Economic and Environmental Implications of India’s Renewable Energy Targets

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# **Abstract**

India was the first country in the world to set up a separate ministry focusing on identification, development and promotion of non-conventional energy resources. India is facing serious problems with respect to energy deficit and is heavily dependent on fossil fuels, especially coal (40%) followed by crude oil (28%) and natural gas (6%), for about 70% generation of electricity. With threats to energy security, adversities of climate change and rising import bill due to external dependency on fossil fuels, renewable energy offers a critical solution as a supplement to achieve energy self-sufficiency and India has laid out ambitious plan to expand its renewable and nuclear power sector. The main objective of this paper is to evaluate the implication of successful implementation of renewable energy targets set by India from emission perspective.

Under the 12th Five Year Plan, India has specified targets for the composition fuel mix by reducing non-renewable energy inputs and increasing renewable energy inputs. The paper will, firstly, begin by identifying the top sectors, which have major share in use of non-renewable energy inputs and emissions to air using Input-Output table and Emission table for 2009. Secondly, we will substitute the non-renewable energy coefficients with the renewable coefficients for the top most sector, which is heavily dependent on non-renewable energy inputs and analyze the impact on economy as a whole. Thirdly, we will assess the impact of substitution of fuels on emissions. Lastly, the paper will conclude by finding the impact on emission by changing total output as per growth projections in 12th Five Year Plan

**Keywords**

Energy efficiency, renewable energy, emissions, economic impacts

**JEL classification**

C67 Input-Output Models, Q43 - Energy and the Macroeconomy, Q42 - Alternative Energy Sources

# **Section 1**

# **Introduction and Background**

The purpose of this paper is to examine the effects of substitution of renewable energy inputs for non-renewable energy inputs on emissions to air, employment and national income. We focus our study on one of the fastest growing economies, India, as in the recent years India’s Energy Policy has been witnessing transformation in terms of use of energy inputs and gradual transition towards green and clean energy. In India, non-renewable energy inputs include coal, crude oil, natural gas, hydro power and nuclear power while renewable energy inputs include wind, small hydro, biomass, bagasse cogeneration, solar and waste.[[1]](#footnote-2)

**Status of Energy Sector in India**

India is heavily dependent on non-renewable energy inputs and except for Coal, the endowments of other non-renewable energy inputs is not adequate to meet the growing input demand. India’s growing dependence on external sources to meet energy input needs not just have a bearing on energy security but also means that extreme fluctuations in international prices can have an adverse impact on India’s trade balance and other macroeconomic indicators. India has energy deficit for decades, which is an additional burden for purchasing energy inputs from abroad.

Source: Energy Statistics 2015, Central Statistics Office, Government of India

The total production of energy from non-renewable sources increased by 3.28% CAGR over FY06 to FY14, however, the year on year growth has been decelerating since couple of years and was at (-)0.07% in FY14. The consumption demand has been growing steadily at 5.28% CAGR over same period and the year on year growth is declining but at a much slower pace compared to the trends in production. Primary reason for the rapid growth in the demand for electricity has been expansion of industrial and manufacturing sector along with rapid urbanization. Although the energy deficit during the peak season has come down from 10.6% in 2011-12 to 4.2% in 2013-14[[2]](#footnote-3), energy shortage still continues to be major bottleneck in the growth path. In order to reduce the demand-supply gap, massive addition to installed generation of capacity is needed to ensure energy security.

Make ‘Renewable Energy’ in India has been identified as a major thrust under the flagship programme of the newly elected National Democratic Alliance (NDA) government to achieve the objective of energy self-sufficiency, energy access and minimize emission intensity. There is huge untapped potential of renewable sources and government has plans to quadruple its renewable power capacity to 175 GW by 2022 to achieve the objective of uninterrupted power supply to every household.To achieve this target, capacity addition of 100 GW of solar power, 60 GW of wind energy, 10 GW of small hydro power, and 5 GW of biomass-based power projects is announced.

