian women are able to give birth in a healthcare facility.

Figure 1. Structure of the Indian economy (2011/12)



A below-normal body mass index is seen in 33% of women and 28.1% of men. A whopping 78.9% of Indian children aged between six and 35 months are anaemic, while 56.2% of married women and 57.9% of pregnant women are also anaemic. Of children under three years, 44.9% are stunted (acute starvation), 22.9% are wasted, and 40.4% are underweight. Such high levels of deprivation, if looked at in absolute terms, would not be found anywhere else in the world. Even in terms of proportions, such high levels of deprivation are perhaps only matched by sub-Saharan Africa.

Energy poverty is another dimension of the development challenge, especially when it comes to providing a decent living standard for the vast majority – 32.7% of Indian households do not have access to electricity. Furthermore, many of the households that do have access are often supplied electricity for a very short period of time and thus continue to rely upon kerosene for lighting their homes. In addition, only around 30% of Indian households have access to modern and clean sources of energy for cooking such as LPG or electricity. The majority of households rely upon traditional and inefficient sources of energy such as firewood, crop residues or cow dung for cooking. Income poverty is highly correlated with and even exceeded by energy poverty and thus, especially in rural areas, energy poverty persists even in those households whose incomes are above the poverty line.

Moreover, delivery of various social services is compromised due to the paucity of electricity. For example, only 35.7% of government-run primary health centres are electrified, which implies that the rest of them lack basic facilities such as piped water supply or refrigeration, and only 47.11% of government-run schools are electrified, which suggests that most of the others lack functioning toilets or well-lit rooms. Furthermore, given the nature of power supply in India outside the major urban centres, there is no guarantee that such amenities would be available even in those health centres or schools that are electrified. This adds another layer of deprivation for the poor and marginalised who often cannot afford private healthcare or education and are forced to rely upon poorly managed and substandard facilities provided by the government.

2. Current energy situation

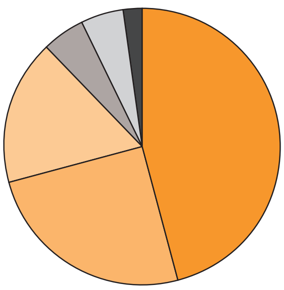
India's rapid development needs significant amount of energy to meet its inclusive development objectives in a sustainable manner and address its development challenges. A significant proportion of the population still uses non-commercial energy sources such as wood, crop residues and animal waste for their energy needs, especially for cooking.

India's energy demand in 2009 was 669 million tonnes of oil equivalent (Mtoe), the third largest in the world after China and the US. However, India's per capita consumption (0.58 toe/capita) is still much lower than the world average (1.8) and Africa (0.67).[1]

Figure 2 shows the share of energy use by sector. Two-thirds of energy demand comes from industry and transport. Cooking is another major source of consumption. Modernising the economy and replacing traditional energy for cooking with commercial energy will drive future energy needs.

India's fossil fuel resources, with the possible exception of coal, are fairly limited. Therefore India has a high level of dependence on imports that form more than a quarter (27.69%) of its energy supplies. Its dependence on petroleum and natural gas is especially high, with almost two-thirds (63.45%) of the supply imported. Oil is the single biggest import into India, accounting for 34.6% of all imports, causing a huge drain on foreign reserves and making the economy vulnerable to price shocks when oil prices become volatile.

Figure 2. Indian energy demand by sector (2012)



Source: Indian Economic Survey 2012-13: Statistical Appendix, http://indiabudget.nic.in/budget2013-2014/survey.asp

To feed its growing number of thermal power plants, India has recently been importing coal to alleviate bottlenecks in indigenous coal production. These imports have become significant in recent years, and currently form about a quarter (24.3%) of coal supplies in the country. However, coal is only 3.5% of the total import bill.

Importing energy has a significant impact on the balance of payments. A persistent negative balance of payments affects the exchange rate, which in turn makes India unattractive to foreign investors.

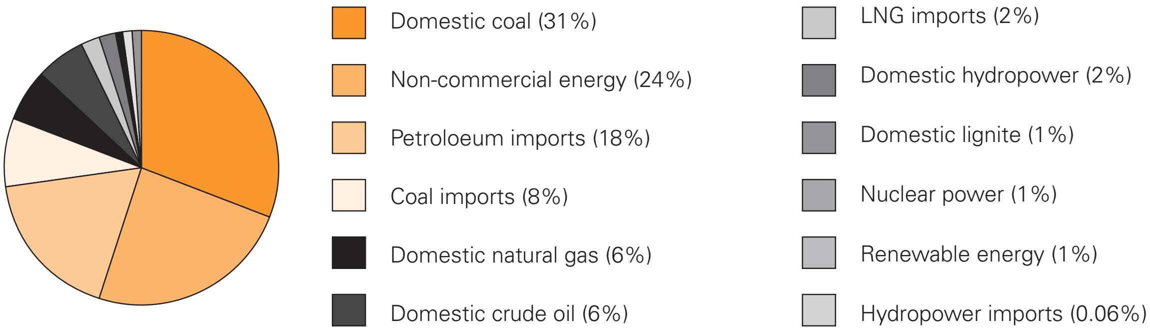
2.1. Main sources of energy

The primary sources of energy in India are both traditional (fuel wood, agricultural residue and animal dung) and commercial sources (fossil and new renewable sources). New renewable sources consist of biogas, solar, wind and off-grid micro and mini hydro.

Figure 3 shows the energy sources used to meet India's energy demand. A quarter of energy comes from traditional and non-commercial sources. Furthermore, fossil fuels (led by coal) form around 70% of the total energy supply.

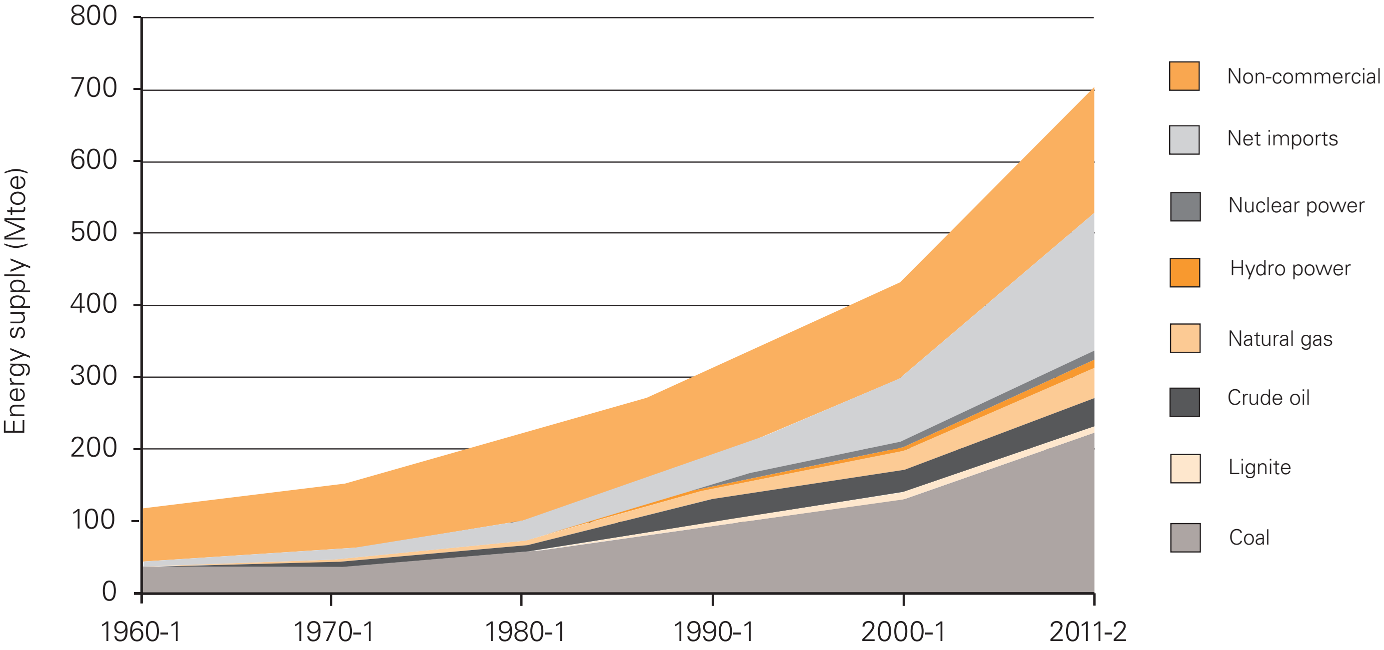
As can be seen from Figure 4,[2] the share of non-commercial energy has decreased over time, but, importantly, the amount used has remained about the same. This is primarily because the share of energy use in the industry and service sectors has increased and the use of commercial energy in households has increased over time. But the growth in numbers of the poor in India, despite the decreasing percentage of poor people, has resulted in continued use of non-commercial biomass. According to the 2011 census, 67.23% of households still cook using firewood, crop residues, cow dung cakes or coal/coal dust (in areas near coal mines). Almost 70% of India's population is still not able to access modern energy sources for even basic necessities such as cooking.

Figure 3. India energy sources by sector (2012)



Source: Planning Commission, *India Energy Security Scenarios 2047*, Government of India, 2014, http://indiaenergy.gov.in

Figure 4. Energy share in India



Source: A Garg, PR Shukla, B Kankal, *Alternate Development Pathways for India: Aligning Copenhagen Climate Change Commitments with National Energy Security and Economic Development,* Indian Institute of Management, 2014.

