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# "Impact of Cleaner Energy in I-O framework with reference to India"

**(Topic: *'Energy Input-Output Modeling'*)**

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In India, we find various sources of power-generation. Over the years, the trend is found to be from conventional energy sources that are non-renewable in nature, to that of non-conventional energy sources which are renewable in nature. And the Planning Commission also recommends the shift towards the renewable energy sources. This can be referred as the change in technology. The Solar Mission launched in 2008 and several other steps taken by the Ministry of New and Renewable Energy are also evident in this subject. This paper seeks to find the impact of change in technology in energy sector in India.

The Central Statistical Organization (the Official Authority of Govt. of India for statistics) provides the data related to total demand for energy in the country, various energy sources with their power-generating capacities and the actual generations by various States and Union Territories. But the data depicting inter-industry transactions is not provided. Even we don't have any firm information/ data regarding environmental repercussions of energy generation, neither provided by the CSO, nor by any other ministries. Data on pollutants generated by different sectors (as defined in I-O table) are also not readily available. Another database, the World Input Output Database provides the national Input-Output tables, as well as the Environmental Emissions & Pollutants tables from 1995 to 2009. It provides tables for 35*35 industries, while CSO publishes I-O tables for 115*115 dimensions (up to 1998-99) or now, for 130*130 dimensions (from 2003-04). Therefore, we combine two datasets provided by CSO & WIOD.

This paper examines the impact of changes that would occur due to change in technology, viz. shift from conventional energy sources to that of solar. This exercise is done for three years, viz. 1998-99, 2003-04 & 2007-08. We have included these years before the implementation of 'Solar Mission', so that we can predict the impact of implementation in future based on previous coefficients. We introduce new inter-industry transaction values with estimated coefficients of 'renewable energy technology'. Initially these are estimated for 115*115 (Or 130*130) I-O tables. Later we aggregate these to 35*35 sectors for which emissions/ pollutants data is available from WIOD tables. Using these estimates, various coefficients regarding pollution are calculated, like 'Pollution emission- Pe coefficient', 'Total Pollution- TP coefficient', backward & forward linkages and direct & indirect effects.

Expected result is the reduction in the quantum of pollution with the shift in favor of cleaner technology, which is verified in this paper through the calculations.

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# Introduction

Energy is a vital input for production and rapid growth of GDP need to be supported by an increase in energy consumption. This is especially so in India, where large sections of the population are still without adequate access to energy. With a targeted GDP growth rate of 8% during Tenth Five Year Plan (2002-07), the energy demand was expected to rise by 5.2%. (Planning Commission documents,1999, 2011). Availability of power in India in 2007-08 was 666007 Million Units, which exceeded the requirement (739343MU) by 73336MU i.e. 9.9%. Thus, we can infer how important the issue of energy availability is!

Another issue is of environmental impacts caused by the energy sector. The environmental effects of various fuels, namely, coal, oil, nuclear etc. are of growing concern owing to increasing consumption levels. The combustion of these fuels in industries has been a major source of pollution. The generation of electric power produces more pollution than any other single industry.

It's important to move from non-renewable energy sources (fossil fuels such as coal, oil and natural gas) to renewable energy sources (as wind, hydro, solar etc.). Renewable energy sources are important to tackle the pollution as well the exhaustion problem of other energy resources. This move goes with the objectives of IPCC and UNFCCC also. Thus Government of India launched India's National Action Plan on Climate Change on June 30, 2008, in view of making India's economic development energy-efficient. Eight missions were announced as the plan of this Action Plan. Based on this vision a National Solar Mission is being launched under the brand name "Solar India".

'The Jawaharlal Nehru National Solar Mission' states the relevance of solar energy on the basis of cost, scalability, environmental impacts and security issues. The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. The Mission adopts a 3-phase approach to achieve targets regarding solar collectors (area covered), on-grid and off-grid solar applications (energy generated). The 3 phases are 2008-2013, 2013-2017 and 2017-2022. The mission has a target of deploying 20,000 MW (currently raised to 100000 MW) of grid connected solar power by 2022 and reducing the cost of solar power generation in the country.

So, we thought it important to assess the performance solar energy as an upcoming source of energy, before the Solar Mission comes into action.

Increasing solar in the current energy mix, would definitely make some change in the impact by energy generation- electricity sector. And the changed energy-mix would also affect all other sectors (i.e. industries) in the economy. This can be referred as the change in technology. Hence we need to study the impact of change in technology- the cleaner technology, as it is called due to non-emissions by solar while generating electricity.

This paper seeks to find the impact of change in technology in energy sector in India. The analysis is made by adopting an energy-environment input-output framework. For analysis, we have considered years- 1998-99, 2003-04 & 2007-08, and compared values calculated.

