Working Paper 305

Low carbon pathways

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Abstract

India's climate debate encompasses issues other than just energy choices and energy efficiency. It is an integrated puzzle around lifestyle choices, the aspirations of 1.2 billion people, and informed actions on the water, air quality and climate fronts. In the wake of the upcoming COP-21 talks at Paris and the already announced US-China agreement on peaking of GHG emissions, India's approach to climate mitigation and adaptation is being keenly watched by people concerned with climate policy, all over the world. This paper outlines one such approach using the India Energy Security Scenarios-2047 tool of the NITI Aayog and explores India's emissions trajectory till the year 2047, if past trends continue, and the trajectory if low carbon energy choices are made. The paper also states the interventions in the demand and the supply sector which can make this transition feasible. Such a transition will not happen, however, without investments in technologies, programs and infrastructure, and an estimate of these investments is provided till the year 2047.

JEL Classification: *Q470, Q480.*

Key Words: *Low carbon pathway, Energy demand and supply, National policies, Energy efficiency*

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Low carbon pathways

Himanshu Gupta

1. Introduction

The NITI Aayog, (the erstwhile Planning Commission), rolled out an Integrated Energy Policy (IEP)[1] in 2006 that defines the concept of Energy Security for India as providing "lifeline energy to all its citizens irrespective of their ability to pay as well meet their demand for convenient energy for citizens to satisfy their various needs at competitive prices, at all times, considering shocks and disruptions that can be reasonably expected". It further talks about exploring options for achieving India's Energy Independence beyond 2050. The concept of Energy Security might seem to be about exploiting domestic resources maximally and delivering energy at the cheapest price to the consumer, but it is often described with the associated implications for food, air quality and water security: in short, sustainability. Because of global and local repercussions, a country cannot simply aim for high levels of growth based on fossil fuels alone. Local effects are a result of carbon intensive fuels used in transport, biomass incineration, etc. Particulate matter emissions from power plants located close to cities have worsened their air quality: Delhi already, is one of the lowest ranking cities in the world with respect to air quality, as per a recent World Health Organization[2] report.

Unabated emissions of CO_2 globally have given rise to fears that we might be on an irreversible path to a world where temperatures are poised to rise by four degrees above those at pre-industrialization level.[3] The effects of such a pathway are both gradual and inflectionary. While climate science is yet to understand completely the tipping points of global warming, the signs from recent events are not encouraging. Cyclone Hudhud resulted in damages of more than 11 billion dollars[4] to the economies of Andhra Pradesh and Orissa, the latter being the most mineral rich state in India. Gradual impacts have started to be felt already in the form of uneven monsoons, gradual rise in sea levels, and disturbing patterns of jet streams leading to polar vortices in the US. Adherence to the UNFCCC's 2 degree pledge will require substantial efforts, and contributions from all nations, OECD and non-OECD, will be crucial. These contributions will raise are issues relating to equity that will be debated in the relevant forums; it is imperative for India, a tropical country, to plan a growth trajectory, which is not only secure but sustainable, especially when 80% of our industrial production, 70% of our buildings stock and more than 80% of our vehicle fleet is yet to be

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1 http://planningcommission.nic.in/reports/genrep/rep_intengy.pdf
2 Ambient (outdoor) air pollution in cities database 2014, World Health Organization
3 http://www.rediff.com/business/slide-show/slide-show-1-special-most-polluting-countries-in-the-world-india-ranks-3/20130808.htm.
4 http://www.dnaindia.com/india/report-cyclone-hudhud-in-andhra-pradesh-and-odisha-caused-us-11-billion-worth-of-losses-united-nations-2064515

bought over the next three decades.[5] The choices we make today will determine our future over the next 3-4 decades.

It is in this context, that the NITI Aayog launched the India Energy Security Scenarios-2047[6] (IESS-2047); the aim was to explore the choices available for achieving energy security before 2047 (one hundred years of independence), and come out with a Max Energy Security pathway using the publicly available web interface. The present paper uses Version 2 of the tool to explore low carbon choices for India and goes on to calculate the cost implications of those low carbon choices. The tool has been recently put online for stakeholders' comments and reviews.

The paper is built upon assumptions around population growth taken from Scenario-B of the Population Foundation of India and, economic growth assumptions are taken from the IESS-2047, Version 2. The user activity demands consistent with those growth assumptions have been taken from the tool as well.

2. Assumptions

GDP: GDP is assumed to grow at a CAGR of 7.4% from the base year 2012-2047, growing at 6.8% from 2012-17, increasing to 8.1% between 2017-22 , peaking at 8.4% in the between 2037-42, and coming down to 5.8% during the terminal years, 2042-47, of the study.

Structure of the economy: In line with the PM's vision of creating 30 million jobs in the manufacturing sector, the share of manufacturing in the GDP will have to rise: the share of manufacturing increases to 34% in the study in the year 2047, from the present levels of 16%.