Table 1. Commercial energy consumption (Mtoe) and percentage, by sector

Sector	1980/1	1985/6	1990/1	1995/6	2000/1	2005/6	2010/1
Agriculture	1.6 (2.3%)	2.4 (2.6%)	4.9 (3.9%)	8.4 (5.3%)	15.2 (7.9%)	15.1 (6.9%)	23.14 (7.32%)
Industry	36.9 (53.7%)	49.2 (53%)	62.9 (50.4%)	77.5 (48.6%)	77.4 (40.4%)	96.2 (44.4%)	137.98 (43.62%)
Transport	17.4 (25.3%)	21.7 (23.4%)	28 (22.4%)	37.2 (23.4%)	33.5 (17.5%)	36.5 (16.8%)	55.34 (17.5%)
Residential and commercial	5.6 (8.1%)	8.9 (9.6%)	12.6 (10.1%)	15.3 (9.6%)	24.1 (12.6%)	32.6 (15.1%)	43.43 (13.73%)
Other energy uses	1.9 (2.8%)	2.7 (2.9%)	3.9 (3.1%)	6.8 (4.3%)	13.4 (7.0%)	18.7 (8.6%)	30.25 (9.56%)
Non-energy use	5.3 (7.7%)	7.9 (8.5%)	12.6 (10.9%)	14.1 (8.8%)	28 (14.6%)	17.5 (8.1%)	26.15 (8.27%)
Total	**68.7 (100%)**	**92.8 (100%)**	**124.9 (100%)**	**159.3 (100%)**	**191.6 (100%)**	**216.6 (100%)**	**316.29 (100%)**

Source: Government of India, Energy Statistics, 2013.

In the past, the main sources of indigenous energy supply were limited to low-grade coal reserves and hydropower. This has resulted in a policy as well as an operational push towards mainly exploiting these two resources. India has some petroleum and gas reserves, but these are limited. The share of imports and coal has increased rapidly, especially since 2000. India has been unable to exploit its hydro potential to the fullest and, as a result, while the absolute contribution has remained the same, the share has drastically declined.

A significant proportion of commercial energy is used for electricity generation. Total installed capacity was 236.38GW (as of March 2012), and is comprised of 56% from coal, 20% from hydropower, 12% from renewable energy and 9% from gas.[3] Most growth in electricity generation has come from coal and gas in thermal power plants, accounting for an overwhelming 66% of total capacity.

2.2. Energy consumption by sector

As mentioned above and shown in Figure 2, industry, cooking and transport are the major sources of energy demand. Table 1 gives the trends in energy use by sectors over time and the share of each sector. Total energy consumption has increased five-fold since 1980. The shares of agriculture and the residential and commercial sectors have increased, whereas that of industry and transport have decreased. The increase in the agriculture sector is reflective of human and animal power being replaced by commercial energy. In the case of residential and commercial use, it is a reflection of increased use of commercial energy instead of the non-commercial sector.

2.2.1. Residential

The main energy used in the residential sector is traditional fuels for cooking. The main energy sources of commercial fuels are petroleum products, electricity and gas. Electricity use has significantly increased because availability has improved and better incomes have led to more people using electrical appliances. Use of LPG has increased considerably. Table 2 shows the change in usage pattern from 2005 to 2011. Residential use of coal has practically vanished.

Table 2. Sources of residential energy – change in usage

	Coal	Petroleum	Gas	Electricity	Total
2005	8.27%	63.06%	2.03%	26.78%	100%
2011	0%	66.73%	0.59%	32.71%	100%

Source: The Energy Resources Institute, *TERI Energy Directory & Yearbook (TEDDY)*, TERI, 2011.

Industry, cooking and transport are the major sources of energy demand. Total energy consumption has increased five-fold since 1980.

2.2.2 Industry

The main source of energy in the industrial sector is coal/lignite (about 64%), used for energy generation and for processing. Coal is followed by petroleum products (about 20%) and electricity (about 15%). The energy-intensive industries accounted for just under 40% of the sector's energy consumption in 2009. Among these, the steel industry consumes about half, the non-metallic minerals (cement, ceramics, etc) and chemical industries use around a quarter each, and the paper industry uses the remainder (5%).

2.2.3 Transport

Almost all (98%) of the energy used in the transport sector comes from petroleum-based fuels, with 2% from electricity, which is mainly used by railways. Even in the rail sector, diesel is the main source of energy for both freight and passenger rail. Road-based freight transport is 100% diesel. Passenger transport uses both diesel and gasoline. India has introduced a policy of blending biofuels and, as a result, a small percentage of fuel consumption comes from biofuels. Furthermore, in many major cities, public transport uses compressed natural gas (CNG) in order to address air pollution. Electricity use in urban passenger transport is expected to increase as a number of cities have implemented electric metro rail systems or are in the process of doing so.

Road transport accounts for 90% of emissions from the sector, as 65% of freight and 90% of passenger traffic are carried by road.[4] The growth in the transport sector is fastest primarily because of road transport. This is expected to continue with the growth in urban populations and increased interconnectivity of cities.

2.2.4 Agriculture

The agriculture sector consumes 7.3% of energy (23Mtoe). The main uses are for operating agro-equipment and pump irrigation, mostly using diesel and electric engines. Diesel and electricity consumption are in roughly the same proportion.

2.2.5 Commerce

The share of energy consumption in the commercial sector is only 2% (6Mtoe). This sector mainly includes academic and healthcare institutions, offices, shops, hotels and restaurants. The main commercial fuels used are electricity (83%) and petroleum products (16%).

3. Efficiency of energy use

As mentioned earlier, India's commercial energy use per capita is only 0.58 toe,[5] well below the world average, far behind advanced OECD economies, and closer to countries in sub-Saharan Africa such as Angola, Zambia and Côte d'Ivoire. The consumption is still low because a significant part of energy for households is based on non-commercial energy sources.

India's electricity consumption per capita is very low (560kWh in 2009) compared to average of about (1,400kWh) in non-OECD countries and world per capita electricity consumption (2,806kWh in 2009).[6] Low electricity consumption is also reflective of the low level of electrification (75% in 2011).[7] Low per capita electricity consumption is also reflective of the low share of electricity in the total final commercial energy use (around 17% in 2011).[8]

India's energy intensity (primary energy consumption) of GDP is 0.191 kgoe/$ (PPP terms) – according to the *Twelfth Five Year Plan* this is comparable with the world average, but behind countries such as the UK, Germany, Japan and Brazil.[9] The US and South Korea have an energy intensity of 0.173 and 0.189 respectively, comparable with India, while China's energy intensity is 0.283 or around 1.5 times India's.[10]

It is a moot point whether India's energy intensity or emissions profile will deteriorate from a global climate change perspective as it pursues more equitable development and inclusive growth.

This level of energy intensity hides the low per capita energy consumption with large disparities in India, such as the dependence of many people on inefficient non-commercial primary energy sources (wood and biomass).

However, it is a moot point whether India's energy intensity or emissions profile will deteriorate from a global climate change perspective as it pursues more equitable development and inclusive growth. This will depend on the policy choices India makes itself from this point forward and policy choices facilitated by international support in the form of access to finance and technology.

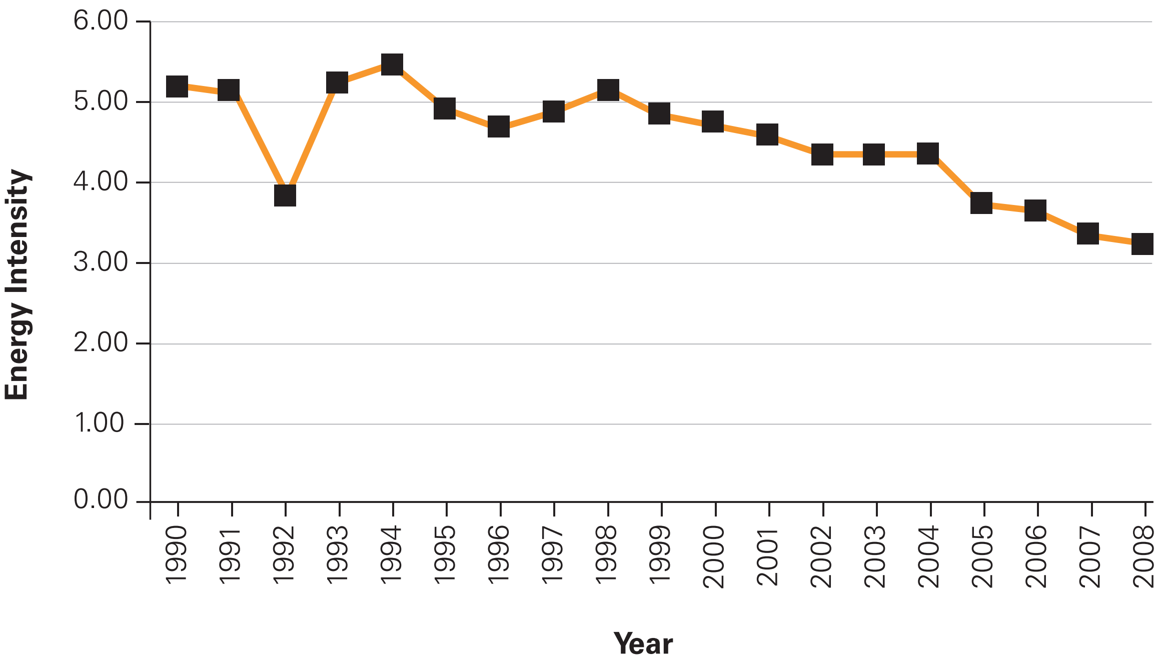
3.1. Current energy efficiency in different sectors

India's energy intensity of GDP has continuously reduced since the first oil shock. Presently it is 0.16 kilograms of oil equivalent (kgoe) per $ GDP in PPP terms compared to 0.30 kgoe/$ in PPP terms in 1980.[11] During the period 1990-2005 energy intensity decreased by 32% and during 2005-2012 it decreased by 7%. The decrease has been even steeper for the non-agriculture economy – 40% during 1990-2005 and 16% during 2005-2012. Compared to India, where the energy intensity decreased by about 1.7% per annum between 2007-2011, the rate of decrease for world as a whole was only 0.04%. The rate of improvement has been better than the European Union (1.2%), China (1.0%) and North America (0.9%).[12]

Energy intensity of the industrial sector in India has continuously decreased since the mid-1990s (see Figure 5).[13] The rate of decline has increased post 2000.