The paper would proceed as follows- Section 1 will review the selected literature on energy-environment IO models. Section 2 & 3 will discuss the methodology & the data respectively. Results and discussions are presented in Section 4 and Section 5 will conclude the paper.

# Section 1: Literature Review

## [A] Input- Output Basic Framework

The basic framework for the Input-Output analysis was provided by Leontief W. It is an application of the static general equilibrium approach to the empirical analysis of production. Traditional input-output accounting identity is given by

$x_i = \sum z_{ij} + f_i$ and $A = Z\hat{x}^{-1}$

where, Z: matrix of inter-industry transactions, f: vector of total final demands and x: vector of total outputs, A: Technology coefficient matrix. Further calculations can be made to find out total requirements of inputs by an industry from another one.

(Leontief, W. 1951)

## [B] Energy-Environment I-O Models

Many energy models are developed by Cumberland (1966), Ayres and Kneese (1969), Bullard and Herendeen (1975), Blair (1979 and 1980) and many more. The issues concerned by many economists in these models are like how to measure energy intensities, embodied energy theory of value, use of hybrid units, study of new energy technology impact, applying structural decomposition analysis, accounting for imports, net energy analysis etc.

(Miller & Blair, 2009).

Leontief has also formed an I-O framework for incorporating environmental repercussions in an economy. He has considered the problem of externalities and gave treatment in an enlarged structural matrix. One of his papers is based on his empirical study regarding 'Air pollution and the economic structure'.

(Leontief, W., 1970)

Herendeen first articulated the conditions for energy conservation which can be given by

$a_{kj}x_j = \sum a_{ki}Z_{ij} + g_{kj}$

where $a_{kj}$ is the total amount of energy of type *k* required to produce a dollar's worth of sector *i*'s input; $x_j$ is the total dollar output of sector *j*; and $Z_{ij}$ is the dollar value of sector *i*'s product consumed by sector *j*. The term $g_{kj}$ is the total energy output of an energy sector.

(Herendeen 1974).

In the paper 'Energy Intensity Analysis: An Input-Output Framework', the authors analyze energy models by Herendeen, Hybrid units model by Bullard & Herendeen and develop a new model based on hybrid units. According to them, α is the energy coefficient matrix which is given by $\hat{F}^{*}(\hat{X}^{*})^{-1}(I-A)^{-1}$; where $\hat{F}^{*}$ is total energy vector, $\hat{X}^{*}$ is total output vector. This coefficient explains overall impact of backward and forward linkages.

(Dash-Saxena, 2000)

A paper by Mukhopadhyay et al. develops a carbon emission model. It is given by

$$F_{pd} = CL_1X_d = CL_1 (I – A_d)^{-1} Y$$

Here $F_p$ is a scalar giving the total quantity of an emission from fossil fuels combustion in India. Emissions under the study are $CO_2$ meaning carbon dioxide, which is defined as pollution type p. C is a vector of dimension m (1*m), of coefficients for the industrial emission intensity per unit of fossil fuel burnt. $L_1$ is a matrix (m*n) of the industrial consumption in energy units of m types of fuel per unit of total output of n industries. In the equation $CL_1$ carries only direct requirement of pollution intensities from industries and $CL_1(I - A)^{-1}$ gives the direct as well as indirect requirement of pollution intensity from industries.

(Mukhopadhyay et al. 2005)

A recent paper by Parikh et al. analyses carbon dioxide ($CO_2$) emissions of the Indian economy by producing sectors and due to household final consumption. The analysis is based on an Input–Output (IO) table and Social Accounting Matrix (SAM) for the year 2003–04 that distinguishes 25 sectors and 10 household classes. The paper tells about the total emission of the Indian economy by fuel type and by demand categories, the major emitting sectors by fuel type, the quantum of direct and indirect emissions by final demand, and the emissions by different expenditure classes in rural and urban areas.

(Parikh J. et al., 2009)

**[C] 'Change in technology' I-O Models**

There are few models developed to examine the impacts of new energy technologies. To name a few, Gowdy and Miller (1968), Herendeen and Plant (1981), Blair (1979), Casler and Hannon (1989) have used input-output analysis for the purpose.

Economic-energy-environmental model incorporating new technologies into the input-output tables was developed by Just. The technology involved a mix of coal gasification and gas turbine topping. The calculations of economic and environmental impacts for the alternative futures (both with and without technological change) were made by the author. This model was able to correct various objections to previous I-O analysis and to have wide applicability in many practical problems.

(Just J., 1974)

The economic analysis done by Anne Carter consists of three sets of innovations. The aim of innovations is to address potential scarcities of natural resources with minimal environmental damage. For the study purpose, comparative dynamics calculations studying impacts of structural changes were made and it was found a substantial combined effect of prospective structural changes and technological changes. An interesting result of the study says that 'increasing power consumption cuts the growth rate more than the switch to new techniques.'

(Carter Anne P.)