Urbanization: In line with UN projections and the rising per capita incomes of Indians, urbanization will increase to 51% in 2047 from the present level of 31%.

Households per capita: Occupancy of households is a function of urbanization, and, in turn, income levels. Urbanization patterns for Indian states have been determined using census data. Tamil Nadu is the most urbanized state in India with 49% urbanization in 2011, and 4.1 people per household. The same has been regressed with urbanization data to arrive at a household occupancy of 3.9 for India in the year 2047**. The base year occupancy rate is 5.1 per household for India.**

Activity demand in the economy:

India's economy is assumed to grow at 7.4% CAGR from 2012-47. The economic activity so generated will lead to a demand for energy as well. The amount of economic activity generated over the 35 years is shown in Table 2.1 below***:***

[5] http://niti.gov.in/content/india_energy.php
[6] http://indiaenergy.gov.in/

Table 2.1: Activity demand in the economy

Indicator	2102	2047
Per capita transport demand (pkm)	5,970	18,132
Per capita steel use (kg)	66	372
Per capita building space - residential (m^2)	10.8	39
Per capita building space-commercial (m^2)	0.6	5.9

Source: Author's calculations

The above level of economic activity will generate a large demand for energy four times that of base year levels as shown in the projections later. Fossil fuels cannot alone lead a secure and sustainable growth. Low carbon alternatives might seem expensive today but will bring benefits in the long term – even today, some low carbon technologies compete with conventional sources of energy. The price of electricity generated by wind turbines at some locations in India is comparable to that of electricity produced by gas turbines or imported coal based electricity. If we add the cost of externality of burning coal and petroleum, this price can compete even with domestic coal-based electricity. An analysis by the IMF, quoted by the New Climate Economy mentions $5-6/gigajoule as the externality cost for coal and $0.4-$0.6 per liter as the cost for diesel in India.[7]

In this context, future energy strategies for India in the long term cannot remain dependent on fossil fuels, which currently dominate the primary energy supply mix. For example, 46% of the primary energy supply required in 2011-12 was met by coal. This will grow to almost 50% in the decade of 2040, going by the reference scenario, which is close to the present policy scenario. This is a cause for concern for two reasons. Firstly, India does not have enough coal to meet this requirement; its coal production will peak during 2037-2042 at a level of 1170 million tons per annum going by the reference scenario of the IESS-2047. Secondly, coal is the biggest contributor to emissions, as it has the highest emission factor and maximum usage among the fossil fuels. India cannot afford to have such a high coal footprint in its electricity-producing, industrial processes, and other emery-consuming activities.

Our strategy for a sustainable and energy-secure future should focus on phasing out fossil fuels, by electrification and, in turn, supply that electricity from clean sources of energy, which are developed domestically. However, clean sources of energy such as bio-fuels, solar, wind, and even hydrogen are currently costlier and require risky investment decisions to be taken now, in order for them to scale in the medium term and compete with conventional sources of energy in the long term. Another approach towards a sustainable and secure energy future could be through the introduction of energy efficiency measures in all energy demand sectors such as agriculture, industry, and transport, and by cutting down energy consumption significantly. This strategy is also capital intensive, but yields results in the

[7] Brahmbhatt M and Kathuria R 2015. India: Pathways to Sustaining Rapid Development in a New Climate Economy: Conference Draft, http://newclimateeconomy.report/india/

short-to-medium time frame. Energy efficiency interventions, mitigate the risk of low carbon technology investments, many of which are not yet commercialized.

This paper aims to look at the reference scenario of the NITI Aayog using the publicly available IESS-2047 tool. With the help of experts and external consultation it will arrive at the baseline low carbon pathway and the costs of achieving it. The cost of not achieving the pathway has been analyzed separately in this report.