Source: Energy Statistics 2015, Central Statistics Office, Government of India

This paper is an attempt to provide more detailed perspective on impact on environmental emissions by substitution of renewable (green) fuel as per 12th Five Year Plan for the year 2012, 2017 and 2030 by using the World Input Output database (WIOD). We consider India’s Input Output table for 2009 as business-as-usual (BAU) case, which incorporates industry by industry table (Refer to Appendix 1.6-1.10 for consolidated results). Specifically, the study analyzes the following questions:

1. What is the total emission for each industry in terms of direct emission and which are the top rank industries?
2. For the top ranked industry, what is the breakup of fuel composition and share of each fuel in total emission?
3. What will be impact of changing fuel composition by reducing non-renewable energy input and increasing renewable energy input in the top ranked industry on total emissions and employment, assuming constant output?
4. After relaxing the assumption of constant output and projecting output as per the growth targets of 12th Five Year Plan, what will be impact on total emissions as a result of fuel substitution by reducing non-renewable energy input and increasing renewable energy input?

The plan of the paper is as follows:

Section 2 will briefly survey the literature on the work related to energy environment especially on emissions under the Input-Output Framework. Section 3 will discuss the methodology adopted and database sources used for building the model. Results are presented in Section 4 and Section 5 will present the conclusion briefly.

# **Section 2**

# **Survey of Literature**

The work on energy environment has been vast and exhaustive. We have focused primarily on studies related to energy and environmental issues under the Input-Output framework in the Indian context presented by some of the renowned economists [Parikh and Gokarn (1993), Singh (1994), Mukhopadhyay and Chakraborty (1999, 2000), Mukhopadhyay (2002, 2002a, 2012), Murthy Panda and Parikh (1997)].

The study by Das and Sarkar (1994) focused on understanding not only the substitution of non-renewable by renewable resources but also on measures industries should adopt for conservation. The Input-Output data from 1973-74 to 1983-84 was considered to examine the structural changes by aggregating the sectors into renewable, non-renewable and other resource to form a 27-sector table.

From the environmental perspective, the concern of Green House Gas (GHG) emission affecting the climate change, especially Carbon Dioxide (CO2) emissions due to use of fossil fuels has been one of the widely discussed issues. India does not have the responsibility of reducing emissions below the current values as per the United Nations Framework Convention on Climate Change (UNFCCC) Rio Summit 1992 but as a signatory of UNFCCC, India is working towards bringing down the growth of emissions. Many studies have been presented to measure the CO2 emissions sector-wise and measures are suggested for reducing emissions without compromising the growth.

Parikh and Gokarn (1993) were one among the few to attempt estimation of emissions from different sectors for 1983-84. Murthy, Panda and Parikh (1997) later developed linkages between economic growth, energy consumption and CO2 emissions in India on the basis of consumption patterns of six different income groups using Input-Output table for 1989-90. Mukhopadhyay and Forsell (2005) estimated the trend of CO2, SO2 and NOX emission between 1973-74, 1983-84, 1991-92 and 1996-97 and estimated the emissions for 2001-02 and 2006-07. The paper also presented linkage between emission and impact on human health.

A more recent study by Parikh J et al. (2009) on CO2 emissions in India by fuel, sector, final demand and expenditure classes for year 2003-04 concluded that most of the emissions are due to use of coal and lignite in production processes and highest direct emissions are due to electricity sector. It also analyzed the impact of lifestyle patterns on emissions.

All these studies are useful, by far very few have analyzed the substitution of fuel inputs and its impact on emissions, especially using the World Input Output Database, without deviating much from the high economic growth trajectory. The present study is directed toward this end.

# **Section 3**

# **Model Formulation& Data Sources**

***Model Formulation***

In the present study, a model is based on basic input-output framework of Leontief (1951). The Input-Output frameworks provides snapshot of the direct and indirect demands of various inputs for producing different outputs by different sectors of the economy. The supply of a commodity both domestically produced and imported and the demand for a commodity for inter industry transfers and for final demand are presented in a consistent manner in the Input Output tables. Thus, it is convenient to compare results across countries and over various years using this methodology.

The mathematical structure of the input-output model can be expressed as follows:

Here, is a vector of outputs of industries in the economy. is a final demand vector of industries.is the technical coefficient matrix, which is a ratio of input from sector to sector as. Technical coefficient matrix shows the interdependencies among output of industries.

And the solution for is given by:

Here, is an identity matrix and is the matrix of total input requirements or Leontief Inverse Equation (2) is also written as,

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The Input-Output table provides data in monetary terms and for this study, we use generalized input-output model by augmenting the technical coefficient matrix to reflect the impact of pollution emissions and employment (Miller and Blair 1985).

To do the accounting of pollution emission, the matrix of pollution output or direct impact coefficients , which gives the amount of pollutant type generated per dollars’ worth of industry output, can be calculated as follows:

Level of pollution associated with a given vector of total outputs is denoted by and can be expressed as,

Here, is the matrix of total environmental impact coefficient, which gives the total impact of pollution per dollar worth of final demand.