## Section 2: Methodology

The methodology of the present study is mainly based on Leontief's Input-Output framework (1951).

We recall the model:

**$X = Ax + F$ ……. (1)**

here X is a vector (n*1) of industrial output. F is a (n*1) vector of final demand of industries and A is a technical coefficient matrix (n*n) describing interdependencies among output of industries. The solution of (1) gives

**$X = (I - A)^{-1} F$ ……. (2)**

where $(I - A)^{-1}$ is the matrix of total input requirements (called as Leontief Inverse matrix). I is an identity matrix (n*n).

$B = \hat{x}^{-1} Z$ **……. (3)**

where, $b_{ij}$ represents the distribution of sector i's outputs across sectors j that purchase inter-industry inputs from i. B represents the Direct output coefficient matrix.

**$(I - B)^{-1} = G$** ***Ghosh Inverse*****…….(4)**

Now, we have calculated various estimates related to Pollution emissions, explained below.

1) Let **P** be (n*m) matrix of the industrial emissions (adjusted to respective 'Total Requirements' given by Leontief matrix) for n industries for m no. of pollutants (say, $CO_2$, $SO_x$, $N_2O$ etc.). Then the direct and indirect impact on amount of pollution emissions considering total requirements (pro-data) by all m pollutants taken together, (Similar to the 'requirement of pollution intensities by industries' estimated by Mukhopadhyay et al.) will be given by

**$Pe = P' * (I-A)^{-1} * F$…… (5)**

2) $\sum \mathbf{a_{ij}p_i}$ (Say, Total Pollution, **TP**) will indicate the weighted sum of pollutions **… (6)**
Weights in this equation are the coefficients of input requirements for sector *i* from sector *j*. Thus, when we change energy-intensities (i.e. the original energy-mix or the technology), by replacing fossil fuels by solar energy (say, by 10% of total electricity generated), our A will change to $A_1$, and so will cause the changes in Pe and backward-forward linkages. The sum, TP will also change consequently on the account of changes in A.

3) $\sum \mathbf{l_{ij}p_i}$ (Say, **TPone**) will indicate the weighted sum of pollutions **… (7)**
Weights in this equation are the coefficients of total requirements i.e. the Leontief inverse for sector *i* from sector *j*. When we change energy intensities, our original L changes, and causes further changes in Pe, backward & forward linkages, as well as TPone.

4) The matrix **$BL = (I-A)^{-1} * P$** gives the coefficients for the backward linkages ……. **(8)**

5) The matrix **$FL = P' * (I-B)^{-1}$** gives the coefficients of forward linkages. ……. **(9)**

The change in TP (due to a change in A (or L, and assuming Final demand, F to be constant) would reflect the impact of changed technology on total pollution emissions (in physical terms). The change in Pe would reflect overall impact of changed technology on pollution emissions including the indirect effects, viz. backward & forward linkages also.

With the help of this analysis, an identification of the highly polluting sectors can also be done, so that it can be used further for policy purpose.

In this paper, to find out this impact, the data for the years 1998-99, 2003-04 & 2007-08 was taken from two different databases; viz. I-O tables published by CSO and the WIOD (National IO tables and Air Emission Data). This consolidation is done in order to overcome the problem of data-unavailability in CSO tables. The CSO-published I-O table is aggregated at the level of aggregation of that of WIOD. The schemes of consolidation of the sectors are prepared on the basis of 'Methods & Sources of Data for I-O tables 1998-99' for the year 1998-99, 'National Industrial Classification, 1998' for the year 2003-04 and that on the 'NIC, 2004' for the year 2007-08, on which the CSO IO tables are based. The schemes are provided as appendices.

In this paper, the coefficients called Pe, TP, TPone, BL & FL values (based on the model) for the two years are compared at 3 scenarios.

Scenario 1: The original IO transaction matrix for 1998-99 (or 2003-04 or 2007-08).

Scenario 2: With the replacement of thermal (+other energy sources) by solar by 10%.

Scenario 3: With the replacement of thermal (+other energy sources) by solar by 20%.

The tables for Scenario 2 & 3 are estimated as follows-

1. To change the energy-mix (90+10 or 80+20 combination of thermal & solar) in the electricity column keeping total output constant.
2. To scale down the row for electricity sector (of thermal energy) by 10% (or 20%) and to scale up the row for electronic sector (as the current inputs for solar energy mainly belong to electronic industry, which belongs to manufacturing sector in our scheme) by the proportional costs for energy generation by the solar at the level of production.

(Main shortcoming of this procedure is unavailability of average solar costs for the years under consideration; hence the costing for 2014-15 is used in these calculations which may not match with the considered years' costing, and hence may not be fully consistent with data for other industries).