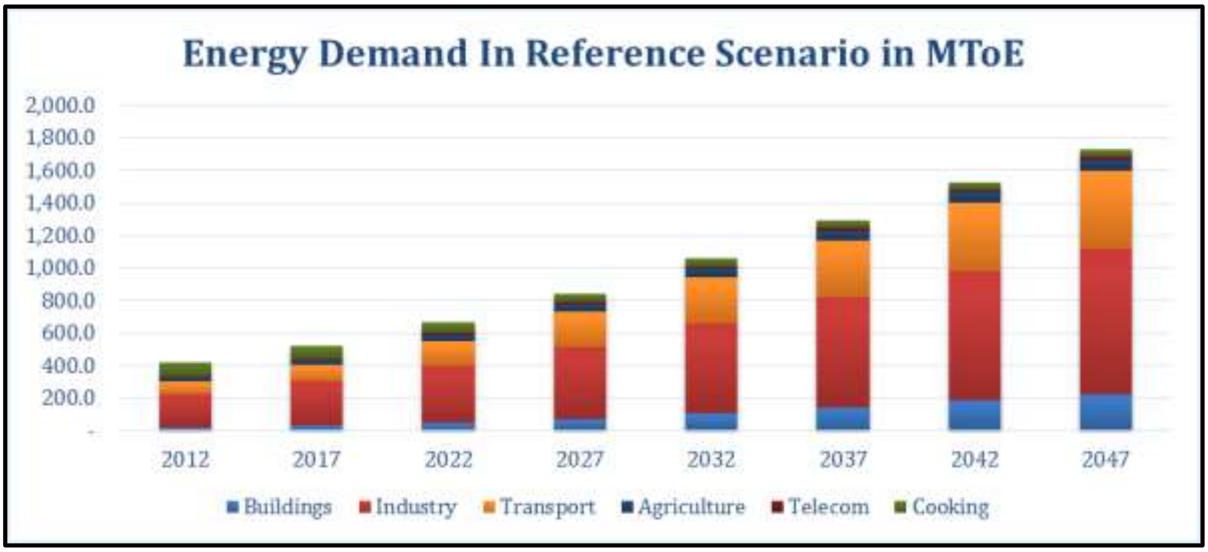
3. Reference Scenario

This pathway envisages a growth rate of 7.4%. The government is expected to implement policies dealing with demand, while the deployment of technologies relating to supply continue in line with past trends This pathway envisages a growth rate of 7.4%, with the population rising to 1.7 billion in the year 2047.

3.1 Demand

India's energy demand rises by a factor of 4 from the base level of 420 Mtoe in 2012, to 1725 Mtoe [Fig 3.1.1] in the year 2047. The per capita primary energy demand grows less than 3 times from 346 Kgoe (2012) to 1013 Kgoe (2047). Buildings and industry demands rise by a factor of 10 and 4.4 between the base year and 2047, respectively. The economy moves towards electricity as a fuel with electricity accounting for 19% of the primary energy supply in the year 2047, driven by moderate renewables deployment in the power sector to a level of 23% [Fig.3.1.1]. This scenario would also entail ramping up of liquid biofuel production in the country, to 11.6 MT [Fig 3.2.1]. Within the transport sector, in a reversal of trends, 15% people travel by rail rather than road (2047), as compared to 14% in 2012. Most of the demand in the buildings sector is fuelled by the rapid growth in housing both, in urban areas by rise in income levels leading to a more rapid increase in air conditioner demand, and in rural areas, by government programs such as housing access for all by the year 2022.

Fig 3.1.1: Composition of the Demand Sector in the reference scenario



3.2 Supply

The supply side equation for India's energy sector will still be dominated by coal with its share rising to 50% in the year 2047 from the base level of 47%, driven by huge demands for coal by power and industry sectors [Fig. 3.2.1]. The share of oil rises to 30% driven mainly by the transport sector. The share of electricity in the primary energy supply increases to 19% in 2047 from the present level of 15% [Fig.3.2.2]. Renewable penetration in the grid increases to 23% in the year 2047, requiring smart grid reforms and considerable investments in grid and balancing capacity to be able to absorb this. Consequently the total primary energy supply increases from 605 Mtoe to 2363 Mtoe in the year 2047.