Similarly, we analyze the impact of employment with the matrix of employment impact, which is given by, where gives the number of labor in physical or value of labor input in monetary units required per dollar worth of industry’s output for each industry.

***Data Sources***

For this analysis, we make use of World Input Output Database (WIOD). We use National Input Output table for Indian Economy for the year 2009, which is a industry by industry table expressed in USD millions.

To calculate and assess the impact of fuel substitution on pollution emission, WIOD Emission to Air data expressed in tonnes for each industry is used. Industry-wise fuel composition and CO2 emission by each fuel for each industry is presented in WIOD CO2 Emission Accounts.

To assess the impact of fuel substitution on employment, data on employment in each industry is given in WIOD Socio-economic accounts. (Refer to Appendix1.1-1.3 for components of each table)

Future projections of change in fuel composition needed for carrying out appropriate substitutions are taken from 12th Five Year Plan developed by the Planning Commission of India for the year 2012, 2017 and 2030.(Refer to Appendix1.4-1.5 for 12th Plan targets of fuel structure and fuel substitution table used in the model)

It is convenient to use WIOD tables than Central Statistical Organization (CSO) tables because WIOD publishes data on both emissions and employment, which otherwise we would have had to calculate separately. It would be interesting to make an assessment and comparative study on both these tables; however, it would require a separate study and hence, we refrain from doing so in this paper.

# **Section 4**

# **Results & Discussions**

In Section 4.1, we begin by considering WIOD National Input Output table for Indian Economy for 2009 as BAU case and calculate the total emissions for each industry in order to rank the industries to arrive at one industry with highest emission. Further, we assess the fuel composition of this industry and calculate share of each fuel in total emission in Section 4.2. On the basis of ranking of industries in Section 4.1, we take the most relevant industry with the lowest share in total emission as a proxy for renewable energy input.We then make a case for substituting non-renewable energy inputs for renewable energy inputs to assess the impact on emission and employment, keeping output constant in Section 4.3. Lastly, in Section 4.4, we relax the assumption of constant output by changing the output according to growth targets projected in the 12th Five Year Plan and assess the impact on emissions and employment of fuel substitution.

***Section 4.1 Total emissions for each industry***

Direct emissions show how much the emissions are for each industry because of the inputs used in production process. Direct emissions are calculated by multiplying total output by emissions per unit of output for industry.Indirect emissions show how much the emissions occur in production of each input, which is later used in production of each industry’s output. Total Emissions are calculated by multiplying direct and indirect emissions by corresponding final demand.

|  |  |  |
| --- | --- | --- |
| **Table 4.1 Industry-wise CO2 Emissions and share in total emissions** | | |
| Industry | CO2 emissions in Gg (kt) per USD million | Share in total emissions$ |
| **Electricity, Gas and Water Supply** | **16,403** | 28.7% |
| Other Non-Metallic Mineral | 4,564 | 8.1% |
| Mining and Quarrying | 3,218 | 5.8% |
| Basic Metals and Fabricated Metal | 2,845 | 5.1% |
| Water Transport | 2,407 | 4.3% |
| Wood and Products of Wood and Cork | 1,811 | 3.3% |
| Pulp, Paper, Paper , Printing and Publishing | 1,780 | 3.3% |
| Chemicals and Chemical Products | 1,674 | 3.1% |
| Coke, Refined Petroleum and Nuclear Fuel | 1,559 | 3.1% |
| Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies | 1,528 | 2.8% |
| Rubber and Plastics | 1,407 | 2.6% |
| Transport Equipment | 1,369 | 2.5% |
| Construction | 1,339 | 2.5% |
| Air Transport | 1,286 | 2.4% |
| Machinery, Nec | 1,268 | 2.4% |
| Food, Beverages and Tobacco | 1,248 | 2.4% |
| Textiles and Textile Products | 1,207 | 2.3% |
| Electrical and Optical Equipment | 1,096 | 2.1% |
| Hotels and Restaurants | 1,047 | 2.0% |
| Inland Transport | 1,030 | 2.0% |
| Post and Telecommunications | 771 | 1.5% |
| Leather, Leather and Footwear | 675 | 1.3% |
| Agriculture, Hunting, Forestry and Fishing | 494 | 1.1% |
| Health and Social Work | 389 | 0.8% |
| Manufacturing, Nec; Recycling | 354 | 0.8% |
| Renting of M&Eq and Other Business Activities | 305 | 0.7% |
| Financial Intermediation | 239 | 0.5% |
| Other Community, Social and Personal Services | 191 | 0.5% |
| Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel | 146 | 0.4% |
| Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods | 139 | 0.4% |
| Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles | 118 | 0.3% |
| Education | 111 | 0.3% |
| Real Estate Activities | 99 | 0.3% |
| Private Households with Employed Persons | 72 | 0.2% |
| Public Admin and Defence; Compulsory Social Security | 10 | 0.1% |
| Extra-territorial organizations and bodies | 0 | 0.0% |