## Section 3: Data Sources

### CSO database

Central Statistical Organization is the Official Authority of Govt. of India for statistics. It coordinates all the statistical activities in the country and evolves & maintains statistical standards. It compiles National Accounts, which include I-O tables. I-O tables for India are made available for 1968-69, 1973-74, 1978-79, 1983-84, 1989-90, 1993-94, 1998-99, 2003-04, 2006-07 & 2007-08. Till 1998-99, tables were for 115 sectors. From 1998-99, these table contain 130 sectors. Thus, the IO tables under study are of 115*115 dimensions and 130*130 dimensions (Commodity by commodity matrix and Industry by industry matrix).

(MOSPI, 2012)

This data is extensive (compared to previous years- eg. 1968-69 IO tables were only 60*60) and official, thus authentic; but the major shortcoming of it is non-availability of annual (or more frequent) data. Another thing is that it does not provide environmental I-O tables. Thus, we need some technique to estimate these tables. For the purpose of current study, we have used another database called WIOD which provides various kinds of I-O tables for the period 1995 to 2009, on annual basis.

### WIOD

The World Input Output Database was the project funded by the European Commission, Research Directorate General (as part of the 7th Framework Programme, Theme 8: Socio Economic Sciences and Humanities. Grant Agreement no: 225 281). It provides tables for 27 EU countries and 13 other major countries in the world (including India) for the period from 1995 to 2009. Tables are for air pollution by various pollutants, $CO_2$ emissions, gross energy use and emissions relevant energy use are also estimated. These tables contain 35 sectors. Sources of data collection are National Accounts Statistics & SUTs. The model used for analysis comprises of two phases- 1) Production, 2) Use. One more phase, 'Post-consumer' i.e. waste management phase is also recognized by the team, but model doesn't incorporate it for obvious reasons of non-availability of sufficient reliable data.

(WIOD, 2012)

But these data are based on several assumptions which may not match with the National tables. For example, the scheme of consolidation of sectors may differ from the National one. And it is compiled at a highly aggregated level (than that of CSO). Thus using that database itself may not be sufficient, and probably not consistent with the National database.

### About the new generated 'data'

Thus, for the purpose of study, two sets of data are compiled with a scheme of aggregation explained earlier. These data are used to estimate the measures as indicated in the earlier section. (Note: In case of 1998-99, CSO provides separate data for railway transport services, and separates 'Other transport services'. Thus, for simplification in this paper, three industries, viz. Air Transport, Water Transport and Inland Transport are aggregated into one 'Transport sector' even at WIOD scheme of aggregation resulting into total of 33 sectors.)

## Section 4: Results and Discussions

As stated earlier, 5 types of coefficients related to Pollution Emissions are calculated for 1998-99, 2003-04 & 2007-08. Let us now look at some of the results of the calculations. We may mention the detailed calculations for every equation have been made, though those are not presented in this paper.

Please note that the units for the following tables, if not stated exclusively, are as follows-

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 tones

**Table: 1 'Pe values' i.e. impact of changed technology on pollution emission**

| Pe Value | CO2 | CH4 | N2O | NOX | SOX | CO | NMVOC | NH3 |
|---|---|---|---|---|---|---|---|---|
| Pe(99) | 2.60E+13 | 1.22E+15 | 5.21E+13 | 1.38E+14 | 1.59E+14 | 9.22E+14 | 2.58E+14 | 1.80E+14 |
| Pe1(99) | 2.55E+13 | 1.21E+15 | 5.20E+13 | 1.37E+14 | 1.55E+14 | 9.22E+14 | 2.57E+14 | 1.80E+14 |
| Pe2(99) | 1.99E+13 | 1.21E+15 | 5.16E+13 | 1.20E+14 | 1.15E+14 | 8.57E+14 | 2.46E+14 | 1.79E+14 |
| Pe(04) | 4.73E+13 | 1.74E+15 | 7.82E+13 | 3.91E+14 | 4.62E+14 | 1.11E+15 | 4.68E+14 | 2.75E+14 |
| Pe1(04) | 4.21E+13 | 1.78E+15 | 7.99E+13 | 3.9E+14 | 4.51E+14 | 1.12E+15 | 4.78E+14 | 2.8E+14 |
| Pe2(04) | 4.23E+13 | 1.80E+15 | 8E+13 | 3.89E+14 | 4.52E+14 | 1.11E+15 | 4.76E+14 | 2.8E+14 |
| Pe(08) | 1.13E+14 | 3.04E+15 | 1.38E+14 | 8.16E+14 | 1.11E+15 | 2.32E+15 | 9.87E+14 | 4.83E+14 |
| Pe1(08) | 1.08E+14 | 3.04E+15 | 1.38E+14 | 8.10E+14 | 1.09E+15 | 2.32E+15 | 9.83E+14 | 4.82E+14 |
| Pe2(08) | 1.11E+14 | 3.01E+15 | 1.38E+14 | 8.10E+14 | 1.10E+15 | 2.30E+15 | 9.80E+14 | 4.82E+14 |

Pe= direct & indirect impact on output of pollutants
Pe1= direct & indirect impact on output of pollutants with 10% replacement
Pe2= direct & indirect impact on output of pollutants with 20% replacement
Numbers in brackets show the years

*Source: Calculated by the author*

As stated in the methodology, the Pe values are calculated as $\mathbf{Pe= P'*(I-A)^{-1}*F}$. Thus these values depict impact of change in technology on the quantum of pollution incorporating both direct & indirect effects (adjusted to total requirements by the industries). The emission levels at Scenario 2 & 3, replacement by 10% & 20% resp., for some of the pollutants are higher than the original scenario. This result is justified when we take cognizance of indirect effects.