Fig 3.2.1: Composition of the Supply Sector in the reference scenario

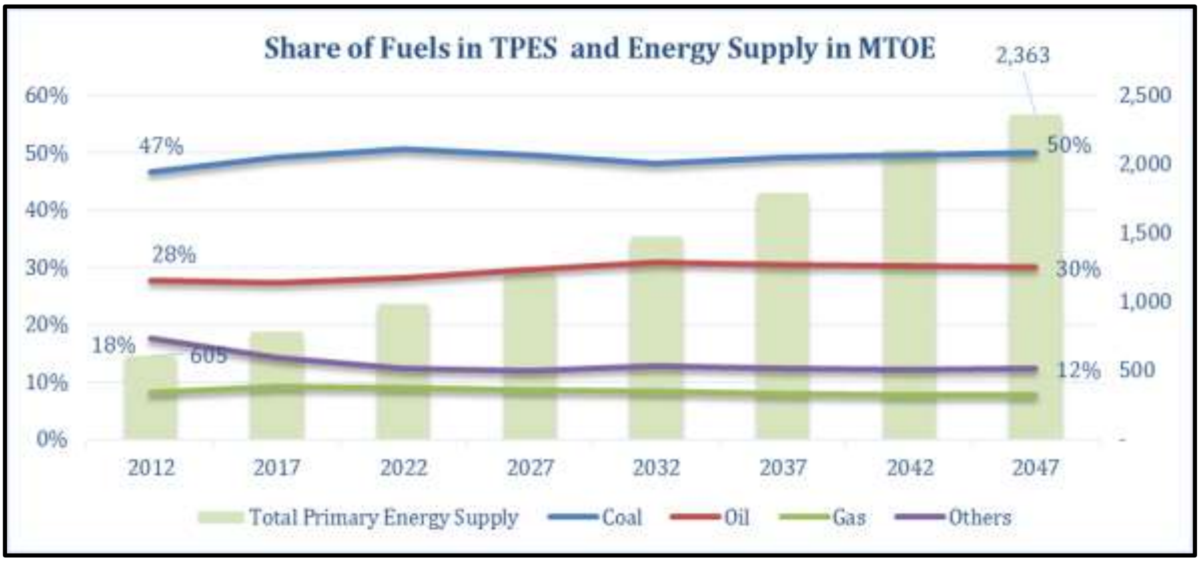
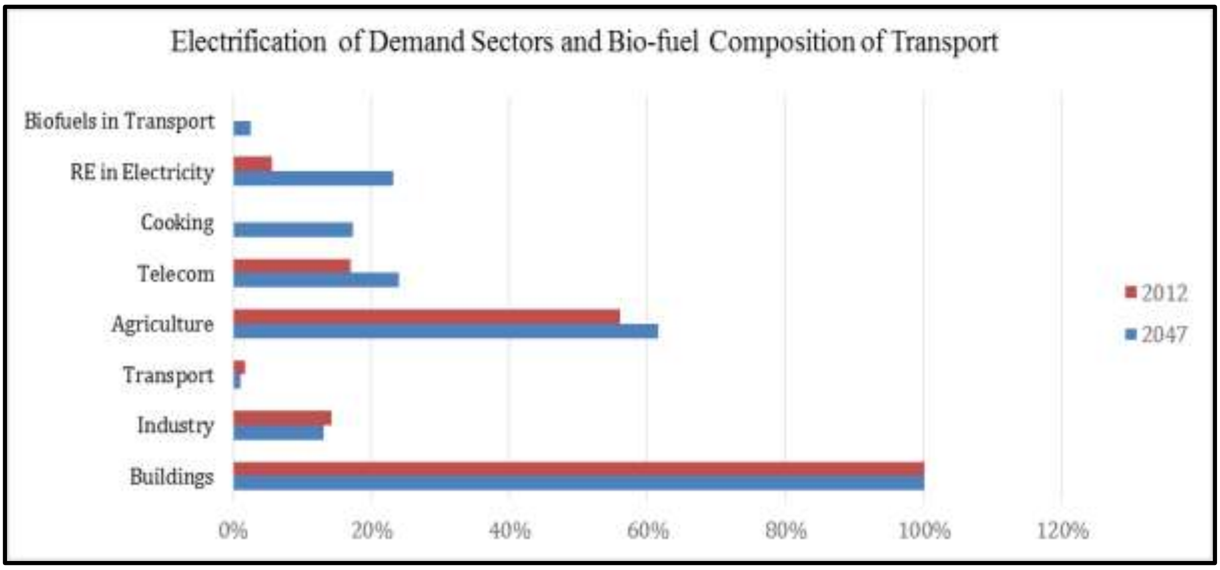


Fig 3.2.2: Electrification* of the demand sectors in the reference scenario



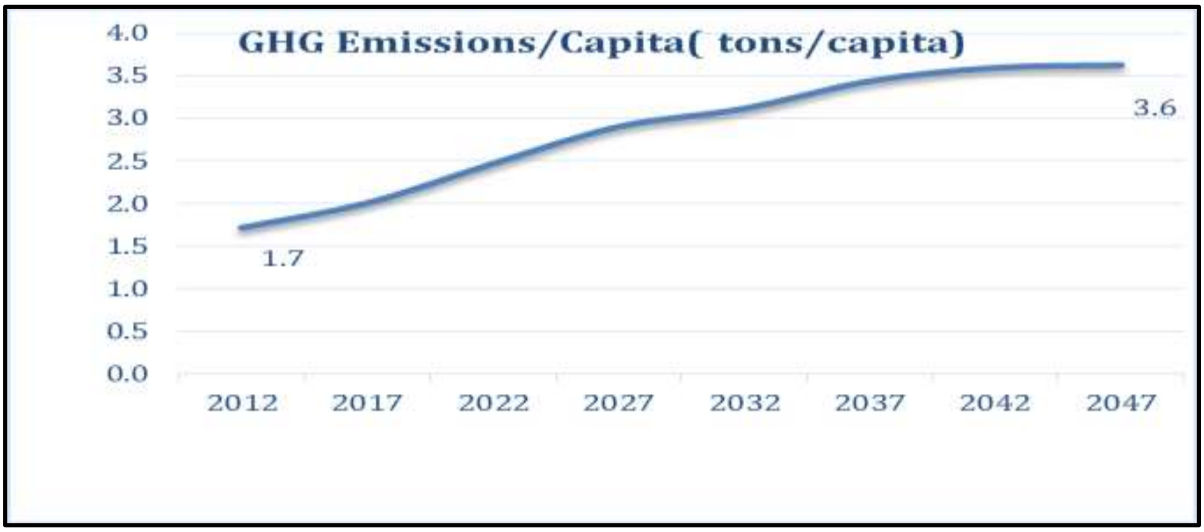
The definition of buildings in this case does not include the cooking sector and includes building envelope, insulation and appliances.