Author’s Calculation

$Total Emissions include Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Nitrogen Oxides (NOx), Sulphur Oxides (SOx), Carbon Monoxide (CO), Non methane volatile organic compounds (NMVOC) and ammonia (NH3)

From the Table 4.1, Agriculture, Hunting, Forestry and Fishing sector’s share in total emission is very low and hence, we use of this sector as a relevant proxy for renewable energy input. On the other hand, Electricity, Gas and Water Supply sector’s share in total emission is the highest and therefore, it would be worthwhile so analyze the fuel components of this industry and the share of each fuel in emission.

***Section 4.2 Fuel composition and contribution of each fuel to total emission***

We use WIOD CO2 emission table to calculate the share of each fuel in total emission for Electricity, Gas and Water Supply Sector as it is the he highest emission industry.Coal (HCOAL)and lignite (BCOAL) together are the highest contributors to emissions (92%), followed by natural gas (NATGAS) with 5% share in total emission and contributions by other fuels like fuel oil, other petroleum products, naphtha, diesel, etc. is extremely small. Table 4.2 below, gives the breakup of fuel contribution as a percentage of total emission for Electricity, Gas and Water Supply Sector.

|  |  |  |
| --- | --- | --- |
| **Table 4.2 Fuel break up and share in total emissions for Electricity, Gas and Water Supply Sector** | | |
| Electricity, Gas and Water Supply | CO2 emissions in Gg (kt) | Share in total Emission |
| HCOALa | 724,210 | 89.01% |
| NATGAS | 41,540 | 5.11% |
| BCOALb | 27,187 | 3.34% |
| LFOc | 13,114 | 1.61% |
| HFOd | 4,493 | 0.55% |
| NAPHTA | 2,785 | 0.34% |
| DIESEL | 123 | 0.02% |
| NonENERGY | 92 | 0.01% |
| OTHPETROe | 53 | 0.01% |
| GASOLINE | 13 | 0.00% |
| TOTAL | 813,610 |  |

Author’s Calculation

aHCoal is called as Hard Coal and derivatives;bBCOAL is Lignite and derivative; cLFO is Light Fuel oil; dHFO is Heavy Fuel oil; eOTHPETRO is Other petroleum products (Bitumen, Ethane, LPG, Lubricant)

According to United States Energy Information Administration, India ranks sixth in production of Electricity using renewable energy inputs. Electricity, Gas and Water Supply sector due to use of non-renewable energy inputs have high emissions (~30% CO2 Emission), which is not compensated by substantially higher share in the total output (3%). In contrast, use of renewable energy inputs is more beneficial from environmental perspective. To support this argument, we observe that Agriculture, Hunting, Forestry and Fishing sector (proxy for renewable energy inputs) has low emissions (1% CO2 Emission) along high share in total output (11%).

***Section 4.3 Substitution of fuel-mix as per 12th Five Year Plan***

The Total Output is calculated in USD millions, Emission Coefficientin Kilotonnes per USD million and Employment Coefficient in 1000 per USD million and the results are compared under the following two scenarios over the span of three years viz., 2012, 2017 and 2030.

***Scenario 1- Changing only renewable energy input with non-renewable energy input and output constant***

In this scenario, first we will only change the input composition of renewable energy inputs, keeping constant non-renewable energy input component and total output. There is no change in the emissions as the share of Agriculture, Hunting, Forestry and Fishing in total emissions is very low (1.1%). Following table shows how the substitution of only renewable energy inputs is carried out:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 4.3 Scenario 1.1Substitutions as per 12th Five Year Plan (%)** | | | | |
| **Industry** | **2012** | **2017** | **2030** |  |
| Agriculture, Hunting, Forestry and Fishing | 6 | 9 | 16 | ↑ |