**Table: 2 'TP values' i.e. weighted sum of pollution (weight=A)**

| TP Value | CO2 | CH4 | N2O | NOX | SOX | CO | NMVOC | NH3 |
|---|---|---|---|---|---|---|---|---|
| TP(99) | 999855.9 | 11321485 | 405959.2 | 4143484 | 6205449 | 30241979 | 7442907 | 1145968 |
| TP1(99) | 958999.6 | 10587367 | 396244.4 | 4040948 | 5913700 | 30396639 | 7402394 | 1135231 |
| TP2(99) | 812176.9 | 11105504 | 389108.3 | 3571954 | 4894836 | 28072207 | 7000508 | 1103917 |
| TP(04) | 1359832 | 13102691 | 543892.5 | 4697946 | 6043630 | 23033478 | 7830151 | 1689903 |
| TP1(04) | 944159.4 | 11630336 | 499317.8 | 3967503 | 4591412 | 20484613 | 7258117 | 1588273 |
| TP2(04) | 931542.9 | 13139938 | 506833.2 | 3869504 | 4530196 | 19845988 | 7068182 | 1566298 |
| TP (08) | 1652457.494 | 13894072 | 590828.1 | 5622635 | 7154226 | 29526356 | 10797840 | 1790757 |
| TP1(08) | 1467987.516 | 13683913 | 575403.8 | 5398527 | 6479248 | 29150453 | 10642349 | 1753455 |
| TP2(08) | 1579391.759 | 13059952 | 574938.4 | 5468542 | 6883077 | 29008891 | 10630869 | 1759238 |

*Source: Calculated by the author*

The TP values indicate the Total Pollution caused by all the industries. It is the weighted sum, adjusted for input requirements, A, and hence varies significantly than Pe values. (Pollution levels are adjusted for the share of the particular industry in the economy, in terms of technology coefficients- A). Thus, all the values for all the 8 pollutants in 3 scenarios (given by TP, TP1, and TP2 respectively) are somewhat similar. (Variation is not large as that is for Pe). The least levels of pollutions for both the years among 3 scenarios are highlighted in green. When compared, the pollution levels are least for 1998-99, then for 2003-04 and highest for 2007-08 (for obvious reasons).

**Table: 3 'TPone values' i.e. weighted sum of pollution (weight=L)**

| TPone Value | CO2 | CH4 | N2O | NOX | SOX | CO | NMVOC | NH3 |
|---|---|---|---|---|---|---|---|---|
| TPone(99) | 3825535 | 54323418 | 1971483 | 16037937 | 23532681 | 1.16E+08 | 28280432 | 5908350 |
| TPone1(99) | 3671179 | 51712585 | 1933101 | 15614508 | 22451982 | 1.16E+08 | 27995610 | 5856698 |
| TPone2(99) | 2863708 | 52011809 | 1856609 | 13037260 | 16901695 | 1.04E+08 | 25626358 | 5624403 |
| TPone(04) | 5113193 | 59700550 | 2373148 | 18790085 | 23968281 | 88815341 | 30281558 | 7490458 |
| TPone1(04) | 3727279 | 54329183 | 2204279 | 16233550 | 19075255 | 79379416 | 28004804 | 7086968 |
| TPone2(04) | 3677942 | 59299465 | 2226427 | 15894680 | 18838724 | 77220570 | 27358366 | 7003632 |
| TPone (08) | 6442507.436 | 64491205 | 2607688 | 23005362 | 29686905 | 1.11E+08 | 40473080 | 8049879 |
| TPone1(08) | 5919042.738 | 63985102 | 2563619 | 22439245 | 27732827 | 1.1E+08 | 40128020 | 7946293 |
| TPone2(08) | 6176858.434 | 61393732 | 2543847 | 22402761 | 28681091 | 1.09E+08 | 39732037 | 7913893 |

*Source: Calculated by the author*

TP and TPone are separately calculated since different weights used in the formula depict different meanings. TPone values also indicate the Total Pollution caused by all the industries. It is the weighted sum, adjusted for total requirements, L, and hence varies significantly than Pe values. (Pollution levels are adjusted for the share of the particular industry in the economy, in terms of total requirement coefficients or input-output coefficients- L). Thus, TPone values are less than TP values. The least levels of pollutions for both the years among 3 scenarios are highlighted in green. When compared, the pollution levels are lesser for 1998-99, than for 2003-04 and for 2007-08 (for obvious reasons).