4. Low Carbon Pathways

As mentioned earlier, our strategy for a sustainable and an energy secure future should focus on phasing out fossil fuels from the demand sectors by electrification, and, generating that electricity using clean sources which are developed domestically. In such a scenario, the following demand and supply side interventions emerge. In choosing a low carbon pathway, the lifestyle requirements of Indians have not been moderated, therefore ownership patterns of Cars in Transport Sector, Buildings, Material Consumption, both remain the same. However, it is assumed that changes in the behaviour of consumers, penetration of clean technologies such as electric vehicles in the transport sector, and in the electricity sector will steer us towards the low carbon pathway by 2047.

In this pathway, every sector contributes to both energy security and environment sustainability. Due to heroic efforts, demand is reduced to the minimum possible in 2047. On the other hand, the supply has been calibrated so as to minimize emissions. GHG emissions rise moderately from 1.7 ton/capita to 3.6 tons/capita by 2047 (population assumed at 1.7 billion), in spite of a tripling in per capita energy supply [Fig.4.1]. Heroic efforts will also entail electrifying demand sectors to the maximum technical, economic and behavioural limit and supplying the electricity required using renewable sources. Also, Coal and Gas based thermal capacity additions are assumed to peak by 2032. Renewables are ramped up in order to meet the targets of 100 GW for solar and 65 GW for Wind as was also announced by the Prime Minister.[8] It is assumed that bio-fuels, second generation, advanced and algal based, will be ramped up by government support, and breakthroughs in commercialization to an extent of 110 MT of oil equivalent.

Fig 4.1: Emissions per capita in the Low Carbon Scenario

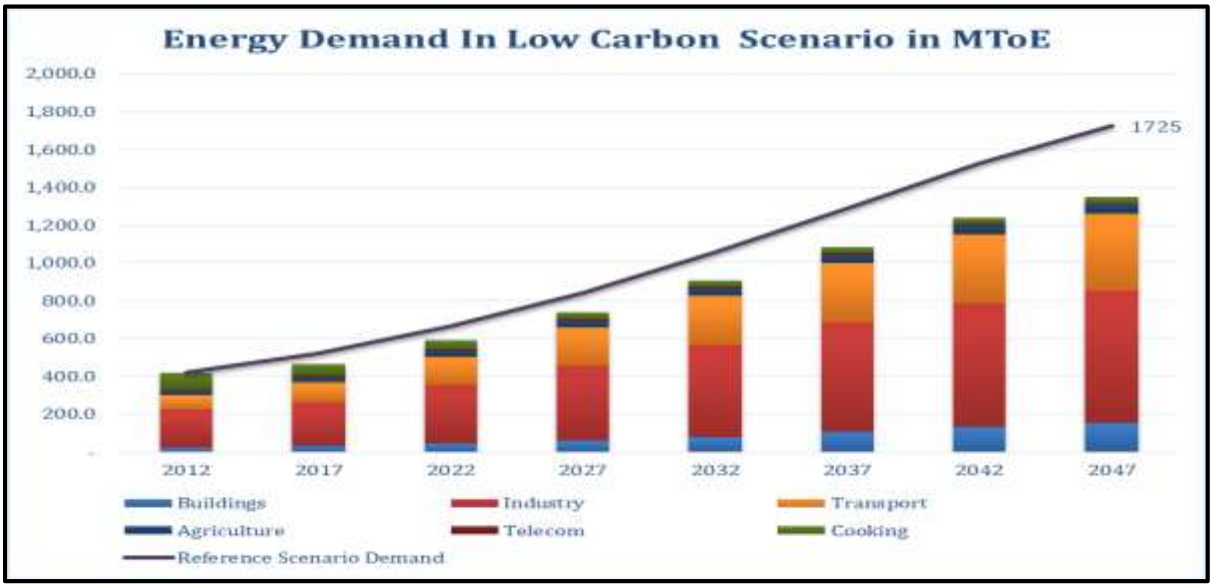


[8] http://pib.nic.in/newsite/PrintRelease.aspx?relid=122567

4.1 Demand

India's energy demand rises by a factor of 3 from the base level of 420 Mtoe in 2012 to 1347 Mtoe [Fig 4.1.1] in the year 2047. The per capita demand of energy rises by merely a factor of 2 from the present level of 346 Mtoe to 790 Mtoe in 2047. Demand from transport and industry increases by a factor of 6.9 and 3.4 respectively, in 2047 as compared to 4.4 in the reference scenario in both the cases. The share of electricity in the primary energy supply increases to 25% in the year 2047, due to electrification of the demand sectors sectors – industry, 22%, and cooking 26%, among others [Fig.4.1.2]. In the transport sector, in 2047, 80% of the two wheelers and 38% of the cars run on electric engine technology.

