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Abstract

The transition to a low carbon economy heralds an economic and social transformation that is exciting as well as challenging. The challenges that face India include: enhancing economic opportunities and living standards for a growing population and addressing the environmental threats. In this backdrop, if India is to realize its development goals. the path towards a low-carbon economy is inevitable. Approaching a low-carbon economy is of critical importance as the country evolves its economic development model, adjusts its economic structure, enhances its technological innovation capabilities and strengthens the sustainability of its economy. Using a "bottom up" policy framework for low-carbon growth based on national preferences, possibilities and policies the present study develops a model with two scenarios. One is business-as-usual reference case (BAU) and the other is low-carbon (LC) scenario. We discuss the financing mechanisms and key policy issues. The low-carbon scenario is characterized by increased use of renewables through solar, wind, geothermal, biomass and hydro, which will reduce fossil fuel demand. Also, use of efficient and clean end-use devices in all the sectors will multiply savings. The analysis shows that economy-wide reductions of the order of 30-35% appear to be technically feasible at reasonable costs, relative to the baseline scenario.

Keywords: Business-as-usual, Emissions, Low-carbon economy, model, technology, Scenario

JEL Code: P28, Q41, Q42, Q48

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Abstract

The transition to a low carbon economy heralds an economic and social transformation that is exciting as well as challenging. The challenges that face India include: enhancing economic opportunities and living standards for a growing population and addressing the environmental threats. In this backdrop, if India is to realize its development goals. the path towards a low-carbon economy is inevitable. Approaching a low-carbon economy is of critical importance as the country evolves its economic development model, adjusts its economic structure, enhances its technological innovation capabilities and strengthens the sustainability of its economy. Using a "bottom up" policy framework for low-carbon growth based on national preferences, possibilities and policies, the present study develops a model with two scenarios. One is business-as-usual reference case (BAU) and the other is low-carbon (LC) scenario. We discuss the financing mechanisms and key policy issues. The low-carbon scenario is characterized by increased use of renewables through solar, wind, geothermal, biomass and hydro, which will reduce fossil fuel demand. Also, use of efficient and clean end-use devices in all the sectors will multiply savings. The analysis shows that economy-wide reductions of the order of 30–35% appear to be technically feasible at reasonable costs, relative to the baseline scenario.

1.INTRODUCTION

Energy is an essential ingredient for existence and development. Energy *per se* is not a need, but the services it provides like cooked food, lighted rooms, and fueled vehicles are. Wider and greater access to energy services is critical in achieving the Millennium Development Goals (MDGs) and thereby helps sustainable human development (World Bank, 2005). Societies with low per-capita energy use tend to have poor human development indicators—low life expectancy, high infant mortality, and low literacy (Reddy and Nathan 2010).

India, like other developing economies, is in a transition. It occupies 134th position out of 182 countries in Human Development Index (HDI) tally (UNDP, 2012). Nearly 0.4 billion people in India (45.1% rural and 7.8% urban households) do not have access to electricity (IEA, 2012; NSSO, 2011). Similarly, 90% of rural and 33% of urban households do not use clean cooking fuels. Energy services need to be delivered to the deprived so that adequate living conditions in terms of food, water, shelter, health care, education, and employment can be attained (Reddy, 2014). India also faces important challenges in energy use from environment point of view. As per International Energy Agency (IEA) estimates, the world energy-induced CO_2 emissions will increase by 57.4% during 2005–30, and India will account for 14.2% of those emissions (IEA, 2012). However, India's share in incremental world energy demand during the same period will be about 6%. The higher share of pollution can be attributed to two factors—India's heavy reliance on coal, which is of low quality with high ash content (low calorific value); and low share of zero-carbon fuels, which is only 1% in total primary energy demand. Additionally, biofuels, which meet 72% of domestic energy and 90% of all rural energy needs (TERI, 2012), contribute to climate change through black carbon emissions. Like other developing countries, the major dilemma India faces today is on the prioritization of energy goals which need to follow the path of low-carbon economy with efficient management of energy carriers and promotion of renewable technologies. A radical transformation of the energy sector is required to move to a low-carbon economy. This requires a shift to energy efficient and low-carbon technologies that not only displace inefficient devices, but also meet the rapid growth in electricity demand, while maintaining affordable and reliable service to consumers. To achieve this goal, radical changes are required at the institution level. In this perspective, this study bears importance as it takes into account the major energy sources, considers the key variables which influence the energy demand and develops a low-carbon scenario targeting high growth, efficient technology and low-carbon, and compares the results with business as usual case with a focus on energy infrastructure.