On the other hand, efficiency in the thermal power sector has deteriorated. The average power plant efficiency has declined from 36% in 1990 to 30% in 2009. This is partially due to aging coal power plants and a reduction in the share of hydroelectricity. The decline is masked to some extent by the addition of gas-based combined cycle plants and cogeneration. Transmission and distribution losses were 25% in 2009 (ie, a quarter of energy produced at a power

Figure 5. Energy intensity of Indian manufacturing from 1990-2008 (toe/output)



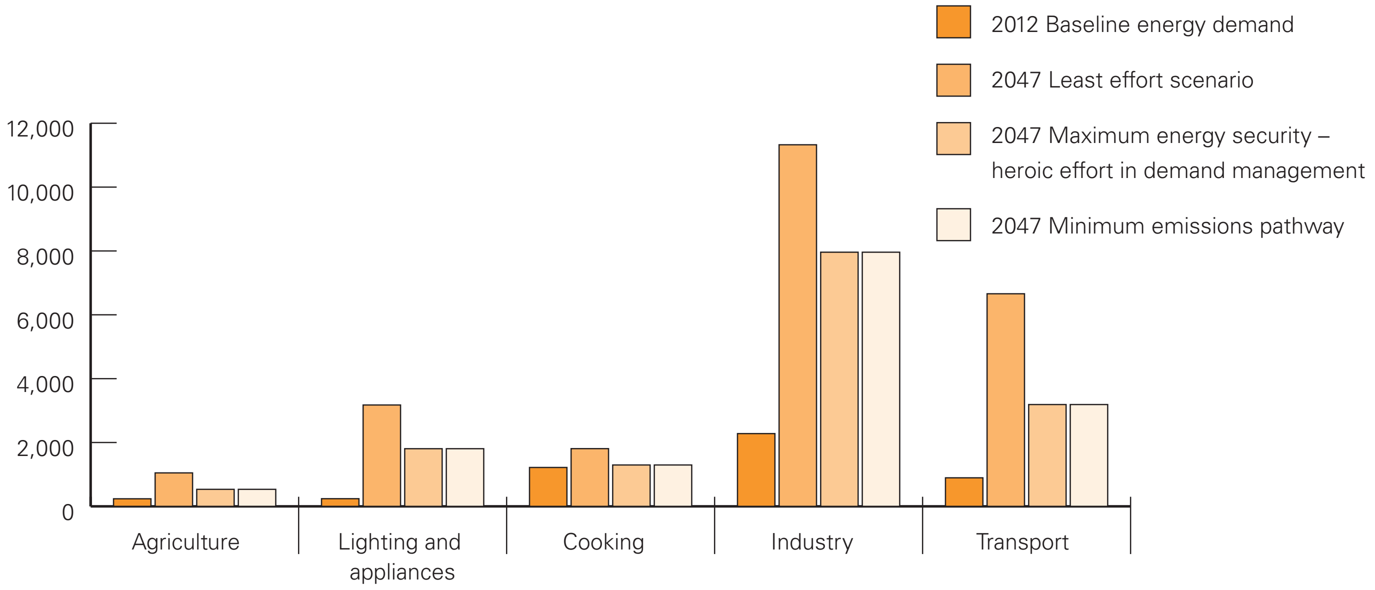
Source: SK Sahu, K Narayanan, Determinants of energy intensity in Indian manufacturing industries: A firm level analysis, *Eurasian Journal of Business and Economics,* 2011, 4, pp13-30.

plant is lost on its way to the end user) and these are the other major main factor for inefficiency in the power sector. However, since 2000 losses have been decreasing (in 2000 losses were 30%). Some 5% of these losses are commercial losses, ie, unpaid electricity.

Energy intensity in India has improved over time, except in the power sector, but it still has room for improvement to match the best energy efficiency economies. Increased access to energy is expected to increase energy intensity, but increased use of modern energy is likely to improve energy intensity.

4. Future energy demand and options for energy supply

Figure 6. Energy demand scenarios, Planning Commission (TWh/yr)



Many studies have been carried out in India, primarily to assess the growth in greenhouse gas (GHG) emissions and identify mitigation opportunities. Most of these studies match each other in the scale of energy demand growth and the sectors where most of the growth is anticipated.

This report examines two studies – from the Indian Government's Planning Commission, and WWF-India and The Energy and Resources Institute (TERI) – and uses their analyses of energy to highlight the sectors where demand for energy is expected to emanate in the future.[14,15] Both these reports look at 2012 to 2050.

For the sake of brevity as well as overall clarity, we will focus on three scenarios:

- Least effort scenario – business as usual
- Maximum energy security (heroic effort in demand management)
- Minimum emissions pathway.

The WWF-TERI report compares the outcomes of the alternate and reference scenarios. The sector definitions for the two studies are the same, except the Planning Commission analyses energy demand for lighting, appliances and cooking (LAC), whereas WWF-TERI uses the more standard sector categorisation of commercial and residential. LAC roughly represents the aggregation of the commercial and residential sectors.

4.1. Energy demand projection by sector

The Planning Commission analysis estimates that in the least effort or business as usual scenario, energy demand would increase almost five-fold by 2047. The three key sectors contributing to this demand are industry, LAC and transport, in that order, and this remains the case for the other two scenarios, though the order changes, with transport demand greater than LAC (Figure 6). The fastest growth in demand is from lighting and appliances (almost a 13-fold increase), followed by transport (almost a seven-fold increase).

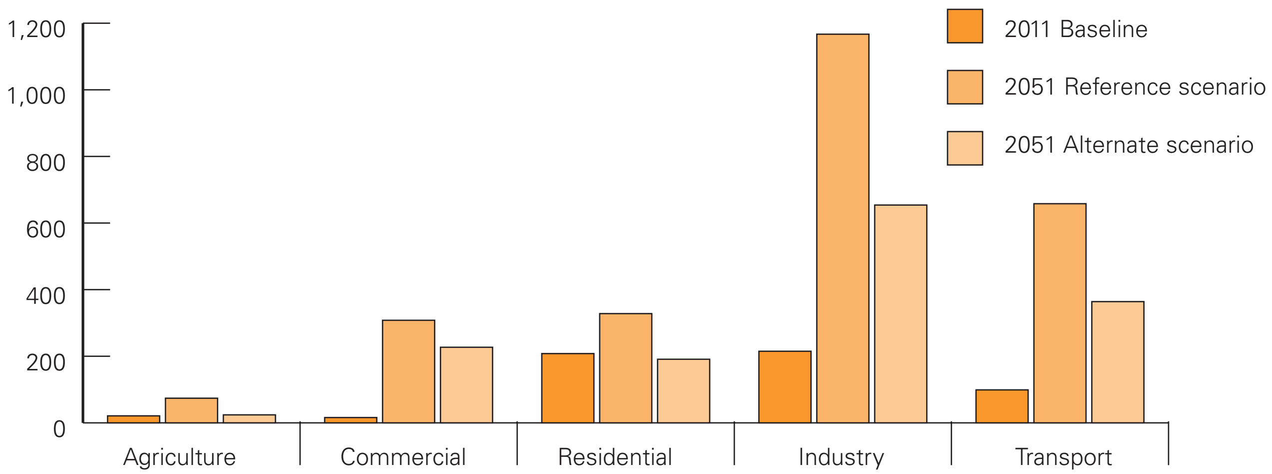
A big reason for this increase in demand from the household sector comes from lower income classes switching from traditional biomass to modern forms of energy and the increasing ownership of appliances as incomes rise. The Energy Sector Management Assistance Program study estimated that the rise in electricity consumption is concentrated, particularly in low-income households.[16] The study estimates that between 2007 and 2031, the share of electricity use by the bottom third of the population will increase from 13% to 19% in urban areas and from 11% to 23% in rural areas.

Another key factor in the increasing demand in the household and transport sectors is the growth in the Indian middle class and its income. This population is estimated at 70 million,[17] and it is expected to increase as the economy grows. The increasing ownership of electrical appliances and personal vehicles will drive the growth in demand from this population.