Fig 4.1.1: Composition of the Demand Sector in the low carbon scenario



On the supply side, the share of coal will come down to 34% in 2047, becoming similar to the share of other fuels (renewables, clean energy and bio-energy) in the system (fig. 4.1.2). The share of electricity in the primary energy supply will rise to 22% in 2047, and the share of renewables in the electricity grid would be 56% in the year 2047 (Fig. 4.1.3), the highest among all the scenarios. Solar and wind power completely satisfy the summer and monsoon afternoon peak (albeit some curtailment might become necessary). Grid balancing support in these seasons is mainly the capacity support (ramping, reserves, and other ancillary services). There has been a deal on an interconnecting grid between SAARC nations off-late. This, if it comes online, might offer additional leeway for excess generation through renewables and reduce the need for curtailment by an equivalent amount. Bio-fuels will meet 30% of the demand for liquid transport fuels (Fig. 4.1.3), which implies massive investments in the R&D of second generation and advanced bio-fuels. As a result, emissions would be lowest across all scenarios, with emissions per capita peaking at 3.6 tons. A comparative analysis of cumulative emissions in both the pathways – reference and low carbon is presented in Fig. 4.1.4.

Fig 4.1.2: Composition of the Supply Sector in the low carbon scenario

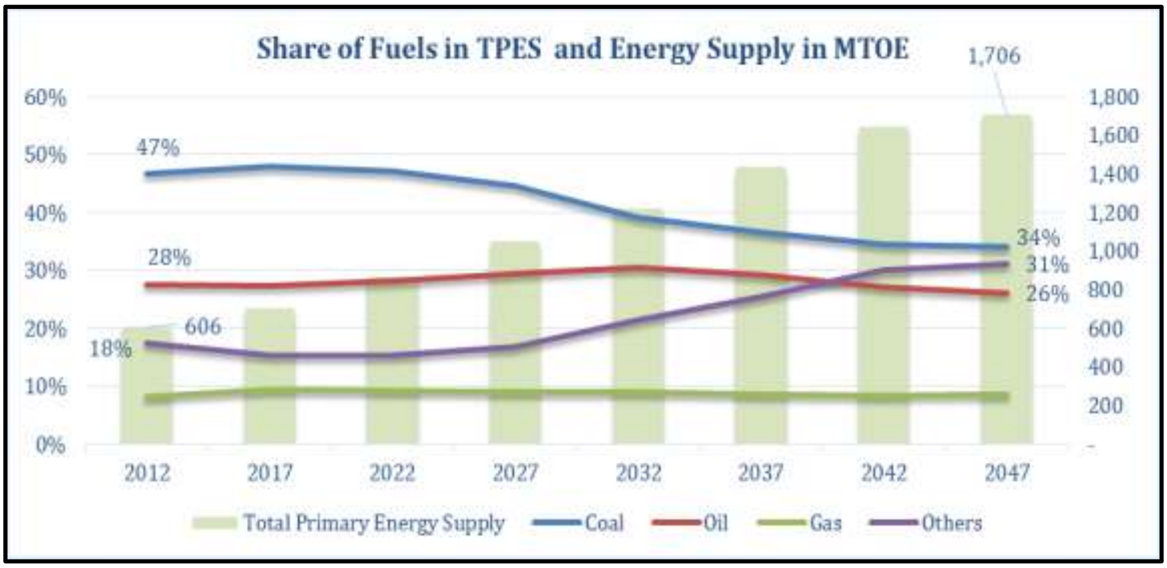


Fig 4.1.3: Electrification of the demand sectors and Bio-Fuel composition of the Transport in the Low Carbon scenario