2.INDIA'S ENERGY DEMAND OUTLOOK

The demand for energy increases with increase in population base, and change in livelihood and lifestyle needs. In India, the energy demand has increased over six fold over the last five decades, whereas the population has increased by 2.7 times. Table 1 provides the energy demand met by different energy sources (Planning Commission, 2012). While total energy demand registered an average annual growth rate of 3.67% between 1990–91 and 2011–12, the commercial energy demand grew at the rate of 4.93% indicating of a declining growth rate for noncommercial energy sources. The share of oil has remained around one-third of the commercial fuel since 1970. The share of natural gas has increased from 1% in 1970–1 to 8.8% in 2011–12 while that of other renewable sources like solar, wind, small hydro, hydrogen, geothermal forms is below 1% of the total primary energy demand.

Table 1: Primary energy demand in India (MTOE)

Type of carriers	1960-61	1970-71	1980-81	1990-91	2000-01	2006-07	2011-12
Coal[a]	35.7 (79.9)	37.3 (62.3)	58.2 (60.2)	97.7 (55.9)	138.0 (49.1)	208.7 (53.3)	283 (51.8)
Oil[a]	8.3 (18.6)	19.1 (32.0)	32.3 (33.4)	57.8 (33.1)	107.0 (38.1)	132.8 (33.9)	186 (34.1)
Natural gas[a]	0.0 (0.0)	0.6 (1.0)	1.41 (1.5)	11.5 (6.6)	25.1 (8.9)	34.6 (8.8)	48 (8.8)
Hydro[a]	0.7 (1.5)	2.2 (3.6)	4.0 (4.1)	6.2 (3.6)	6.4 (2.3)	9.8 (2.5)	12 (2.2)
Nuclear[a]	0.0 (0.0)	0.6 (1.1)	0.8 (0.8)	1.6 (0.9)	4.41 (1.6)	4.86 (1.2)	17 (3.1)
Total Commercial[b]	42.8 (36.5)	60.3 (41.0)	99.8 (47.9)	181.1 (59.7)	296.1 (68.4)	391.5 (72.6)	546 (76.4)
Non-Commercial[b]	74.4 (63.5)	86.7 (59.0)	108.5 (52.1)	122.1 (40.3)	136.7 (31.6)	147.6 (27.4)	169 (23.6)
Total	117.2	147.1	208.3	303.2	432.8	539.1	715

Notes: a The number in the bracket shows the percentage with respect to total commercial fuels
[b] The number in the bracket shows the percentage with respect to total fuels
Source: Planning Commission (2012)

3.FUTURE ENERGY SCENARIOS—THE KEY CONSIDERATIONS

In the twenty-first century India faces twin challenges: expanding opportunities for a growing population and addressing environmental concerns. It is about fostering growth and development while ensuring that natural assets continue to provide resources and environmental services on which our wellbeing relies. It is also about enhancing investment and green innovation which will underpin sustained growth and give rise to new economic opportunities and accelerate the transition towards a low-carbon economy (Moe, 2012).

In order to project future energy needs, important factors influencing energy demand are identified. These factors are classified as: (i) macroeconomic and demographic, (ii) supply-side, and (iii) demand-side. To segregate sustainable development considerations, the demographic and macroeconomic factors have been assumed to hold good for both baseline and low-carbon (LC) scenarios[1]. The factors considered here are not exhaustive, nevertheless are considered important from the Indian perspective

3.1 Macroeconomic and demographic factors

3.1.1 Economic growth

The causality between energy and Gross Domestic Product (GDP) has been established in various cross-country studies. In the Indian context, Sahu (2008) has shown positive relationship between energy and GDP. India's average annual GDP growth rate was about 3% in the 1970s, which increased to 5.6–5.7% in the 1980s and 1990s (RBI, 2009). In the current decade (2001–10), it has accelerated to about 9% between 2005 and 2011 (PMEAC, 2012). So, a conservative estimate of growth in future would be to continue to grow at the same annual average rate of the current decade, i.e., 7.2% for the next decade (2011–20) which might ease out by one fifth to about 5.8% in the following decade (2020–2030). The annual average growth rate is assumed to be 1.5% points higher, i.e. 8.7% for 2011–20 and 7.3% for 2020–30 respectively. Accelerated structural and institutional reforms and faster infrastructural development are considered as the main drivers for growth.

3.1.2 Population

Increase in population leads to increase in energy consumption simply because with more people there would be more basic energy needs like cooking, lighting and transportation.

[1] The low-carbon economy is characterised by activities which emit low levels of carbon dioxide into the atmosphere. To achieve this, we have to switch from fossil fuels to renewables and increase the efficiency of devices. New fuel-efficient engines, bio fuels in transport sector and energy-efficient devices in household sector are examples of technologies, processes and services which meet this need.

India's population is expected to grow at an average annual growth rate of 1.1% during 2010–30 (Census of India, 2011). In this study it is considered to be 0.1% less because of assumptions of relatively higher GDP growth rate and urbanization would lead to higher household income. Literature shows that income affects fertility negatively (Becker and Lewis, 1974; Jones et al., 2008).