The biggest energy demand sector by far remains industry, expected to have a five-fold increase, accounting for approximately 45% of total energy demand. This sector is seen as an engine for creating jobs and incomes.

The energy demand in the other two scenarios, maximum energy security (heroic effort in demand management) and minimum emissions pathway, are identical and lower than the energy demand in the least effort scenario. In these two scenarios, the overall increase in demand is only three-fold, and the greatest reduction in demand comes from lighting and appliances, and transport. Though the amount of demand reduction in industry is the same as transport, it is a smaller percentage reduction compared to baseline energy demand in the industrial sector.

Figure 7. Energy demand scenarios, WWF-TERI (Mtoe/yr)



The work done by WWF-India and TERI seems to mirror the demand projections of the Planning Commission. The alternative scenario suggests that demand could be moderated to increase to only around three-fold through strong demand management resulting from enhanced efficiency or energy use, as well as increased use of electricity in place of liquid or solid fuels. The sector-wide demand projections are shown in Figure 7.

It needs to be pointed out here that future demand projections for India are much higher than projections for other major economies. This is due to the fact that a large number of people remain trapped in poverty and are expected to become better off as the industrial sector expands and provides better paying jobs than the agricultural sector presently offers. This would, in turn, mean that more people would be able to afford clean sources of energy for meeting their basic energy demands of heating and lighting their homes, as well as have access to better and faster means of mobility.

The energy demand growth in India will come from three factors:

- **Unmet modern energy demand** – this is demand from a population that has energy needs, but no access to modern energy sources for meeting their demand. So either they consume less than their demand or use traditional energy sources. As energy access improves, the demands of this segment will be addressed, thus adding to the demand growth.

- **Increasing incomes** – as incomes increase, the use of appliances and transport will increase. Thus the per capita energy for households and their transport needs will increase over time.

- **Economic growth** – the energy demand to meet the growth in commercial and industrial activity. The growth in energy demand in the industrial sector and some of the demand in transport (for transport of freight) reflects this growth in energy demand.

The biggest source of growth in demand is still industry and transport, both related to increasing economic activities, which is key to creating jobs and resources to address poverty.

Figure 8. Energy supply scenarios, Planning Commission (TWh/yr)

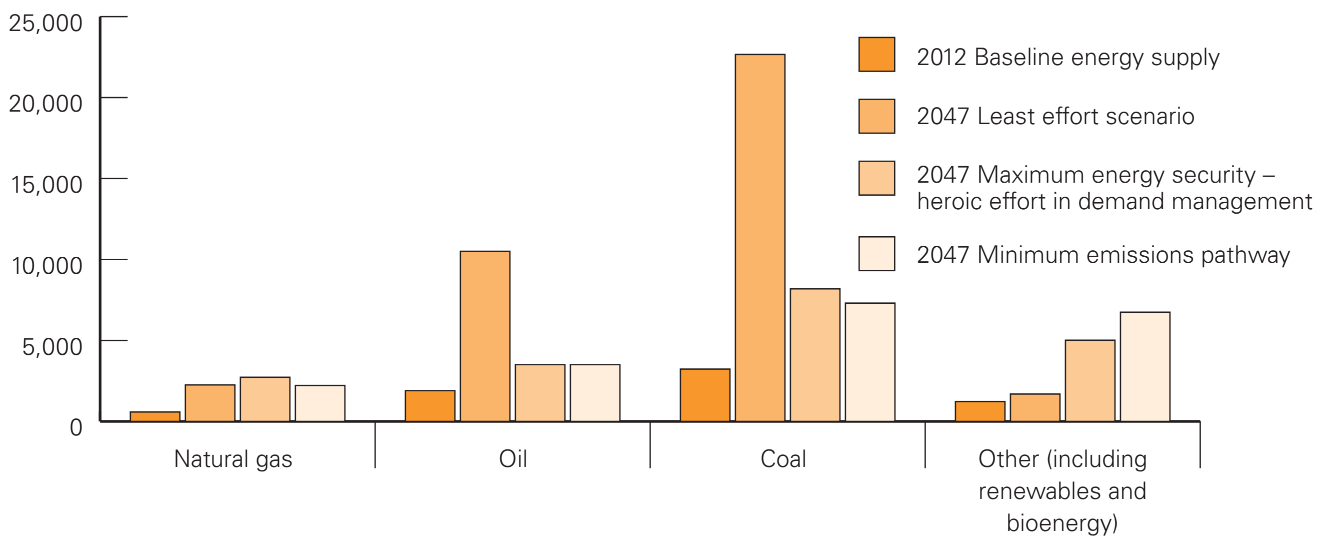
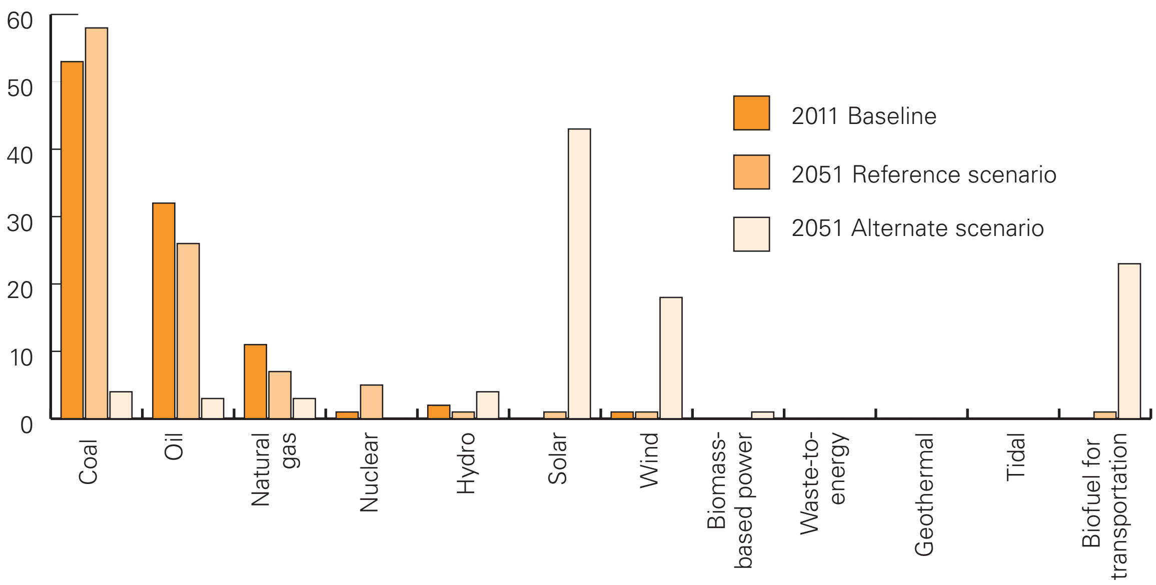


Figure 9. Energy supply scenarios (%), WWF-TERI.



4.2. Sources of energy to meet projected demand

The Planning Commission study also analysed the source of energy. The share of coal in the total primary energy supply increases to 61% in 2047, compared to 47% in 2012. The key demand for coal comes from electricity generation and industry. Oil demand is driven mainly by the transport sector and remains static at 27%. The share of electricity in the primary energy supply increases to 19% in 2047.[18] The share of renewables in the grid is minimal and remains near present levels in 2047, at 5%. The shift of energy need to electricity in the demand sector is not high and occurs in the service and agriculture sectors. In fact, the electricity share in commercial energy use in industry is projected to reduce.

Figure 8 shows the sources of energy supply for the Planning Commission scenarios. In the least effort scenario, coal and oil remain the dominant sources of primary energy supply. Coal increases its share from 47% to 61%, while oil accounts for around 27-28% of the primary energy supply. Renewables continue to languish and contribute around the same proportion of energy supplies in 2047 as they do at present. The share of electricity in the primary energy supply increases to 19% in 2047, a large part of which comes from import of electricity from neighbouring countries.[19]

In both the maximum energy security (MENS) and minimum emission pathway (MEP) scenarios, oil and coal based supplies of energy are assumed to increase, by about 2-2.5 times. Thus the share of coal the primary energy supply drops to 42% in MENS and to 31% in MEP. The decrease in the relative share of coal compared to the business as usual scenario largely comes from an increased use of renewables in the electricity sector (29% in MENS and 62% in MEP). The share of biofuels in transport increases to 67% in both the MENS and MEP scenarios, which in turn reduces significant demand for oil, the share of which declines to 20%.

Increased electrification of demand in services, household and transport, coupled with increased use of renewable energy (RE), reduces the demand for fossil fuel. Imports of electricity, and electricity from large hydro and nuclear also help reduce the share of fossil fuels. To ensure that the global temperature rise stays below 2˚C, a complete shift away from fossil fuels and towards RE is a must and the analysis highlights such a shift will require a significant effort.

The WWF-TERI report suggests that India could shake off its dependence on fossil fuels, particularly coal and petroleum (Figure 9). Thus, while the reference or business as usual scenario projects that by 2051 around 90% of India's primary energy supplies will be provided by coal, oil and natural gas, the alternate scenario projects that solar, wind and biofuels could meet around 84% of the country's primary energy needs.

The two reports presents views from either end of a spectrum. The Planning Commission report is the establishment view – the view of energy experts and planners. The WWF-TERI report is more of a RE enthusiast report, but does also involve energy experts.

Given that we face a carbon-constrained future, there is a need to engage intensively with decision makers as well as the general public in India to embrace a renewable future and achieve energy security, rather than being dependent upon fossil fuels, a significant proportion of which would need to be imported, compromising India's future energy security.