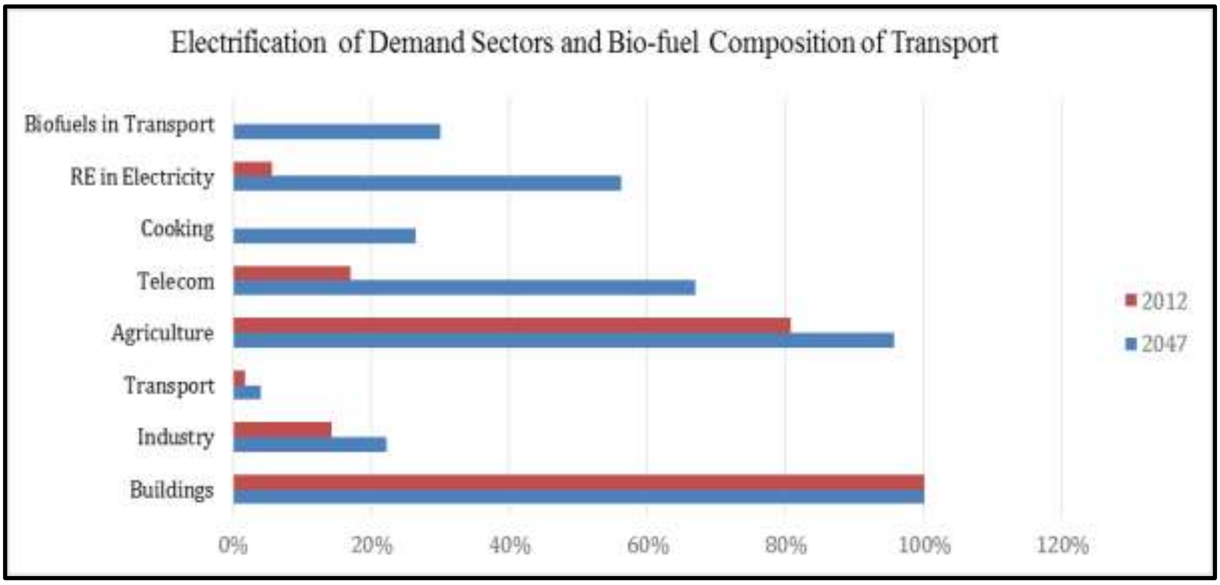
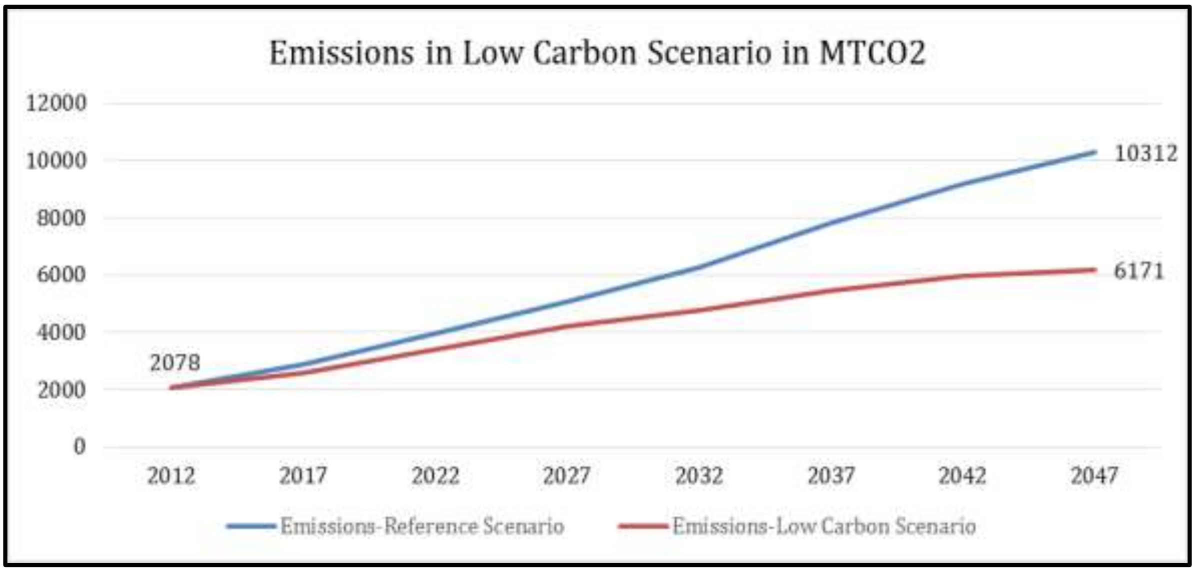


Fig 4.1.4: Emissions trajectory in ref and low carbon scenario



A first look at the graph clearly shows that emissions in the minimum emissions or low carbon pathway will be a notch higher than the anticipated target of 2 tons/capita as advocated by the UNFCCC for preventing a temperature rise beyond two degrees.. That said, there are equity issues associated with the fair allocation of carbon budgets based on historical cumulative emissions which are likely to be resolved in appropriate forums. The emissions analysis for the 2012-2047 period of the study,, doesn't take into account historic emissions. In any case, this transition would come at a huge cost to the economy. This paper tries to explore the feasibility of various low carbon choices and tries to estimate the cost of transitioning for India to a low carbon pathway. For the purposes of this paper we have taken into account the capital investments required in various demand sectors to realize energy efficiency. The paper refrains from exploring the mitigation potential of CCS as we do not believe that it will make a dent in industry scenario as projected by studies such as the IEA New Policy Scenario.