3.1.2 Urbanization

India has a large urban–rural divide in access to modern energy services. In rural areas, 84% of households rely on biomass for cooking and only 8.6% use LPG, whereas the corresponding figures for urban areas are 23% and 57%. Similarly, more than 92% of the urban households are electrified, whereas nearly 44% of rural households depend on kerosene for lighting (NSSO, 2011). The UN (2010) has estimated India's average annual urbanization growth rate at 2.6% between 2010 and 2030. However, we assume it to be 10% more than the UN estimates by 2030. Increase in urbanization improves energy infrastructure and access to modern energy services as it is generally less costly to supply urban communities.

3.2 Supply-side factors

3.2.1 Energy availability and fuel shift

Both the availability and quality of a particular fuel influence its demand. India's coal, though readily available, is of a poorer quality in relation to internationally traded coal. If abundance and indigenous production favour coal among fossil fuels, its high ash content and CO_2 emissions prove to be its disadvantages. Efficiency can be improved with coal washing and blending of indigenous coal with better quality imported coal. In both baseline and LC scenarios the share of imported coal is expected to rise. However, under LC scenario the overall demand for coal would decline because of fuel-switch and higher efficiency in power generation due to clean coal technologies (CCTs). Natural gas has been considered a substitute to coal in power generation and industry, and substitute to oil in transportation.

Among the non-carbon fuels, though renewable, hydro will stagnate owing to the prevailing opposition against mega hydro projects. Nuclear energy, unlike hydro, is expected to register a higher growth rate in future. It is assumed that India's nuclear capacity will increase to 25GW by 2030 in LC scenario, whereas for baseline it is less by one-fourth. The growth rate of non-commercial energy will be comparatively less in LC scenario as the availability and affordability of modern fuels including decentralized renewable systems improve in rural areas. Also, an increased efficiency of *chullas* (traditional stoves) using firewood is assumed in LC scenario. In regard to other renewables, India is expected to have a higher growth rate in LC scenario for all renewable energy technologies (RETs), particularly solar heater, wind energy, and small hydro.

3.2.2 Power Plant efficiency

One of the most important concerns under energy infrastructure is the efficiency of plants which transforms natural resources to energy. The thermal efficiency of coal-fired power plants in India is 27%, whereas the same in OECD countries is 37%. This study assumes that the efficiency gap between India and OECD countries remains the same in the baseline, whereas it reduces to half in the LC scenario. This implies that during 2010–30, the plant efficiency increases from 27% to 32% and 37% under baseline and LC, respectively. Higher efficiency under LC is achieved by 2020 through plant modernization and development of integrated gasification combined-cycle (IGCC) and supercritical plant technology.

3.2.3 Control on T&D losses

The energy loss during transmission and distribution is like carrying water in a leaking pot, which makes the vessel half empty by the time it reaches its destination. India's high T&D

losses can be attributed to high voltage network losses, defective or absence of meters, and theft. T&D loss for developed countries is 7−8%. Considering remote rural areas and system configuration, a reasonable and permissible T&D loss for India can be 10−15% (Kumar and Chandra, 2008). In the present model, the T&D loss is assumed to decrease to 23% and 18% by 2030 in the baseline and LC scenarios, respectively.

3.3 Demand-side factors

3.3.1 Vehicle stock and modal shift in transportation

A transportation modal shift from private to public transport system is assumed under LC scenario as the government is proposing to construct rapid transit bus system and urban rail networks. However, personal vehicles will also increase due to economic growth and income expansion making them affordable to large sections of the population (Reddy and Balachandra, 2012). Owing to increased fuel efficiency, under LC, vehicle stock will be higher compared to the baseline.

3.3.2 Energy intensity in Industry

Indian industrial sector has progressed in efficiency over the last two decades, particularly in case of iron and steel, and cement industries. However, there is further scope for improvement since a significant portion of Indian industrial output is derived from small-scale, often rural-based enterprises, fuelled by inefficient boilers, motors, and equipment (Reddy and Ray 2012). LC scenario considers mandatory auditing for energy-intensive industries noted in the Energy Conservation Act 2001, which would lead to a 10% increase in efficiency over baseline.

3.3.3 Household Appliance stock and efficiency

Appliance stock influences electricity demand in households. With increase in disposable income, households' appliance stock will increase, which explains the more than 90%

variation in the residential electricity consumption (Reddy, 1995). Under LC, there would be increase in appliance efficiency. Compact fluorescent lamps (CFLs) are examples of appliances where technological advances have resulted in improvement in energy efficiency by a factor of five without compromising lighting levels. Similarly, improvements in the efficiency of fuelwood stoves and a shift from biomass fuels to gaseous fuels will further reduce household energy use significantly.

4.THE FORECASTING MODEL

The model developed in this paper is an integrated energy–engineering–environmental–economic system model that is a variant of MARKAL and other such models (Reddy and Balachandra, 2003). Unlike other economic models that have been used previously, this is a bottom-up approach which covers all sectors of the energy economy. While at present there are a couple of national-level models used in government energy forecasting and analysis, there is not a single model that is specific to India. In fact, there are no publicly available bottom-up energy–engineering–environmental–economic models that cover all sectors a country's energy system. As India is striving towards carbon emission reduction, there is a strong need for this kind of transparent, flexible, and accessible model to help form informed policy decisions.