The Intergovernmental Panel on Climate Change is very clear that to avoid catastrophic climate change (warming above 2˚C) requires the world to immediately move towards reducing fossil fuel use.[20] India has to move rapidly to a low-carbon pathway. India has to be enabled to make the required energy transition by a transfer of international finance and technology to allow it to leapfrog to a cleaner pathway.

4.3. Energy resources availability and RE potential

The current share of renewables in the primary energy supply is only around 1%. There are a number of efforts to increase this share, largely focused on wind and solar electricity. The official estimates for renewable energy, primarily electricity generation, are shown in Table 3.

Thus, much of the renewable energy potential in India is as yet unrealised even when considering the government's official, conservative estimates. There are, however, other estimates that are much more optimistic.

The point that one must underscore is that while official estimates of renewable energy potential in India are perhaps overly conservative, even with the existing state of technological maturity of renewable energy, the potential for renewable energy deployment and utilisation is much higher than recognised in the energy governance establishment.

Table 3. Official estimates of renewable energy

Resource	Estimated potential (GW)	Installed capacity (GW)
Wind	102.8	19.1
Small hydro	19.7	3.6
Biopower	22.5	3.6
Solar power	600,000	1.7

Geothermal
Though geothermal power is not so well developed in India, the Geological Survey of India estimates there is potential of 10,000MW (about 5% of current installed electricity capacity in India). India plans to set up its first geothermal power plant, with 2-5MW capacity, at Puga in Jammu and Kashmir.

Wind
The costs of producing electricity from wind power are reducing rapidly, making it a viable alternative to conventional power for grid electricity. It can also be used off-grid for water pumping and battery charging.

Estimated potential in India is 102.8GW,[21] of which about 12% has been installed (as of June 2012). Most of the potential wind power identified so far is onshore. The government has taken steps towards exploiting offshore wind potential by setting up an energy committee on offshore wind. The Ministry of New and Renewable Energy published a draft national offshore wind policy in 2013 and is establishing an offshore wind authority.

Solar
Solar radiation (athe mount of solar energy that strikes a square metre of the earth's surface in a single day) ranges from 4-7kWh/m^2/day in India. There are approximately 300 sun days a year. Based on land area, the theoretically estimated potential of solar in India is approximately 600TW.

Tidal
There is an estimated potential of tidal energy in the order of 8,000MW. The Ministry of New and Renewable Energy has sanctioned a demonstration project for setting up a 3.75MW capacity tidal energy power plant in Sunderbans region, West Bengal.

Biofuels
Biofuels are one of the main options being examined by the transport sector. However, the potential impact on food production is a major concern. Any diversion of land to biofuels could reduce food production and increase prices. This would undo efforts to address poverty since poor people spend a large share of their income on food. Efforts to create energy security through developing the potential of biofuels should therefore ensure that they do not compromise food security.

India has huge biofuels potential and presently produces around 1,550 million litres of biofuels. The main feedstocks are sugarcane molasses and the jatropha tree. Currently, jatropha occupies only around 0.5 million hectares of wastelands across the country, of which 65-70% are new plantations less than three years old. The Planning Commission on Development of Biofuels has earmarked an estimated 13.4 million hectares of marginal/wastelands as suited to growing jatropha, but a recent study has shown that farmers do not have any incentive to use their fertile lands for jatropha cultivation at present.

Second generation technologies, generating biofuels from lignocellulose, and production from algae are alternatives that are better options from a food security perspective. The challenge is the timeframe over which commercially ready technologies for these would become available.

Much of the renewable energy potential in India is as yet unrealised; current share of renewables in the primary energy supply is only around 1%.

5. Strategic implications of reducing dependence on fossil fuel

A key driver for energy planning in India is energy security, ie, reducing dependence on imports. India's fossil fuel resources, with the possible exception of coal, are fairly limited. Of late, India has been importing coal to feed its growing number of thermal power plants, and is presently importing almost a quarter (24.3%) of its total coal consumption. Coal is only 3.5% of the total import bill currently, but this could balloon if domestic supplies are not augmented.

A key driver in the Planning Commission model is energy security. RE, biofuels and coal are key energy sources for ensuring a low dependence on imports. The analysis states the limitation of domestic coal availability and thus the MENS scenario limits coal imports to ensure low energy dependence (21% in 2047).[22] The energy dependence reduces further in MEP, as the share of RE increases to 14%, compared to 31% in 2012. This addresses one of the key economic issues of balance of payments, which has implications for growth. But the report recognises that MENS and MEP scenarios will require significant incremental costs.

A key challenge for the government is rapidly increasing access to electricity. Most fossil fuel based options have three to four years lead time, plus the additional cost of creating the transmission grid to connect them. In that regards, RE based electricity provides the possibility of rapid delivery, especially in areas where the grid is not available – though remote systems may have to be designed to be compatible with future grid connectivity. There is a need to explore and provide people with decentralised and/or off-grid options to meet their energy requirements at a faster pace than can be fulfilled by centralised, fossil fuel fired, power generation systems.

In addition, there are social and environmental impacts of coal mining and producing electricity through using coal, and these are already having a disproportionately large impact on poor and marginalised communities in many parts of India. Even with a very low penetration of motorised vehicles – only around 25% of Indian households own one – pollution levels in most major metropolises are unacceptably high, posing a threat to the health and wellbeing of the urban population. Finally, the economic costs of renewable energy deployment are dropping quickly, while the costs of continued reliance on coal are increasing rapidly. Thus, decentralised renewable energy can already compete favourably with coal in the power sector, especially if the costs of transmission and distribution, and associated energy losses, are added up.

Both reports highlight the costs of moving to a high RE use scenario. The Planning Commission highlights that MEP is highly cost intensive, and would require adoption of storage and balancing technologies at a rapid pace for integrating RE into the supply system. WWF-TERI estimates an additional investment of approximately $10 trillion over a 40-year period, ie, roughly about $250bn a year for the next four decades. This is the incremental cost of developing the energy delivery system to move towards 100% RE, and includes the cost of RE technologies. These estimates are based on present technology costs and available technologies.

The key factor in making the rapid transition to low-carbon development possible is to lower the costs of technologies and development of new ones. The transition to a much lower carbon India is needed as the country modernises its energy system in a carbon-constrained world. However, this cannot happen without international support, both in terms of finance and, more importantly, investment by developed countries in technologies to enable transition to a 100% RE future.

6. Existing low-carbon policies, strategies and mitigation options

India's emissions from the energy demand and supply process were estimated to be 1,726 million metric tons of CO_2 equivalent ($MtCO_2e$) in 2012. India's gross emissions in 2011 were 2,358.04 $MtCO_2e$, the third highest after China and the US. When per capita emissions are considered, India is in the bottom quartile at 1.93 tCO_2e, accompanied by countries like Burkina Faso, Sierra Leone, Samoa, Fiji, Pakistan and Nepal. This is far below the global average as well as far behind other high emitters, such as Kuwait and Qatar in the developing world, and Australia, Canada and the US in the developed world.

These emissions will increase with anticipated economic growth. India has been one of the fastest growing economies in the world, especially since 2002.[23] While its growth has tapered off drastically in recent years owing to the global economic slowdown, it is still considered as one of the world's growth areas.

In the Planning Commission's least effort scenario, the estimated GHG emissions from growth are 12 $GtCO_2$, roughly six times 2012 levels. Even with efforts to ensure energy security, which helps reduce emissions, emissions will still increase, though the growth is much lower.

GHG emissions from energy use arise from the following factors:

- addressing unmet energy demand of those without access or adequate access to modern energy
- increasing economic activity
- increasing incomes.

The Indian Government has focused on two pillars for managing energy demand and addressing energy security and the environment impacts of fossil fuel use:

- measures to reduce energy demand through energy efficiency
- increasing clean and renewable energy in the energy mix.

Internationally, the Indian Government has voluntarily agreed to reduce the emissions intensity of its GDP by 20-25% from 2005 levels by 2020. The government launched the National Action Plan on Climate Change (NAPCC), which includes eight missions to tackle climate change on a sector-by-sector basis, of which four are focused on mitigation. Two of these missions – the Jawaharlal Nehru National Solar Mission and the National Mission for Enhanced Energy Efficiency – focus on addressing energy need as well as emissions from the energy sector.

In terms of energy efficiency improvements to contain the demand of energy and thus emissions, the National Mission for Enhanced Energy Efficiency (NMEEE) is the key driver for achieving energy efficiency. It aims to save about 5% of the country's annual energy consumption.

A number of schemes and programmes aim to save fuel in excess of 23Mtoe, avoid capacity addition of 19,000MW, and mitigate 98 million tons of CO_2 emissions per year by 2014-15. Some of these measures are:

- The Market Transformation for Energy Efficiency initiative envisages aggregating small demand-side management projects under one roof, thereby reducing the transaction costs in obtaining Clean Development Mechanism funds. The focus is on increasing energy efficiency in agriculture, small and medium-sized enterprises, the commercial building sector and distribution transformers, and increasing the use of energy-efficient lamps. It also supports actions to reduce the costs of producing energy-efficient appliances.
- Because increasing industrial use is a high source of energy demand, the Perform, Achieve and Trade (PAT) Mechanism for Energy Efficiency aims to address energy use in 15 large energy-intensive industries. Each sector is set an energy efficiency improvement target and overachievement will be rewarded through certificates which can be sold on the market. The first three years of the scheme were expected to see savings of 9.78Mtoe and 26.21 million tonnes of GHG emissions, resulting in an expected avoided capacity addition of 5,623MW.