Table 4.1.4: Investments Cost of Low Carbon Interventions in Billions of Dollars (2012-47) over Reference scenario.

Sector	Investment Costs (USD Billion)	% Share in the overall investment costs
Buildings	308	15%
Transport	302	15%
Industry	157	8%
Bio Energy and Others	366	18%
Electricity	631	31%
Finance	266	13%
Total	**2030**	**0.7% of GDP(2012-47)**

Before interpreting the table, it is worthwhile to note that the investment costs have been annualized to calculate the cost of energy efficiency interventions in the demand sector. Each sector's costs include capital, and finance cost. Capital costs refer to the costs of electric vehicles, electric locomotives, and insulation in residential and commercial buildings, for example. The real investments costs will be even higher. Further, these costs are relative costs/ incremental costs as compared to those of the reference scenario. We have assumed constant real finance costs of around 4% for India between 2012-47, looking at the case studies of other developed countries and looking at the trajectory of the finance costs during their transition from medium per capita income countries to high per capita income countries. Some of the assumptions in calculating capital and operating costs might differ from those projected in the IESS-V2 put online for review, because expert opinion held that costs projected in the NITO Aayog's model might differ in sectors such as biofuels. Fuel savings have not been estimated for the pathway because of uncertainties in projecting their price in the short as well as long term. Recent movements in the prices of spot coal and oil are a reflection of the uncertainty in estimating prices even in the short term; in the long term, the uncertainty will be even higher, as European coal demand is flat and coal demand from China is likely to have peaked last year.[9] Moreover, these fossil fuel savings will be realized over a period beyond 2047. However, looking at India's development narratives, investments are required to be made now.

The table indicates that the low carbon pathway will cost $ 2030 billion for India during the period 2012-47, which is 0.7% of the GDP in the same period. These costs do not take into account the savings from reduced consumption of fossil fuels and benefits resulting from improved air quality and water savings. Close inspection reveals that almost 18% of the pathway costs will be incurred on bio-fuels, second generation and advanced. These technologies are still in the laboratory and significant investments will be required in R&D and their commercialization. 31% of the costs will be incurred on electricity, and the pathway talks about 55% penetration of renewable electricity into the grid. Costs in the transport sector are moderate compared to those in the other sectors, and are primarily incremental investments that will give momentum to Electric Vehicles and Fuel Cell Vehicles in the country to the desired levels of penetration. Cumulatively, these investments will amount to 0.7% of the cumulative GDP between 2012-47 at 2012 prices.

Conclusion

1. The climate debate for India encompasses issues other than just energy choices and energy efficiency. It is an integrated puzzle around lifestyle choices, aspirations of 1.2 billion people, and informed actions on the water, air quality and climate fronts. We have not dealt with air quality and water issues in this study and the conclusions are limited to impacts on emissions and energy demand/supply. Further, the study evaluates energy related emissions as outcomes. Land use and livestock related emissions were not modelled in this study

2. More than 90% of steel till 2047 is yet to be produced and more than 80% of our residential building stock is yet to be constructed giving us a window of opportunity to

[9] http://thinkprogress.org/climate/2015/05/27/3662681/chinas-coal-use-peaked/

make informed choices now. These choices will determine our future for the next 50 years taking into consideration the asset life of the infrastructure that needs to be created in order to meet these lifestyle choices.

3. In case of the reference scenario, the emissions rise from the base level of 2 GT to the 2047 level of 10.3 GT CO_2 equivalent, the current level of China's annual emissions. With heroic efforts around energy efficiency interventions in the demand sector and a shift to low carbon choices in the supply sector, these emissions could be limited to 6.1 GT in 2047. In evaluating these choices, we have kept the lifestyle ambitions of Indians constant across both the scenarios. As an example, ownership level of cars is not only an outcome of income levels, but also the society structure and culture issues, which cannot be modelled. Any interventions in those areas, and the likely response of Indians to those policy interventions have been kept outside the scope of this study.

4. The level of 6 GT is still higher than the envisaged levels of 2 GT, but any further effort to mitigate emissions to below 6 GT requires changes in lifestyle, changes in the way we consume materials and design buildings, which other studies have tried to model. Many equity issues are associated with the envisaged level of 2GT which needs to be resolved in the appropriate forums.

5. The investment cost of bringing down emissions to 6 GT is likely to be around 2.03 trillion dollars, 0.7% of GDP from the year 2012-2047. Within that, 31% of investments will need to be made in electricity sector, primarily in renewables, and 18% in the bio energy sector. The investments required in the demand sectors – transport, buildings and industry – are likely to be less than those in the supply sector: 15%, 15% and 8%, respectively. It may be noted that these costs should be used as indicative costs and their determination is highly uncertain.

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