The present model has been developed for forecasting the demand of different energy carriers. The growth rate of each carrier can be expressed by key demographic, macroeconomic, supply, and demand factors as follows[2],

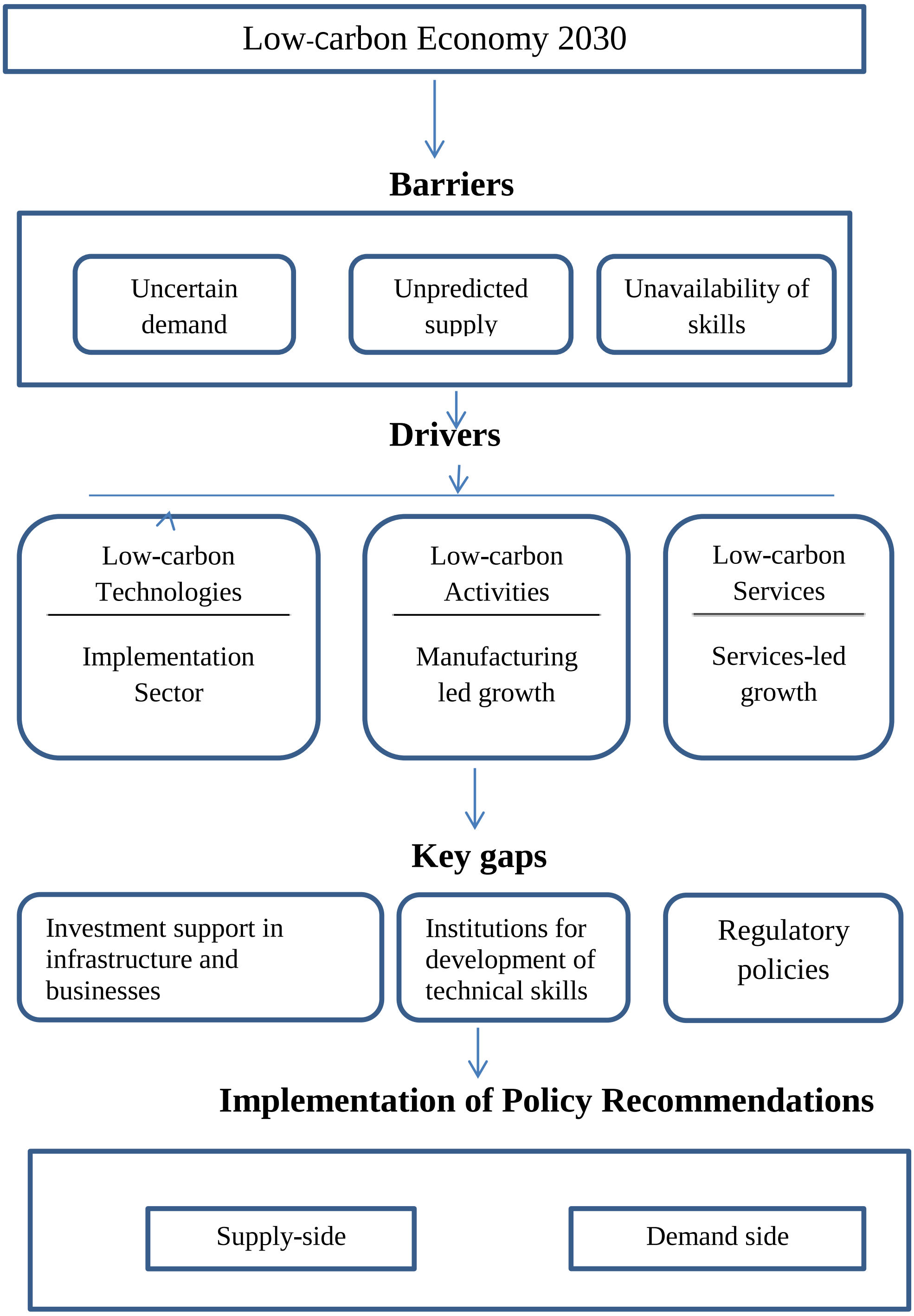
$$d_i = f\,(g, p, u, s_i, e_i, t_i, i_i, v_i, m_i, n_i, o_i) \qquad (1)$$

[2] Note that we have not considered the price variables as the same have already been accounted for fuel quantity shifts. Also, the international price of oil is assumed to be the same under both scenarios as also that there is no specific price administration by government under LC.
Barriers

where, d_i = Demand growth rate for energy carrier i (%), g = GDP growth rate (%), p = Population growth rate (%), u = Rate of urbanization (%), s_i = Rate of change in demand for energy carrier i due to fuel shift (%), e_i = Rate of change in energy efficiency during generation for energy carrier i (%), t_i = Rate of change in T&D efficiency of energy carrier i (%), i_i = Rate of change in energy efficiency of industry using energy carrier i (%), v_i = Rate of change in vehicle stock using energy carrier i (%), m_i = Rate of change in demand of energy carrier i due to mode shift (%), n_i = Rate of change in appliance stock using energy carrier i (%), o_i = Rate of change in efficiency of appliances using energy carrier i (%). The formulation of transition pathways follows an approach based on various elements which include: (i) characteristics of existing energy regime; (ii) technologies, activities and services; and (3) specific gaps at various levels. The relation between these elements is illustrated in Figure 1.