- To address the anticipated increase in energy demand from household sector through increased access to appliance, the Standards and Labelling Programme involves the mandatory energy-efficiency labelling of frost-free refrigerators, tubular fluorescent light bulbs, air conditioners and distribution transformers. Labels for direct cool refrigerators, induction motors, pump sets, ceiling fans, LPG stoves, electric geysers and colour televisions are voluntary.

- The Energy Efficiency Financing Platform is another complementary strategy under NMEEE, focusing on the creation of mechanisms to help finance demand-side management programmes in all sectors by capturing future energy savings.

The other arm of the strategy is to increase the use of renewables in the energy mix. The key programmes to address these are:

- **Jawahar Lal Nehru Solar Mission (JNNSM)** – the biggest effort in promoting renewables. This has a goal to deploy an ambitious 20,000MW of grid-connected solar power by 2022. In addition, the JNNSM offers two types of incentives to solar projects: generation-based incentives and a capital subsidy scheme.

- **Renewable purchase obligation (RPO)** – in order to provide incentives for rapid deployment of all available technologies for renewable energy, the State Electricity Regulatory Commissions are mandated to impose RPOs on power distribution companies and some other categories of bulk power purchasers. Those states that cannot generate adequate renewable power to meet their RPO targets can purchase Renewable Energy Certificates. These are issued to renewable energy producers based on their actual production. In 2011, the government adopted a tariff policy to support a State Electricity Regulatory Commission regulation requiring a fixed percentage of energy purchase by power utilities from renewable sources under its RPOs. RPO regulation is also seen as a tool to support the JNNSM by including a specific solar component as part of the RPO. The solar power purchase obligation for states may rise to 3% by 2022.

- **Feed-in tariff** – to provide incentives to RE-based electricity, the Central Electricity Regulatory Commission has established different tariffs to promote the use of solar, biomass and wind energy. Certain state governments provide an add-on tariff, on top of the tariff set by the commission.

- **Other fiscal incentives** – central and state governments have given various concessions to renewable power/energy producers, such as allowing 100% foreign direct investment for renewable power projects, concessional import duties, domestic tax exemptions or outright tax holidays.

- **Decentralised renewable-based electricity access** – as part of its national rural electrification policy, the government is promoting decentralised distribution-cum-generation, preferably through alternative sources of power, provided these are more cost-effective than grid integration. As of September 2012, 284 projects based on solar photovoltaic/biomass/small hydro covering 682 villages/habitations and 73,904 households with a sanctioned cost of INR2.83bn ($45.6m) were under implementation.

To complete the efforts and raise revenues to support some of the above measures, the government has doubled the tax on mined and imported coal from INR50 ($0.83) to INR100 ($1.67) per metric ton. According to the Economic Survey for 2011-12, the government expects to collect INR100bn ($1.61bn) from its Clean Energy Fund by 2015.

Urban development is also a key source of energy demand, but there is a challenge in terms of providing a good quality of life to urban dwellers. One of the national action plans on climate change focuses on sustainable habitat. The Mission is about providing sustainable living spaces by addressing energy demand, air pollution from transport and better waste management.

Key elements are:

- Extending the existing Energy Conservation Building Code.
- A greater emphasis on urban waste management and recycling, including power production from waste.
- Strengthening the enforcement of automotive fuel economy standards and using pricing measures to encourage the purchase of efficient vehicles.
- Incentives for the use of public transportation.

The Indian Government has focused on two pillars for managing energy demand and addressing energy security: energy efficiency and renewable energy.

7. Sustainable inclusive development through low-carbon pathways

Sustainable inclusive development is the key in India to lift people out of poverty, provide basic infrastructure of health, education, access to energy, and opportunities for gainful employment. The Indian Government's *Twelfth Five Year Plan* outlines inclusive and sustained growth as a key objective. These are defined as reducing poverty, improving quality of life and ensuring all segments of society benefit from economic growth. The plan identifies 27 indicators of inclusive growth, which one could put into two groups – providing access to basic needs (education, sanitation, decent accommodation, safe drinking water, clean energy) and providing productive income opportunities. Energy access is part of inclusive growth and will be a key source of growth in energy demand.

Energy is key to economic development, which is a must for inclusive growth. The energy challenge has implications for growth through energy dependency. A challenge in developing the country is ensuring a healthy balance of payments (the balance between import expenditure and export earnings of an economy), and an energy dependency with a minimal impact on balance of payments, but this can create uncertainty depending on the sources of supply. Renewable energy and coal are the two main indigenous energy sources. As previously seen, there are limitations to coal availability, although this is presently a cheaper option if environment externalities are taken on board.

Thus the challenge of sustainable inclusive growth for low-carbon development is to reduce the increase in demand and rapidly increase the share of RE to meet demand.

7.1. Barriers to sustainable development with low-carbon options

There are four major barriers that currently inhibit more rapid deployment of renewable energy in India.

The first is the scarcity of available public financing to leverage financial resources for fully implementing some of the innovative policy initiatives that have been enacted for renewable energy deployment. For example, a cornerstone of the policy framework for incentivising renewable energy is the interconnected measures of RPOs and Renewable Energy Certificates. RPOs are to be enacted and enforced by the State Electricity Regulatory Commissions.

Any failure to meet RPOs ought to result in punitive measures such as penalties in the form of purchase of additional Renewable Energy Certificates at a higher or forbearance price. However, this never happens. The major reason is that the distribution companies mandated to meet their RPOs are already functioning at a loss. This is because electricity tariffs are kept artificially low by the State Electricity Regulatory Commissions in order to meet the objectives of universal access to energy, resulting in operating losses for distribution companies. Thus, there is no appetite within the system to beat the distribution companies with the RPO stick, while they are already reeling from the burden of operating with non-remunerative tariffs.

One might then ask a legitimate question – why are electricity tariffs not rationalised? This issue has been addressed over time by setting up regulatory commissions to regulate on prices and better targeting of electricity pricing for the poor through life line tariffs. Tariffs in India are among one of the highest in world in PPP terms. The lowest life line tariff is around $0.10 in PPP terms.[24] This, along with the fact that 95% of the population lives at an economically vulnerable level, means that it is very difficult to increase tariffs of public goods (such as electricity) for fear of a political backlash. And no government, or perhaps only a very brave one, would like to take such political risks, having been elected by the very same vulnerable populations.

One big challenge is to integrate the variable and uncertain renewable electricity generation into the grid, though India is not yet at that stage. Further, RE sources cannot be optimised in terms of their location and could be very distributed, thus requiring significant investments in extending the grid.

A report by the American Physical Society, *Integrating Renewable Electricity on the Grid*, highlighted the challenge that 'accommodating more than approximately 30% electricity generation from these renewable sources will require new approaches to extending and operating the grid'.[25] Greater uncertainty and variability of RE in the grid can be balanced and can be dealt with by switching in fast-acting conventional reserves (hydro, gas); by installing large-scale storage on the grid; or expanding the transmission coverage enabling access to larger pools of resources in order to balance regional and local excesses or deficits.

This is further aggravated in India, where the existing grid is inadequate and is unable to even handle the traditional structure of large generation sources and defined areas of demand. A report from the Federation of Indian Chambers of Commerce and Industry on the power transmission grid highlighted that the expansion and connectivity has lagged behind growth in generation capacities.[26]

The lack of a well-integrated national grid with adequate capacities has resulted in non-evacuation of power from surplus areas and islands of high and low power costs. The increased involvement of the private sector in power generation has also had an impact on transmission planning and development, and requires much more coordination.

Increasing market-based flows also means that system needs to be strengthened to demand supply management and defence systems. This results in limitations upon how much renewable energy can be absorbed into the system. Thus, Tamil Nadu, which has led the country in installing wind energy and overachieved its own targets, is unable to fully evacuate the wind power that it is able to generate.

At present, grid balancing through creating fast-reacting convention sources for ramp are used. Therefore, another aspect of increasing renewable power in the overall power mix is that there will be a need to make additional investments for grid balancing and have idle base load capacity (mostly gas-fired power plants as they are easier to ramp up – but this adds to the challenge of energy security – or large hydro power plants) to kick in when renewable energy production drops suddenly. There will also be a need to invest in storage of renewable power as the RE share grows. Globally, much more investment needs to be directed towards R&D in this particular area. There is also a need to develop smart grids, discussed in the next section.

The third reason why some renewable energy is not being as rapidly deployed as possible is because the technological choices that are available involve difficult social and environmental trade-offs. A case in point is the low level of deployment of the current generation of biofuels. Despite there being a policy on increased blending of biofuels in gasoline and diesel, blending targets have not been achieved. This, in turn, is because of the trade-offs involved in competing land use for growing food as well as the environmental impacts of promoting mono-cropping and plantations for extracting the current generation of biofuels. Third generation biofuels, however, appear more promising and could be deployed on a much larger scale.

The fourth reason – and this is not specific to renewable energy – is that the capacity of the government to engage in a public debate about making difficult choices is limited. Everybody understands what is required to be done. However, there is little wisdom on how best to do so without hurting those who are vulnerable. Furthermore, there are vested interests who are happy with the status quo and, due to their political clout, are able to resist changes to Indian energy governance.