Result of this exercise is as follows, showing no change from the BAU case as highest emission inputs are held constant and output is kept constant reflecting no change as a result of substitution:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4.4 Scenario 1.1 Changing only renewable energy input with all non-renewable energy input constant** | | | | | | |
| **Year** | **Emissions#** | **% change** | **Employment^** | **% change** | **Output\*** | **% change** |
| 2009BAU | 56.01 | NA | 5.6245 | NA | 2,590,618 | NA |
| 2012 | 56.01 | 0% | 5.6245 | 0% | 2,590,618 | 0% |
| 2017 | 56.01 | 0% | 5.6245 | 0% | 2,590,618 | 0% |
| 2030 | 56.01 | 0% | 5.6246 | 0% | 2,590,618 | 0% |

\* (millions of US$); #amount of pollutant (Kilotonnes); ^ Number of employees (thousands)

Since our objective is to see the impact of substitution of fuels on emission, we will change the input composition only of renewable energy inputs to maintain constant output by keeping constant non-renewable energy input component of coke, refined petroleum and nuclear fuel. The table below shows the fuel composition used in this scenario:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 4.5 Scenario 1.2 Substitutions as per 12th Five Year Plan (%)** | | | | |
| **Industry** | **2012** | **2017** | **2030** |  |
| Electricity, Gas and Water Supply | 21 | 17 | 14 | ↓ |
| Agriculture, Hunting, Forestry and Fishing | 6 | 9 | 16 | ↑ |

The exercise shows that there is negligible decline in for 2017 and 2030 as compared to BAU case 2009. The share of Electricity, Gas and Water Supply industry in the total employment is very low (0.6%) and the reduction in employment in 2012 (-0.3%) is not likely to impact drastically in the long run, which is supported by negligible reduction in employment in 2017 and 2030. Following are the results, which supports this observation:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4.6 Scenario 1.2 Changing only renewable energy input with coke, refined petroleum and nuclear fuel input constant** | | | | | | |
| **Year** | **Emissions#** | **% change** | **Employment^** | **% change** | **Output\*** | **% change** |
| 2009BAU | 56.01 | NA | 5.6245 | NA | 2,590,618 | NA |
| 2012 | 50.24 | -10.3% | 5.6057 | -0.3% | 2,590,618 | 0.0% |
| 2017 | 49.23 | -2.0% | 5.6024 | -0.1% | 2,590,618 | 0.0% |
| 2030 | 49.06 | -0.3% | 5.6019 | -0.01% | 2,590,618 | 0.0% |

\* (millions of US$); #amount of pollutant (Kilotonnes); ^ Number of employees (thousands)

In this scenario, there is steep decline in emissions in the first year (2012) and later the decline is moderated. Hence, it is clear that increasing use of only renewable energy input in Electricity, Gas and Water Supply industry is not sufficient to reduce emission. There is a need to simultaneously reduce inputs of non-renewable energy input including coke, refined petroleum and nuclear fuel industry in order to see the impact on emissions in a broader sense.

***Scenario 2-Changing both renewable energy input and non-renewable energy input with output constant***

In this scenario, we increase renewable energy inputs and reduce all the non-renewable energy inputs viz., inputs of Electricity, Gas and Water Supply industry and Coke, Refined petroleum and Nuclear fuel industry. The table below gives how the input substitution changes according to 12th five year plan targets:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 4.7 Scenario 2 Substitutions as per 12th Five Year Plan (%)** | | | | |
| **Industry** | **2012** | **2017** | **2030** |  |
| Coke, Refined Petroleum and Nuclear Fuel | 73 | 74 | 70 | ↓ |
| Electricity, Gas and Water Supply | 21 | 17 | 14 | ↓ |
| Agriculture, Hunting, Forestry and Fishing | 6 | 9 | 16 | ↑ |

For Coke, Refined Petroleum and Nuclear Fuel sector, the input substitution increases in 2017 and decreases again in 2030, this is mainly because of higher contribution from nuclear fuel in generation. In Table 4.6, there is no change in output over three years as we are keeping output constant by adjusting final demand vector.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4.8 Scenario 2 Changing renewable energy input and non-renewable energy input with output constant** | | | | | | |
| **Year** | **Emissions#** | **% change** | **Employment^** | **% change** | **Output\*** | **% change** |
| 2009BAU | 56.01 | NA | 5.6245 | NA | 2,590,618 | NA |
| 2012 | 50.16 | -10.4% | 5.6037 | -0.4% | 2,590,618 | 0.0% |
| 2017 | 49.09 | -2.1% | 5.5992 | -0.1% | 2,590,618 | 0.0% |
| 2030 | 48.88 | -0.4% | 5.5975 | -0.03% | 2,590,618 | 0.00% |