5.RESULTS—ENERGY DEMAND FOR LC VIS-A-VIS BASELINE

Table 2 gives the projected demand for different energy carriers for baseline and low-carbon scenarios. In the baseline scenario, coal will remain dominant fuel with its share reigning supreme at over 40% of all carriers. Oil will also progressively increase its share from 24% to about 28%. The consumption of natural gas will increase approximately four fold, and its share will increase from 6.6% to 11%. In the absence of any radical policy disfavouring fossil fuels, these fuels together dominate energy scene accounting for more than 80% of energy demand in 2030. The production of electricity from hydro is likely to be relatively flat. Nuclear power emerges out as a clear option for power generation. The power generation from the other renewable sources continue with a share below 1% and may not make much of an impact.



Adopted from Charles Levy, 2010

Figure 1: Low-carbon economy—Bottom-up approach

Table 2: Energy demand and CO_2 emission under baseline and LC scenarios

Source	2010	Baseline Scenario		LC Scenario		Savings	
		2020	2030	2020	2030	2020	2030
Total primary energy demand (MTOE)							
Coal	256 (41.2)	431 (43.3)	578 (41.4)	361 (40.4)	386 (35.8)	70	192
Oil	150 (24.2)	261 (26.2)	387 (27.7)	242 (27.1)	309 (28.6)	19	78
Gas	41 (6.6)	87 (8.7)	154 (11.0)	78 (8.7)	109 (10.1)	9	45
Nuclear	5 (0.9)	12 (1.2)	32 (2.3)	14 (1.6)	46 (4.3)	-2	-14
Hydro	12 (1.9)	19 (2.0)	26 (1.9)	18 (2.0)	22 (2.0)	1	4
Non-commercial	155 (25.0)	181 (18.2)	208 (14.9)	174 (19.5)	182 (16.9)	7	26
Other renewables	2 (0.3)	5 (0.5)	12 (0.9)	6 (0.7)	25 (2.3)	-1	-13
TOTAL	621	996	1397	893	1079	103	318
CO_2 emissions (Mt)							
Coal	953 (67.9)	1594 (65.3)	2129 (61.9)	1342 (63.4)	1450 (59.0)	252	679
Oil	363 (25.9)	659 (27.0)	978 (28.4)	607 (28.7)	770 (31.4)	51	208
Gas	88 (6.2)	188 (7.7)	333 (9.7)	169 (7.7)	236 (9.6)	19	96
TOTAL	1403	2440	3440	2118	2456	322	984

Note: Number in parenthesis gives the share in the total

In the low-carbon scenario, the share of fossil fuels will decline to less than three-fourths by 2030. Among the fossil fuels, coal will lose its share by about six percentage points. Oil and gas will decline from 4.9% to 3.7% and 6.8% to 5.0%, respectively. Nuclear and other renewables will increase their share in the total energy demand registering an average annual growth rate of 11.7% and 13.5%, respectively. The share of hydro will not differ much from the baseline

Table 2 also provides energy savings under both LC and baseline scenarios. In 2030, the annual energy savings will be 318 MTOE, i.e., 23% of the total baseline energy demand. The same during the study period will be about 129 MTOE. It is worth noting here that savings in energy in LC scenario should not be construed as cut down on energy services, it rather reflects the efficient use of fuel and fuel substitution. The saving primarily comes from declining share of coal, which contributes 60% of the saving.

There is a reduction in energy-induced CO_2 emission in LC scenario when compared to the baseline. CO_2 emission in 2030 is estimated to be 2456 Mt, i.e., 29% less than the baseline. The average annual reduction of CO_2 emission turns out to be 403 Mt during the study period.

Various infrastructural needs for generating electricity under LC include (i) modernization of power plants, (ii) efficient power grid of long-distance transmission lines and local distribution lines, (iii) power development of units based on renewable sources, and (iv) efficiency improvements in the household and industrial sectors. Table 3 suggests the investment needs in LC scenario under different heads. The investment for coal is Rs 1,547 billion (US$25.8 billion) which includes mining and port development, with the former cornering almost 95% share. In the case of oil, refinery turns out to be the major head accounting for more than three-fourths of total investment by 2030, which is around Rs 7,300 billion (US$122 billion). In case of natural gas a substantial amount of capital investment is needed, in both production and transmission infrastructure. The and downstream requirement of investment for natural gas is equally shared. The investments required to install this additional capacity for electricity would be Rs 35.2 trillion (US$ 0.6 trillion) accounting for 71% of the total investment. This includes all modes of electricity generation, viz., coal, nuclear, hydro, wind, biomass, and solar. The demand-side investment is the most critical component under low carbon scenario. These investments include advanced technologies to promote energy efficiency and fuel shifts.