Recently, *The New Climate Economy Report* highlighted that a key challenge is the inability of many economies to mobilise sufficient finance to meet their infrastructure needs, primarily from a lack of public financing capacity and high-risk perception of the market.[27] New and innovative financial products are needed to lower the perceived risk of investments in low-carbon assets. This also requires strengthening of national and international development banks.

7.2. Policy changes required for low-carbon switchovers

The IPCC fifth assessment report (AR5) has clearly highlighted the limited carbon budget available to ensure the world stays below 2˚C warming. This requires developed countries to lead with steep reductions and invest in developing new technologies that would enable the possibility of a fast switch-out of fossil fuels across the world.

The recent report *The New Climate Economy* states: 'Rapidly falling costs, particularly of wind and solar power, could lead renewable and other low-carbon energy sources to account for more than half of all new electricity generation over the next 15 years. Greater investment in energy efficiency – in businesses, buildings and transport – has huge potential to cut and manage demand.' The report further states: 'Well-designed policies in these fields can make growth and climate objectives mutually reinforcing in both the short- and medium-term.'

In general, the three key elements of shifting to low-carbon pathways are energy efficiency, low-carbon electricity and fuel switching. In the Indian context, the switch to oil or gas is not a viable option because of its energy dependency implication, so the two key pillars are energy efficiency and renewable energy. Energy efficiency is a zero emission option and net zero cost option.

Immediate actions on energy efficiency and conservation are key to leapfrogging to a RE future. Energy efficiency measures are economically beneficial because they avoid incurring expense to create energy infrastructure, thus directly aiding economic growth. Apart from the immediate environmental benefits, delaying the creation of infrastructure allows the possibility of using RE instead of fossil fuel energy infrastructure.

Energy efficiency
In the Indian context, energy efficiency efforts in the following areas would benefit both sustainable development and climate change:

- Reduction in transmission and distribution losses, which are as high as 20%, compared to technical norm of 6-7%.

- Wider coverage and faster improvements in EE in industry through the PAT scheme (which is already operational). A significant share of industrial energy use is fossil fuels, so EE will reduce use. Industry needs to increase electricity use, which can be increasingly made renewable over time.

- Residential and commercial buildings offer a significant potential for energy savings directly through design features (building practices and construction material) and through improved end use. This reduces the cost of energy for the residential and commercial sectors.

- Mandatory and increasing fuel efficiency for private, public and commercial vehicles, as well as an effective shift of passenger traffic to public transport and freight traffic to rail. Public transport is an important sustainable development option for growing urbanisation. It reduces congestion, is more democratic by providing equal access to lesser income groups, and helps reduce local air pollution.

The key challenges in EE are higher upfront costs (though long-term running costs are much lower), access to financing, and general lack of awareness. A more generic challenge in the Indian context is implementation, which requires effective monitoring and evaluation systems. Public awareness is key to changing attitudes and highlighting the gains – as energy costs in India are quite high, payback is faster. Funding mechanisms for financing EE measures and using energy efficient appliances are essential. For energy efficient appliances, a financial mechanism whereby equipment manufactures could access financing for their products at a lower interest rate would help faster diffusion.

Most importantly, the government should put in place the human resources and institutional capacities to measure, analyse and continuously evaluate the impact of EE programmes.

Renewable energy
Using 100% renewable energy is the only option to keep the Earth's warming below 2˚C. An important element of enabling the world move to 100% RE as early as 2050 is for developed countries to achieve these targets at a much earlier date, as is the case in Denmark which has a goal to move to 100% RE in electricity and heating by 2035. This is important for two reasons. Firstly, such an aggressive target for RE in developed countries coupled with aggressive EE targets in all countries enables the world to keep to the 2˚C path in the medium term. Secondly, this

will reduce the cost of RE in the short and medium term and increase investment in developing RE technologies and their integration into the transmission and distribution grid.

Increasing the electrification of demand – As highlighted in earlier sections, electricity is a key source, but not the major source, of energy use in all sectors. Thus, electrification of demand has to be an integral part of transforming to a RE future. But there are limitations to this in the short to medium term, the most challenging one being the inadequacy of the transmission and distribution grid. The first focus therefore has to be on strengthening the grid. This does not necessarily mean expanding the grid, but rather improving connectivity across regions and between countries to allow the transmission of power from one area to another.

Development and investments in smart grids and technologies for increasing RE integration – A bigger challenge comes from the technical constraints of integrating high levels of RE into the electricity grid. One of the approaches to increasing RE generation is decentralised renewable generation, and integrating this generated power into the grid adds to the existing challenges of variability and uncertainty of RE sources. Smart grid technologies and technologies to store energy and smooth supply from RE need to be developed and become affordable and commercially available to speed up the move towards 100% RE.

Significant investments are required in R&D for developing software and hardware for smart grids as well as storage technologies, which will be challenging given India's limited resources. Developed countries need to invest in developing and making available these technologies. The Indian Government should look at opportunities to collaborate on such technology developments, because it would be beneficial to be an early user of these programmes and eventually reduce the costs of using the technology. Furthermore, a strategy for strengthening the transmission and distribution grid should build in the possibility of integrating elements of smart grids, to minimise the total investments in moving to a smart grid in future.

Sustainable hydro and biofuels to help transition to 100% RE – In the short to medium term, sustainable hydro and biofuels could be transitional fuels, because India has significant hydro potential and also could gain from hydro development in neighbouring countries. The studies discussed above also highlighted that shifting out of fossil fuel would require using biofuels and hydro. Sustainably developed hydro also provides ramping capacity and thus offers the possibility of higher level RE integration into the grid.

Biofuels are especially relevant in the Indian context because a large share of the increase in energy will come from transport. However, biofuels need to be produced in a sustainable manner without conflict with the food production system. Biofuels could also be a source of fuel for industry and cooking, displacing fossil fuels. There are a number of socio-environment concerns with large hydro and biofuels. Thus adequate safeguards are critical to ensure that the social and environment impacts are addressed thoroughly, including the rights of indigenous people and displaced people to have a say in the development and to be compensated fairly for any loss. Second generation biofuels (lignocellulosic feedstocks and municipal solid waste) and third generation algae-derived biofuels could be the focus because they do not impact food availability. In terms of first generation biofuels, using feedstock that does not compete with land for food production (jatropa) could benefit rural development as well.

Nuclear is a false solution – The Indian Government has set store by nuclear energy and available information on planned and proposed nuclear plants shows that by 20205 India may install around 40GWe capacity. Nuclear energy in the Indian context has major disadvantages – high costs (around INR9 [$0.15] per unit),[28] long gestation periods (roughly five to seven years), increases in fuel dependency, and the inherent danger of a nuclear disaster. On the other hand, some experts state that cost of new power plants will come to about INR2.5-3 ($0.04) per unit, far below the price of wind or solar, because they believe most plants will run for at least 40 years, and amortising it over 25 years is not appropriate in estimating the costs.

Nuclear is considered the best option to address both the international pressure on India to reduce emissions and its need for growth. Nonetheless, the risks, gestation period and implications for energy dependency are a good argument for not pursuing the nuclear option. Investments in nuclear are through loans on the government's books because these projects are implemented through public sector enterprises. The government could actually use the funding from its own revenue to leverage private sector investment in RE on a much larger scale than nuclear. It would also be able to deliver energy at a faster pace, as RE is scalable, unlike nuclear. The level of investment envisaged for nuclear is huge, so diverting that to RE could create a momentum that might bring the costs down at a faster pace.

Making RE competitive with fossil fuel – A big challenge in using RE electricity is India's current electricity prices, which are high in PPP terms. As mentioned earlier, consumers do not have the capacity to absorb higher costs and any increase would have political implications for the government. Therefore, bringing down the cost of RE is central to a 100% RE future. Until then, RE electrification will have to be based on use of public money to align the profitability of private sector.

The first step in this direction is a need to rationalise the existing fossil fuel subsidy regime, again in a manner in which it does not hurt those who are vulnerable, but also does not give a free ride to those who are not. This is easier said than done, however, and more thinking is required to find ways of being able to do so. There are, however, other policy and infrastructure bottlenecks that are fairly significant and need to be addressed.

A number of analyses indicate that wind in high wind density areas in India is competitive with fossil fuel based power. Solar based decentralised energy for remote areas and areas that are not connected to the grid (compared with the cost of grid extension included in energy generation from fossil fuel) is also suggested to be competitive with fossil fuel based electricity. A study by the Institute of Energy Economics and Financial Analysis estimated electricity from wind and solar energy would be cheaper than imported coal-fired power generation from 2018 onwards.[29] The study states that wind would be 20% cheaper than imported coal in 2018, and solar plants commissioned in 2015 will deliver electricity at 96% the cost of electricity from imported coal.

An HSBC report in 2013 stated that wind is competitive with new coal power plants based on tariff bids in the range of INR4.5-7/kWh ($0.08-0.13/kWh) for new coal capacity submitted in December 2012 in Uttar Pradesh state. These were much higher than tariff bids received in 2011, which were INR3.3-5.6/kWh ($0.06-0.10/kWh). In comparison, the wind feed-in tariffs range from INR3.51-5.92/kWh ($0.06-0.11/kWh) across seven key wind states covering 70% of India's installed wind capacity.[30]

But most of these calculations are based on imported coal. The present government is investing significantly in enhancing domestic coal production. In the shorter term, domestic coal availability could increase and keep the price of coal-based power down. However, as mentioned earlier, coal availability is limited in India in the long term. Resources could be better spent on bringing down costs of renewables rather than investing in options that will have to be abandoned in the near future. Nonetheless, given the development need, new fossil fuel based power plants cannot be ruled out in the immediate future. But it will be beneficial to start thinking of phasing out coal/fossil fuel based capacities as an integral part of long-term energy planning.