\* (millions of US$); #amount of pollutant (Kilotonnes); ^ Number of employees (thousands)

As compared to the result in Scenario 1, the result of this exercise does not deviate drastically. The emissions are declining at same rate and change in employment is not very significant. Hence, the substitution of fuel inputs exercise has a positive impact on bringing down the level of emissions. So far, we have assumed that the output remains constant; however, in reality output is not constant. It is, therefore, essential to see how the emissions are affected by substitution of fuel inputs with variable output. In next section, we will use growth targets projected in the 12th five year plan to see the effect on variable output.

***Section 4.4 Impact on Emission without compromising on growth***

In the earlier scenarios, the output growth is constant. For an emerging country like India, output growth is dynamic and the assumption of constant output is far from reality. The substitution of renewable energy input for non-renewable energy input at the cost of compromising high growth prospect is not beneficial for a potential fastest growing economy. Hence, taking into consideration actual output growth of 6.2%[[3]](#footnote-4) in 2012 and the Planning Commission targets for 2017 at 8.2% and 2030 at 9%, we scale up the final demand vector of the respective years accordingly. By relaxing the assumption of constant output, following are the results for this exercise:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4.9 Changing renewable and non-renewable energy input with output changed as per 12th Plan targets** | | | | | | |
| **Year** | **Emissions#** | **% change** | **Employment^** | **% change** | **Output\*** | **% change** |
| 2009BAU | 56.01 | NA | 5.6245 | NA | 2,590,618 | NA |
| 2012 | 52.73 | -5.8% | 5.2976 | -5.8% | 2,729,305 | 5.4% |
| 2017 | 48.73 | -7.6% | 4.8964 | -7.6% | 2,947,631 | 8.0% |
| 2030 | 44.70 | -8.3% | 4.4923 | -8.3% | 3,210,506 | 8.9% |

\* (millions of US$); #amount of pollutant (Kilotonnes); ^ Number of employees (thousands)

From the Table 4.9, it is observed that the emissions are declining at more or less same rate at which the output is rising. In addition to this, the employment is also declining at the same rate as the decline in emissions. Therefore, it means that there seems to be a linkage between the emission impact and employment impact.

# **Section 5**

# **Concluding Remarks**

To conclude briefly:

1. Keeping in perspective high growth targets set in the 12th five year plan, India’s growth policy should take into account environmental impacts of using excessive non-renewable energy inputs to achieve energy self-sufficiency by adding additional capacity. An appropriate linkage should be established between environmental balance, resource utilization and economic growth while formulating both growth and energy policy. Therefore, it is essential to set the fuel substitution target’s to maintain high growth with low emissions.
2. The share of electricity sector’s output in total output is 2.51% but the share of emission is 29.58% as a result of this, even though the substitution of fuel mix reduces the output of electricity sector, the overall impact on the total output is negligible.
3. With the changes in fuel substitution, there is an impact not only on the sector output and emission levels but also on the level of employment. Hence, it is essential to consider the linkage between the fuel substitution and level of employment while formulating the policy. There is a need to assess the changes in level of employment in order to take appropriate measures to ensure absorption of excess labor generated, if any, as a result of fuel substitution.

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# **Appendix**

WIOD National Input Output table

|  |  |  |  |
| --- | --- | --- | --- |
| **A1.1 National Input Output table- 35 Industries classification** | | | |
| c1 | Agriculture, Hunting, Forestry and Fishing | c19 | Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel |
| c2 | Mining and Quarrying |
| c3 | Food, Beverages and Tobacco | c20 | Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles |
| c4 | Textiles and Textile Products | c21 | Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods |
| c5 | Leather, Leather and Footwear | c22 | Hotels and Restaurants |
| c6 | Wood and Products of Wood and Cork | c23 | Inland Transport |
| c7 | Pulp, Paper, Paper , Printing and Publishing | c24 | Water Transport |
| c8 | Coke, Refined Petroleum and Nuclear Fuel | c25 | Air Transport |
| c9 | Chemicals and Chemical Products | c26 | Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies |
| c10 | Rubber and Plastics | c27 | Post and Telecommunications |
| c11 | Other Non-Metallic Mineral | c28 | Financial Intermediation |
| c12 | Basic Metals and Fabricated Metal | c29 | Real Estate Activities |
| c13 | Machinery, Nec | c30 | Renting of M&Eq and Other Business Activities |
| c14 | Electrical and Optical Equipment | c31 | Public Admin and Defence; Compulsory Social Security |
| c15 | Transport Equipment | c32 | Education |
| c16 | Manufacturing, Nec; Recycling | c33 | Health and Social Work |
| c17 | Electricity, Gas and Water Supply | c34 | Other Community, Social and Personal Services |
| c18 | Construction | c35 | Private Households with Employed Persons |