Table 3: Investments needs (in Rs. billion) in Low Carbon Scenario

Type/Heads	Mining	Exploration and development	Refinery	Generation	Transmission and distribution	Liquefiction	Port develop-ment	Total*
Coal	1466 (94.8)						80 (5.2)	1547 (3.1)
Oil		1608 (22.0)	5702(78.0)					7311 (14.8)
Natural gas		1588 (51.0)			1230 (39.5)	296(9.5)		3114 (6.3)
Electricity				18746 (53.2)	16491 (46.8)			35236 (71.2)
Demand-side								2276 (4.6)

Note: * The values in parenthesis for this column give the share of investment of each type; the values in parenthesis for other columns give the share of investment of each head for a particular type.
Ref: Reddy and Nathan, 2010.

6.A POLICY FRAMEWORK FOR LOW CARBON ECONOMY

The Indian government has taken several policy measures with targeted financial provisions to boost low-carbon technology diffusion. A Clean Energy Fund was established with a tax of US$1 per tonne of coal to be used to fund research and innovative projects in low-carbon technologies. In addition, two schemes, viz., Renewable Energy Certificate and Renewable Purchase Obligation were launched resulting in increase in investment of 25% in 2012 (a total of US$ 4.5 billion) . However, investors are likely to focus on areas where there are clear and immediate paybacks despite the probability of higher returns over time. This is because of two reasons. The first is the unclear policies and policy frame-work which are still being developed. The second is the heavy focus on economic growth, which depends on the critical role of fossil fuels to power it. That is, access to energy and energy security is likely to be dominant considerations for policymakers (Venugopal and Srivastava, 2013). This has implications for the level of support that will be provided to low-carbon technologies.

6.1 Prioritizing supply efficiency

To reduce the un-predictability of supply, improved supply efficiency is essential since it eases the supply constraints by producing more output from the same input. At the same time, it reduces pollution by releasing less CO_2 for the same energy use. In the present study, two supply-side efficiency factors are identified to be critical for LC scenario—generation and T&D—both requiring technology improvements. Efficiency needs to be targeted as a policy-strategy. Due to shortage of funds, T&D loss investment gets low priority than new generation. Hence, it must be emphasized that new generation is incremental, whereas check on T&D loss can be universal gain, which can lessen generation need. T&D loss coupled with absence of accounting in certain cases has been identified as the critical cause of financial losses for the distribution companies and State Electricity Boards (SEBs) (Kumar and Chandra, 2008). Moreover, high T&D losses are unwarranted given the prevailing power deficit (overall requirement deficit 9.9% and the peak demand deficit 16.6%) (CEA, 2012). Since T&D loss is very high in certain atates (Bihar: 50%, Orissa and Madhya Pradesh: 40%), state-specific target can improve the overall efficiency.

6.2 Commercialization of renewable energy technologies

The energy efficient and renewable energy technologies will take two to three decades for diffusion to dominate the market. To diffuse quickly, the new (low-carbon) technologies need a bundle of desirable attributes which include: (i)*Technological Dynamism:* continued innovation, so costs fall/quality rises, (ii) *Innovational Complementarities:* users improve own technologies and find new uses. Also, technology developers should ensure that the technology (i) should be competitively priced, and (ii) should have appropriate carbon price. However, for the technology to successfully penetrate and change the consumer behaviour appropriately, there is an urgent need for policy interventions.

One of the important changes in LC scenario over baseline is the increased share of other renewable sources by two and half times in total energy demand. In India, the demand for LC technologies is uncertain in spite of their potential. This is because most of the renewable energy programs are carried out with policy objective of 'one-time demonstration' than 'commercialization' (Balachandra et al., 2010). A market infrastructure is needed for expansion, replication, and maintenance of renewable energy projects.