**Table: 4 Industries with major 'backward linkages' for the year 1998-99**

| | CO2 | CH4 | N2O | NOx |
|---|---|---|---|---|
| **Original case** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Electricity,Gas & Water Sup. |
| | Mining & quarrying | Other community services | Chemicals & chem. products | Mining & quarrying |
| | Basic Metals & Fabricated Metals | Chemicals & chem. products | Retail trade, repairs of HH goods | Inland, Air & Water Transport |
| **With 10% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Electricity,Gas & Water Sup. |
| | Mining & quarrying | Other community services | Chemicals & chem. products | Mining & quarrying |
| | Basic Metals & Fabricated Metals | Chemicals & chem. products | Retail trade, repairs of HH goods | Inland, Air & Water Transport |
| **With 20% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Electricity,Gas & Water Sup. |
| | Mining & quarrying | Other community services | Chemicals & chem. products | Agri., Hunting, Forest,Fishing |
| | Basic Metals & Fabricated Metals | Chemicals & chem. products | Retail trade, repairs of HH goods | Inland, Air & Water Transport |

| | SOx | CO | NMVOC | NH3 |
|---|---|---|---|---|
| **Original Case** | Electricity,Gas & Water Sup. | Inland, Air & Water Transport | Mining & quarrying | Agri., Hunting, Forest,Fishing |
| | Mining & quarrying | Mining & quarrying | Agri., Hunting, Forest,Fishing | Chemicals & chem. products |
| | Inland, Air & Water Transport | Electricity,Gas & Water Sup. | Inland, Air & Water Transport | Retail trade, repairs of HH goods |
| **With 10% replacement** | Electricity,Gas & Water Sup. | Inland, Air & Water Transport | Mining & quarrying | Agri., Hunting, Forest,Fishing |
| | Mining & quarrying | Mining & quarrying | Agri., Hunting, Forest,Fishing | Chemicals & chem. products |
| | Inland, Air & Water Transport | Electricity,Gas & Water Sup. | Inland, Air & Water Transport | Retail trade, repairs of HH goods |
| **With 20% replace.** | Electricity,Gas & Water Sup. | Inland, Air & Water Transport | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Mining & quarrying | Mining & quarrying | Mining & quarrying | Chemicals & chem. products |
| | Basic Metals & Fabricated Metals | Coke, Ref. Petrol. & Nuclear | Inland, Air & Water Transport | Retail trade, repairs of HH goods |

*Source: Estimated by the author on the basis of calculations for backward linkages*

**Table: 5 Industries with major 'backward linkages' for the year 2003-04**

| | CO2 | CH4 | N2O | NOx |
|---|---|---|---|---|
| **Original case** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Mining & quarrying | Other community services | Chemicals & chem. products | Electricity,Gas & Water Sup. |
| | Coke, Ref. Petrol. & Nuclear | Mining & quarrying | Retail trade, repairs of HH goods | Mining & quarrying |
| **With 10% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Mining & quarrying | Other community services | Chemicals & chem. products | Mining & quarrying |
| | Basic Metals & Fabricated Metals | Chemicals & chem. products | Retail trade, repairs of HH goods | Chemicals & chem. products |

| | | | | |
|---|---|---|---|---|
| **With 20% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Mining & quarrying | Other community services | Chemicals & chem. products | Mining & quarrying |
| | Basic Metals & Fabricated Metals | Mining & quarrying | Retail trade, repairs of HH goods | Electricity,Gas & Water Sup. |

| | **SOx** | **CO** | **NMVOC** | **NH3** |
|---|---|---|---|---|
| **Original Case** | Agri., Hunting, Forest,Fishing | Mining & quarrying | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Coke, Ref. Petrol. & Nuclear | Mining & quarrying | Chemicals & chem. products |
| | Mining & quarrying | Agri., Hunting, Forest,Fishing | Chemicals & chem. products | Retail trade, repairs of HH goods |
| **With 10% replacement** | Agri., Hunting, Forest,Fishing | Mining & quarrying | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Coke, Ref. Petrol. & Nuclear | Mining & quarrying | Chemicals & chem. products |
| | Mining & quarrying | Basic Metals & Fabricated Metals | Chemicals & chem. products | Retail trade, repairs of HH goods |
| **With 20% replacement** | Agri., Hunting, Forest,Fishing | Mining & quarrying | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Coke, Ref. Petrol. & Nuclear | Mining & quarrying | Chemicals & chem. products |
| | Mining & quarrying | Agri., Hunting, Forest,Fishing | Chemicals & chem. products | Retail trade, repairs of HH goods |