WIOD Emission to Air table

|  |
| --- |
| **A1.2Variables in WIOD Emission to Air Table for each Industry** |
| Emissions of CO2 (carbon dioxide) in Gg (kilotonnes) |
| Emissions of CH4 (methane) in tonnes |
| Emissions of N2O (nitrous oxide) in tonnes |
| Emissions of NOx (nitrogen oxides) in tonnes |
| Emissions of SOx (sulphur oxides) in tonnes |
| Emissions of CO (carbon monoxide) in tonnes |
| Emissions of NMVOC (non-methane volatile organic compounds) in tonnes |
| Emissions of NH3 (ammonia) in tonnes |

WIOD CO2 Emission data table

|  |  |  |  |
| --- | --- | --- | --- |
| **A1.3Fuel Input Components in WIOD CO2 Emission Table for each Industry** | | | |
| HCOAL | Hard coal and derivatives | WASTE | Industrial and Municipal Waste |
| BCOAL | Lignite and derivatives | BIOGASOL | Biogasoline |
| COKE | Coke | BIODIESEL | Biodiesel |
| CRUDE | NGL and feedstocks | BIOGAS | Biogasoline |
| DIESEL | Diesel oil for road transport | OTHRENEW | Other Combustible renewables |
| GASOLINE | Motor Gasoline | ELECTR | Electricity |
| JETFUEL | Jet Fuel (Kerosene and gasoline) | HEATPROD | Heat |
| LFO | Light Fuel Oil | NUCLEAR | Nuclear |
| HFO | Heavy Fuel Oil | HYDRO | Hydroelectric |
| NAPHTA | Naphtha | GEOTHERM | Geothermal |
| OTHPETRO | Other Petroleum Products (Bitumen, Ethane, LPG and Lubric) | SOLAR | Solar |
| NATGAS | Natural Gas | WIND | Wind Power |
| OTHGAS | Dervied Gas | OTHSOURC | Other Sources (Boiler, Chemical Heat and Heat Pump) |

12th Five Year Plan Targets

|  |  |  |  |
| --- | --- | --- | --- |
| **A1.4 Changing Structure of Fuel for Electricity** | | | |
| **Fuel** | **Generation** | | |
| 2012 | 2017 | 2030 |
| Coal | 70 | 69 | 58 |
| Oil | 0 | 0 | 0 |
| Gas | 7 | 5 | 3 |
| Hydro | 14 | 12 | 11 |
| Renewables | 6 | 9 | 16 |
| Nuclear | 3 | 5 | 12 |

Substitution in respective Industries in WIOD National Input Output table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **A1.5 Fuel input substitution in Electricity Production** | | | | |
| **Industry** | 2012 | 2017 | 2030 | Notes |
| Coke, Refined Petroleum and Nuclear Fuel | 73 | 74 | 70 | (Summing Coal, Oil and Nuclear) |
| Electricity, Gas and Water Supply | 21 | 17 | 14 | (Summing Gas and Hydro) |
| Agriculture, Hunting, Forestry and Fishing | 6 | 9 | 16 | (Renewables) |