India is considered as one of the leaders in renewable energy field which includes biogas, solar, wind, small hydro power and other emerging technologies. Solar water heating, is virtually free from government subsidies and is considered the most successful renewable energy technologies (RET). Wind energy has achieved the highest penetration into the market among all RETs. The growth rate in capacity is 35% in the last three years, and most of it has come through commercialized projects and private investment. India has a strong technology and manufacturing base to produce wind turbines and blades indigenously and they are exported to both developed and developing countries. Small hydro projects are the next RET, which are attracting private sector participation; and most capacity addition is now being achieved through private investment. The state acts as a facilitator in terms of survey on project sites, renovation and modernization of old stations and development/up-gradation of water mills, customs duty and tax concessions. Solar PV is the next RET in the path of successful diffusion with a long list of private manufactures and enjoying financial subsidy from government. Biomass power is at pre-commercial stage with a capital subsidy of up to Rs. 80 million per project. Fiscal incentives like import duty concessions, excise duty exemption, tax holiday for 10 years, and in some cases preferential tariff are given for biomass and cogeneration power projects. Among the emerging RETs in demonstration stage Waste-to-Energy is apt and prominent. The projects related to this technology are government driven and heavily subsidized. Up to 50 percent of the capital cost is supported with interest subsidy. Financial incentives are given to state nodal agencies and urban local bodies to provide free garbage and land for waste-to-energy projects, for assessment, promotion, co-ordination, documentation, training and monitoring of projects. The other RET which is picking momentum is solar electricity and the others which are under exploration are hydrogen/fuel cell/battery-operated vehicles/biofuels and geothermal/tidal energy.

6.3 LC technologies—Skill development

Despite high unemployment rate, Indian companies are finding it difficult to source people with the required skills that a modern manufacturer needs. Much needs to be done to help companies get the skilled workers they need. Targeted collaboration between the public and private sectors is needed. In LC technology industry, the direct and indirect employment is in photovoltaic equipment production and manufacturing, raw material industries and other solar-power generation industries. We propose two ways in which businesses and government can collaborate to close this skills gap. The first is the collaboration between government authorities and business houses to develop industry-endorsed training programs that give graduates nationally recognized technological skills and provides skilled employees with a diploma certificate. Developed with industry input and support, these programs can give students an education that they can take with them wherever the job market leads them to. Secondly, we propose creating a nationwide, online skills database that would link students, colleges and employers. Both small and large companies would be encouraged to register on the site, listing the types of skills they need and, where appropriate, the partnership training they are offering or are willing to offer through local colleges. Colleges, meanwhile, would register the courses they offer and the areas in which they would be interested in partnering with businesses. Owned by the government and supported by subscription fees to participating companies this database could substantially ease the process of forming public–private skill partnerships and develop millions of skilled workers.

6.4 Demand side efficiency—Activities and Services

Energy efficiency in the residential involves the replacement of inefficient technologies with efficient ones and fuel switching from non-renewable to renewable technologies. In the residential sector, fuel shifts—from biomass fuels to gasous fuels (biogas and LPG), and technology shifts—replacement of existing inefficient devices with efficient ones (for cooking, lighting, water heating, etc.). With low-capital costs and high returns, efficiency measures hold out the promise of relatively low cost abatement that works directly to delink carbon from growth, the essence of a low-carbon economy. The efficiencies can be improved to as high as30 %, from the existing 10%, through improvements to stoves at negligible costs. Among the gasous fuels, biogas is an inherently renewable and environment-friendly source of energy that can make significant contribution to India's energy needs and also a shift to a low-carbon energy system (Reddy and Srinivas 2009). To realise the potential for biogas, we need to build a national gas grid to feed bio-methane into the grid. Similarly, there should be shift from inefficient IB to efficient CFL. Since 20% of the electricity use is from the household sector and 40% of household electricity use is for lighting, the shift will lead to a full transformation of the market. Reddy et al. (2010), mention of a saving of 64GWh simply by implementing cost-effective efficiency measures

In industrial sector, one example of fundamental savings that can be achieved is through technology shift —motors, pumps, fans, compressors and other machinery which are often based on highly inefficient designs. Motor systems account for almost two thirds of electricity consumption. Including Variable Speed Drives (VSDs) into the system will ensure that the pace of the motor matches the level at which the device needs to be operated at any given moment. By applying VSD into the design, the energy consumption of the motor can be reduced by 60 per cent (Reddy and Ray 2010).

Road transport accounts for about 50 per cent of petroleum product use and 25% of carbon emissions. Reducing emissions from transport has to be a key part of any effective strategy to shift to a low-carbon economy. Biofuels from Jatropa offer great opportunities in this direction. In addition, scope exists for blending biofuel with diesel. Along with biofuels, electric cars using batteries reduce petrol use significantly. Shifting from road to rail transport which needs a new high-speed rail network also will help. This is due to the increasing/saturating railway capacity and congested roads (Reddy and Balachandra 2012).

6.5 Infrastructure security

Security to energy infrastructure is important since it is vulnerable to physical disruptions, which could come from natural events like earthquakes, or from accidents. Any disruption in the infrastructure can have significant consequences for other sectors as it interconnects them through complex and inter-dependent network. Consequently, security must form an integral part of energy infrastructure policy.

In economic development, structural economic and social changes are intrinsic elements in achieving a LC economy which means that we need to develop policies that accelerate the existing structural changes. Pursuing an LC economy requires the reallocation of resources within and across broad economic sectors. In general, the largest declines in sectoral economic shares of output are found in fossil-based electricity and transport sectors. In most cases, the sectors which have gained the most are construction and services. Actually, the LC is a preferable and less risky future development path, which creates significant employment opportunities in various sectors (Levy, 2010),.