*Source: Estimated by the author on the basis of calculations for backward linkages*

## Table: 6 Industries with major 'backward linkages' for the year 2007-08

| | **CO2** | **CH4** | **N2O** | **NOx** |
|---|---|---|---|---|
| **Original case** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Mining & quarrying | Other community services | Chemicals & chem. products | Mining & quarrying |
| | Basic Metals & Fabricated Metals | Mining & quarrying | Retail trade, repairs of HH goods | Electricity,Gas & Water Sup. |
| **With 10% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Mining & quarrying | Other community services | Chemicals & chem. products | Mining & quarrying |
| | Basic Metals & Fabricated Metals | Mining & quarrying | Retail trade, repairs of HH goods | Retail trade, repairs of HH goods |
| **With 20% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Mining & quarrying | Other community services | Chemicals & chem. products | Mining & quarrying |
| | Basic Metals & Fabricated Metals | Mining & quarrying | Retail trade, repairs of HH goods | Electricity,Gas & Water Sup. |

| | **SOx** | **CO** | **NMVOC** | **NH3** |
|---|---|---|---|---|
| **Original Case** | Agri., Hunting, Forest,Fishing | Mining & quarrying | Mining & quarrying | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Coke, Ref. Petrol. & Nuclear | Coke, Ref. Petrol. & Nuclear | Chemicals & chem. products |
| | Mining & quarrying | Basic Metals & Fabricated Metals | Chemicals & chem. products | Retail trade, repairs of HH goods |
| **With 10% replacement** | Agri., Hunting, Forest,Fishing | Mining & quarrying | Mining & quarrying | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Coke, Ref. Petrol. & Nuclear | Coke, Ref. Petrol. & Nuclear | Chemicals & chem. products |
| | Mining & quarrying | Basic Metals & Fabricated Metals | Agri., Hunting, Forest,Fishing | Retail trade, repairs of HH goods |
| **With 20% replacement** | Agri., Hunting, Forest,Fishing | Mining & quarrying | Mining & quarrying | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Coke, Ref. Petrol. & Nuclear | Coke, Ref. Petrol. & Nuclear | Chemicals & chem. products |
| | Mining & quarrying | Basic Metals & Fabricated Metals | Agri., Hunting, Forest,Fishing | Retail trade, repairs of HH goods |

*Source: Estimated by the author on the basis of calculations for backward linkages*

Backward linkages can be found with the formula $\mathbf{(I-A)^{-1}*P}$. As the name suggests, they refer to the effect of the activities at the previous stage of the chain. And thus, they imply the higher (or lower) energy-intensity embedded at the prior stages of the economic activity. In the table, we have provided the list of three industries for each pollutant at each scenario, with the largest backward linkages. And hence, in order to achieve lower levels of emissions in the future, we have to concentrate on these industries. Thus, 'agriculture, logging, forestry & fishing' sector should be given more attention in the future. (The industries highlighted are the industries for which the rank is changed than the original scenario).

**Table: 7 Pollutant-wise highest values for 'backward linkages'**

| | CO2 | CH4 | N2O | NOX | SOX | CO | NMVOC | NH3 |
|---|---|---|---|---|---|---|---|---|
| BL(99) | 1043626 | 21710483 | 970756.1 | 3194185 | 7411902 | 20485269 | 3254641 | 3461872 |
| BL1(99) | 956463.7 | 21671667 | 970311.3 | 2904718 | 6820201 | 20415630 | 3217206 | 3461534 |
| BL2(99) | 520739 | 21698998 | 969814.7 | 1524122 | 3814789 | 19630314 | 3080203 | 3459542 |
| BL(04) | 1278177.9 | 24889516 | 1152226.7 | 4764840 | 5478859 | 15223433 | 4529786 | 4169238 |
| BL1(04) | 666075.9 | 24843009 | 1150888 | 4744941 | 5439817 | 13839374 | 4513322 | 4166169 |
| BL2(04) | 651290.9 | 24888793 | 1151105 | 4741953 | 5437836 | 13615929 | 4507582 | 4165456 |
| BL(08) | 1186425 | 25803053 | 1212232 | 5785370 | 8364943 | 24873053 | 7601801 | 4374161 |
| BL1(08) | 882482.8 | 25795057 | 1211667 | 5779150 | 8337271 | 24599979 | 7502627 | 4372961 |
| BL2(08) | 1070031 | 25748984 | 1211241 | 5776955 | 8350443 | 24610918 | 7517186 | 4372197 |

*Source: Calculated by the author*

The highest values for the backward linkages for the industries stated in Table: 4, 5 & 6 are provided in Table: 7. The least values for each year are highlighted. In 1998-99, in case of NMVOC, no value is recognised as 'least' although the value for 20% replacement is the least one, the highest rank industry is changed in three scenarios.