Consolidated Result of all the scenarios

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **A1.6 Impact of changing fuel substitution on emission, output and employment under different scenarios** | | | | | | | | | | | | |
|  | **Total Emission Impact (Kilotonnes per $ million)** | | | | **Total Output ($ million)** | | | | **Total Employment Impact (1000 employees per $ million)** | | | |
| Scenario | BAU | 2012 | 2017 | 2030 | BAU | 2012 | 2017 | 2030 | BAU | 2012 | 2017 | 2030 |
| 1.1 | 56.01 | 56.01 | 56.01 | 56.01 | 2,590,618 | 2,590,618 | 2,590,618 | 2,590,618 | 5.62 | 5.62 | 5.62 | 5.62 |
| % change | NA | 0.00% | 0.00% | 0.00% | NA | 0.00% | 0.00% | 0.00% | NA | 0.00% | 0.00% | 0.00% |
| 1.2 | 56.01 | 50.24 | 49.23 | 49.06 | 2,590,618 | 2,590,618 | 2,590,618 | 2,590,618 | 5.62 | 5.61 | 5.60 | 5.60 |
| % change | NA | -10.30% | -2.02% | -0.35% | NA | 0.00% | 0.00% | 0.00% | NA | -0.33% | -0.06% | -0.01% |
| 2 | 56.01 | 50.16 | 49.09 | 48.88 | 2,590,618 | 2,590,618 | 2,590,618 | 2,590,618 | 5.62 | 5.60 | 5.60 | 5.60 |
| % change | NA | -10.45% | -2.12% | -0.44% | NA | 0.00% | 0.00% | 0.00% | NA | -0.37% | -0.08% | -0.03% |
| 2 | 56.01 | 52.73 | 48.73 | 44.70 | ,590,618 | 2,729,305 | 2,947,631 | 3,210,506 | 5.62 | 5.30 | 4.90 | 4.49 |
| % change | NA | -5.85% | -7.59% | -8.26% | NA | 5.35% | 8.00% | 8.92% | NA | -5.81% | -7.57% | -8.25% |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **A1.7 Share of Electricity, Gas and Water Supply industry, Coke, Refined Petroleum and Nuclear Fuel industry and Agriculture, Hunting, Forestry and Fishing industry in emissions and output in different scenarios** | | | | | | | | | | | | |
|  | **Share in Emission (%)** | | | | | | | | | | | |
|  | Electricity, Gas and Water Supply | | | | Coke, Refined Petroleum and Nuclear Fuel | | | | Agriculture, Hunting, Forestry and Fishing | | | |
| Scenario | BAU | 2012 | 2017 | 2030 | BAU | 2012 | 2017 | 2030 | BAU | 2012 | 2017 | 2030 |
| 1.1 | 29.58% | 29.58% | 29.58% | 29.58% | 3.07% | 3.07% | 3.07% | 3.07% | 1.13% | 1.13% | 1.13% | 1.13% |
| 1.2 | 29.58% | 27.24% | 26.77% | 26.69% | 3.07% | 3.21% | 3.24% | 3.24% | 1.13% | 1.18% | 1.19% | 1.19% |
| 2 | 29.58% | 27.20% | 26.71% | 26.61% | 3.07% | 3.21% | 3.24% | 3.25% | 1.13% | 1.18% | 1.19% | 1.20% |
| 3 | 29.58% | 29.41% | 29.36% | 29.33% | 3.07% | 3.11% | 3.12% | 3.13% | 1.1% | 1.1% | 1.1% | 1.1% |
|  | **Share in Total Output (%)** | | | | | | | | | | | |
|  | Electricity, Gas and Water Supply | | | | Coke, Refined Petroleum and Nuclear Fuel | | | | Agriculture, Hunting, Forestry and Fishing | | | |
| Scenario | BAU | 2012 | 2017 | 2030 | BAU | 2012 | 2017 | 2030 | BAU | 2012 | 2017 | 2030 |
| 1.1 | 2.51% | 2.51% | 2.51% | 2.51% | 4.29% | 4.29% | 4.29% | 4.29% | 10.56% | 10.56% | 10.56% | 10.56% |
| 1.2 | 2.51% | 2.51% | 2.51% | 2.51% | 4.29% | 4.29% | 4.29% | 4.29% | 10.56% | 10.56% | 10.56% | 10.56% |
| 2 | 2.51% | 2.51% | 2.51% | 2.51% | 4.29% | 4.29% | 4.29% | 4.29% | 10.56% | 10.56% | 10.56% | 10.56% |
| 3 | 2.51% | 2.09% | 2.02% | 2.00% | 4.29% | 4.22% | 4.19% | 4.16% | 10.56% | 10.64% | 10.66% | 10.67% |

The values in shaded portion are constant values due to assumption of constant output.

1. Ministry of New and Renewable Energy Achievements ([Link](http://www.mnre.gov.in/mission-and-vision-2/achievements/)) [↑](#footnote-ref-2)
2. Central Electricity Authority Monthly Reports ([Link](http://www.cea.nic.in/reports/monthly/gm_div_rep/power_supply_position_rep/peak/Peak_2015_01.pdf)) [↑](#footnote-ref-3)
3. Central Statistical Organization, Government of India Press Release [↑](#footnote-ref-4)