6.6 Required Mechanisms

6.6.1 Financial Mechanism

The greatest challenge the country faces in moving to a low-carbon economy is financing the upfront costs of technology investments and designing supportive policies and programs to overcome the barriers to regulatory, institutional, and market development. The typical characteristics of any energy infrastructure program are higher initial expenses which result in lower energy bills in the future. Higher spending by consumer inhibits the full realization potential of the infrastructure. For example, in India's rural electrification program, the whole effort to make electricity available to rural households goes in vain as the final connection to the household remains unaffordable to the villagers. This makes households to rely on kerosene for lighting, which is inefficient and causes indoor air pollution. It also defeats the purpose of kerosene subsidization. Models based on entrepreneurs, who act as middle layer between government and consumers, can help overcome this bottleneck. For some interventions, in particular, in energy efficiency, the initial investments are offset by savings in new generating capacity, resulting in “negative” investment cost differences when upstream effects are considered. Investment by the public sector will be critical, but financing will not have to come entirely from the government; there is considerable scope to involve the private sector in financing investments in energy efficiency.

6.6.2 Institutional mechanism

It is important to develop new institutions, enhance the capacity of the existing ones, and clubbing all to develop and implement LC policies and integrate them into existing processes rather than creating stand-alone policy agencies. The policies include macro and structural economic, energy and environmental, transport and infrastructure, and innovation. The political responsibilities for these policies should be divided between the Ministries of Energy and Finance, and a number of line ministries including Ministries of Environment and Forests.

An important policy action to drive LC technologies is interventions to overcome specific market failures, notably those linked to the dominance of existing technologies and firms. Thus, there is need to support private investment in innovation, notably R and D, support for RETs stimulation of the growth of new entrepreneurial firms, and the facilitation of the transition to LC in small- and medium-sized enterprises (SMES). Policies to foster green innovation should not only focus on the creation and supply of new technologies and innovation, but also on the diffusion and take up of green innovation in the market-place, including policies to foster diffusion, strengthen markets for green innovation and change consumer behaviour.

6.6.3 Market risks

Low-carbon market risks, including policy, technology, and operational risks which range from unexpected policy changes to technology failures can significantly affect low-carbon markets. If the market is new, then, public financing instruments like first-loss equity, debt investments and concessional loans can encourage investment. In mature markets like solar, wind, and energy efficiency, flexible loans, partial risk and credit guarantees, and risk sharing facilities will boost the investor confidence. Given the varied investment conditions in India what is required is a unique combination of finance and policy support to scale-up private sector investment.

7.CONCLUSIONS

Under the climate regime India's energy sector faces a difficult challenge. On one hand, the country needs to expand its energy base to sustain growth, make energy reach the deprived, while, on the other hand, energy course needs to follow an efficient and low-carbon path. In this paper, we tried to map these twin objectives through a sustainable development strategy. We have forecast future demand for different energy carriers under two scenarios: baseline and low carbon future (LC). The important factors influencing energy demand are GDP, population, urbanization, resource availability, and diversification of energy supply, efficiencies in generation, transmission and utilization, growth of vehicles and appliances, and modal shift in transportation. Through a mathematical model, the growth rates for different energy carriers are estimated and the demand projections are made.

There is a reduced growth rate for fossil fuels in LC scenario compared to baseline during the study period (2010–2030). Compounded annual growth rate for coal reduces from 4.2% to 2.1%, from 4.9% to 3.7% for oil, and from 6.8% to 5.0% for natural gas. There is an increased growth rate for nuclear and other renewables like solar, wind and small hydro. Overall, in LC scenario the average annual energy saving during the study period is estimated to be 129 MTOE, and the corresponding reduction in energy-induced CO_2 emission is 403 Mt.

The higher share of imports of fossil fuel in future necessitates improvement of import infrastructure. For power sector, the focus of infrastructure will be on modernization of plants and improvement of T&D efficiency. In the transportation front, infrastructure is needed for rapid mass transit systems and speedy promotion of alternative fuels like Compressed Natural Gas (CNG) and biofuels. In industrial sector, the improvement of energy efficiency in energy-intensive industries is the key. The infrastructure in commercial and residential sectors includes efficient buildings and the infrastructure to promote energy-efficient appliances like improved cooking stoves, CFLs and solar water heaters. There is a need to experiment and gain experience, especially in fostering skill development, developing new investment mechanisms and regulatory policies. One must note that one kg of coal available in nature loses 87.2% of its energy to reach as electricity to the consumer. So there is a need for introspection both by energy providers and consumers to use energy resources diligently.

Making effective and efficient investments by the government in the LC economy is a complex one. It requires weighing diverse criteria against one another, from emission reduction potential to macroeconomic impacts to social considerations. Understanding of issues involved, risk factors associated with heavy public expenditure, and the evaluation criteria that provide critical tradeoffs will be crucial in making public policy and investment decisions, and successfully building a low-carbon economy.

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