Off-grid for energy access in the short term – Off-grid options for communities with no or poor access to the grid are win-win solutions for communities and the environment, and are also economically viable.

In this scenario, it makes much more sense to aggressively deploy off-grid renewables in energy-deprived communities. Off-grid solutions would also be much better for government-run schools and health centres to ensure that they can efficiently serve marginalised, deprived and poor communities, since power supply from the grid is either highly inadequate or non-existent. An additional aspect of off-grid application is in the agriculture sector. In many parts of the country, especially the eastern states such as Bihar, West Bengal and Assam, farmers could easily replace diesel-fired pumps used for irrigation with solar powered pumps that would reduce their expenditure on diesel, avoid emissions from diesel combustion, and reduce the demand for a resource that puts a very high burden on India's trade balance.

This should only be considered a short-term solution, as off-grid may only address basic minimum energy needs. In the short term it would be faster to deliver energy access, as grid penetration in many parts of the country is poor, and grid extension would take time. But in the long term, these systems will have to be connected to the grid for meeting higher energy demand.

The above-mentioned measures may be possible ways forward in the short term. However, there is no getting around the fact that in the medium to long term, certain technologies, such as third generation biofuels and concentrated solar power, would need to mature and become available for rapid deployment if India's renewable energy potential is to be realised. This would need international financial and technological transfers at a scale that hitherto has not been witnessed. However, the deployment of next generation renewable technologies could be accelerated further by rapid deployment of the current generation technologies wherever they have achieved maturity and are feasible, so that there is greater confidence in a renewable future among decision makers and the general public.

The report *The New Climate Economy* concludes that globally 'infrastructure requirements for a high-carbon economy, across transport, energy, water systems and cities, are estimated at around $90 trillion or an average of $6 trillion per year over the next 15 years.' It further states that significantly scaled-up energy efficiency combined with compact cities and a reduction in fossil fuel investment could limit the investment requirements to an estimated $270bn a year.[31] For some, these gains are key for developed countries to significantly scale up investment in RE.

Off-grid solutions would be much better for government-run schools and health centres to ensure that they can efficiently serve marginalised, deprived and poor communities.

8. Case examples

8.1. Village-based solar micro grid

An initiative by Minda NexGenTech Ltd led to the setting up of a solar power-based micro grid and a subsequent transformation in the village of Indira Nagar, Rajasthan. Prior to installation of the solar plant, kerosene lamps were used for lighting. Activities such as cooking, washing, sewing and fertiliser mixing were not possible after sunset. Now, however, the 240W solar power plant provides basic lighting to all the houses in the village.

The arrival of power has also sparked an entrepreneurial spirit among women. Evening hours are now spent under energy-efficient LED bulbs grinding pulses and sewing to supplement family incomes. Access to energy has increased the hours children can spend studying, facilitated women's education initiatives and brought about a social revolution in the village.

The solar power plant is based on the BOM (built, operate and maintain) working model, with each household contributing INR150 ($2.50) as a monthly charge for usage, along with an initial connection charge. This has resulted in a minimal financial impact on the villagers, as they had paid about the same amount each month for three litres of kerosene and charging mobile phones.

Objectives of the activities initiated through the solar power plant were:

- Basic lighting and mobile phone charging
- Generation of additional income and better standard of living
- Removal of kerosene lamps
- Better health, safety and education.

Pulse grinding
Women from 12 households are using extra productive hours during the evening to grind pulses. Each woman collects 5kg of pulses from the distribution centre every second day. The grinding is done in addition to their daily work, using the LED lighting provided by the solar power plant.

Sewing centre
The sewing centre involves girls from Indira Nagar who are aged 10-18 years. A local representative conducts regular training sessions, enabling them to learn a new trade and generate additional income to support their families.

Education centre
During the evenings, women are learning to read and write under energy-efficient LED lamps powered by the solar plant.

Enabling village-level entrepreneurs
Minda NexGenTech Ltd has adopted an approach to combine energy access in rural areas with sustainable rural development. It is envisaged that village-level entrepreneurs will invest and operate micro grids to provide basic lighting facilities to rural households for a monthly rental.

The use of solar power, along with the various initiatives and innovations, has provided numerous opportunities to the villagers to use the available natural resources for their benefit. The overall impact has been an opportunity to build the future of the villagers, and to provide not only light, but sustainable, all-round rural development.

8.2 Lalpur's tryst with biogas

Lalpur is a remote village in Jharkhand's Madhupur district. The main source of livelihood is agriculture, and the villagers depended upon kerosene and firewood to meet their energy needs. The negative health impacts of smoke emitted from burning kerosene and firewood for cooking was severely affecting the health of local women. In addition, firewood collection was a very time-consuming activity since the women had to travel long distances on foot.

The village consists of about 52 houses with approximately 89 cows, 75 bulls, 4 buffaloes, 110 goats and 76 sheep. About 4kg of dung is collected from each cow, bull and buffalo each day, so the village gets about 670-700kg of dung daily. The average number of people per household is six, and each household cooks and consumes 1.5kg of rice, 1kg of vegetables and 200g of pulses per meal.

To ensure that all the households in Lalpur get access to quality biogas for meeting their heating and cooking requirements, it has been estimated that a biogas plant measuring 35m^3, capable of supplying 1,500 cubic feet of gas per day, would be required. An assessment of cooking and heating requirements showed that the average consumption of gas would be approximately 30 cubic feet per family per day for cooking three meals.

However, a community biogas plant would be fairly labour intensive and would also require a regular and sustained supply chain process to be put in place to ensure that the plant is run round the clock.

Therefore, in order to acclimatise people to operating a biogas plant, it was decided to install two small pilot plants, which would supply gas to four households. The idea was to use this as a training pilot, and to put systems in place before a community biogas plant is built in the village.

The two pilot plants that were installed require a total of 40kg of dung and 40 litres of water every day (20kg of dung and 20 litres of water per plant). They supply nearly 60 cubic feet of gas, which is sufficient to meet the cooking and heating requirements of about 20 people, covering four households.

A system to ensure daily collection of dung has been put in place, with responsibilities assigned in rotation to designated family members from the four beneficiary households. A system of monthly cleaning has also been put in place.

The pilot plants have now been in operation for nearly two years. In that time the plant was inoperative only for about four days, due to a pipe leak, which required the replacement of the pipe and some coupling accessories.

Furthermore, the two plants also release slurry of 20kg (dried weight), which is used in an organic farm that the local community organisation has set up as a pilot in Lalpur.

8.3. The Perform Achieve and Trade scheme

The National Action Plan on Climate Change has eight missions, including the National Mission on Enhanced Energy Efficiency (NMEEE). This has the objective of enhancing energy efficiency in the country. One of the initiatives under NMEEE is the development of a market-based mechanism to drive delivery of additional energy savings cost-effectively.

Following on from this, the Ministry of Power designed the Perform, Achieve and Trade (PAT) scheme for mandatory trading in energy saving certificates for energy intensive industries.

Eight intensive industrial sectors (thermal electric power generation, fertilisers, iron and steel, cement, pulp and paper, aluminium, chloralkali and textiles) were identified for the initial implementation of the PAT scheme.

The scheme became operational in 2010, after parliament approved the Energy Conservation (Amendment) Bill 2010, and was finally notified on 30 March 2012, covering 478 industrial plants. The categories of industrial plants covered under the scheme included thermal power plants (144), large iron and steel (67 plants), and cement (85 plants).

Table 4 gives an overview of the reduction in emissions and the number of actual industrial units (designated consumers) covered in each of the industry categories, along with their baseline and targeted specific energy consumption.

The scheme was, until recently, identifying baselines as well as designing monitoring, reviewing and reporting protocols. The scheme is now into its first implementation phase where energy efficiency targets have been allocated for the various industrial units. It is one of the most ambitious initiatives of the government on energy efficiency, as well as one of the first market-based mechanisms devised in the developing world for emissions reductions.

Table 4. An overview of emissions reduction in industry

Sector	Baseline SEC, toe/t of product	Percentage SEC reduction	Target SEC, toe/t of product	Target energy savings, Mtoe	Number of designated consumers
Aluminium	2.005	5.354	1.897	0.456	10
Cement	0.088	4.793	0.084	0.816	85
Chloralkali	0.393	6.138	0.369	0.054	22
Fertiliser	1.375	2.775	1.337	0.478	29
Iron and steel	0.549	5.863	0.517	1.485	67
Pulp and paper	0.656	0.656	0.622	0.118	31
Textiles	0.227	0.227	0.215	0.094	90
Industry total	0.230	5.486	0.217	3.501	334
	Baseline NHR (kcal/kWh)	**Percentage NHR reduction**	**Target NHR (kcal/kWh)**		
Thermal power plants	2,775.56	2.149	2,715.919	3.359	144
Total				6.86	478

SEC = specific energy consumption; NHR = net heat rate

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