**Table: 8 Industries with major 'forward linkages' for the year 1998-99**

| | CO2 | CH4 | N2O | NOx |
|---|---|---|---|---|
| **Original case** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Electricity,Gas & Water Sup. |
| | Inland, Air & Water Transport | Other community services | Chemicals & chem. products | Inland, Air & Water Transport |
| | Basic Metals & Fabricated Metals | Food & Beverages | Food & Beverages | Agri., Hunting, Forest,Fishing |
| **With 10% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Electricity,Gas & Water Sup. |
| | Inland, Air & Water Transport | Other community services | Chemicals & chem. products | Inland, Air & Water Transport |
| | Basic Metals & Fabricated Metals | Food & Beverages | Food & Beverages | Agri., Hunting, Forest,Fishing |
| **With 20% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Electricity,Gas & Water Sup. |
| | Inland, Air & Water Transport | Other community services | Chemicals & chem. products | Inland, Air & Water Transport |
| | Basic Metals & Fabricated Metals | Food & Beverages | Food & Beverages | Agri., Hunting, Forest,Fishing |

| | SOx | CO | NMVOC | NH3 |
|---|---|---|---|---|
| **Original case** | Electricity,Gas & Water Sup. | Inland, Air & Water Transport | Inland, Air & Water Transport | Agri., Hunting, Forest,Fishing |
| | Inland, Air & Water Transport | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Food & Beverages |
| | Construction | Coke, Ref. Petrol. & Nuclear | Construction | Chemicals & chem. products |
| **With 10% replacement** | Electricity,Gas & Water Sup. | Inland, Air & Water Transport | Inland, Air & Water Transport | Agri., Hunting, Forest,Fishing |
| | Inland, Air & Water Transport | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing | Food & Beverages |
| | Construction | Electricity,Gas & Water Sup. | Construction | Chemicals & chem. products |
| **With 20% replacement** | Electricity,Gas & Water Sup. | Inland, Air & Water Transport | Inland, Air & Water Transport | Agri., Hunting, Forest,Fishing |
| | Inland, Air & Water Transport | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing | Food & Beverages |
| | Basic Metals & Fabricated Metals | Construction | Construction | Chemicals & chem. products |

## Table: 9 Industries with major 'forward linkages' for the year 2003-04

| | CO2 | CH4 | N2O | NOx |
|---|---|---|---|---|
| **Original case** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Construction | Other community services | Chemicals & chem. products | Electricity,Gas & Water Sup. |
| | Coke, Ref. Petrol. & Nuclear | Coke, Ref. Petrol. & Nuclear | Food & Beverages | Inland Transport |
| **With 10% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Inland Transport | Other community services | Chemicals & chem. products | Inland Transport |
| | Coke, Ref. Petrol. & Nuclear | Food & Beverages | Food & Beverages | Construction |
| **With 20% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Coke, Ref. Petrol. & Nuclear | Other Comm. Services | Chemicals & chem. products | Inland Transport |
| | Construction | Coke, Ref. Petrol. & Nuclear | Food & Beverages | Construction |

| | SOx | CO | NMVOC | NH3 |
|---|---|---|---|---|
| **Original case** | Agri., Hunting, Forest,Fishing | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Inland Transport | Construction | Food & beverages |
| | Coke, Ref. Petrol. & Nuclear | Construction | Coke, Ref. Petrol. & Nuclear | Chemicals & chem. products |
| **With 10% replacement** | Agri., Hunting, Forest,Fishing | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Inland Transport | Construction | Food & beverages |
| | Inland Transport | Construction | Coke, Ref. Petrol. & Nuclear | Chemicals & chem. products |
| **With 20% replacement** | Agri., Hunting, Forest,Fishing | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Inland Transport | Construction | Food & beverages |
| | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing | Coke, Ref. Petrol. & Nuclear | Chemicals & chem. products |

## Table: 10 Industries with major 'forward linkages' for the year 2007-08

| | CO2 | CH4 | N2O | NOx |
|---|---|---|---|---|
| **Original case** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Construction | Other Community Services | Food & beverages | Electricity,Gas & Water Sup. |
| | Basic Metals & Fabricated Metals | Coke, Ref. Petrol. & Nuclear | Chemicals & chem. products | Construction |
| **With 10% replacement** | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Coke, Ref. Petrol. & Nuclear | Chemicals & chem. products | Construction |
| | Basic Metals & Fabricated Metals | Other Community Services | Food & beverages | Inland Transport |
| **With 20% replacement** | Electricity,Gas & Water Sup. | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing | Agri., Hunting, Forest,Fishing |
| | Coke, Ref. Petrol. & Nuclear | Coke, Ref. Petrol. & Nuclear | Chemicals & chem. products | Construction |
| | Construction | Other Community Services | Food & beverages | Coke, Ref. Petrol. & Nuclear |

| | SOx | CO | NMVOC | NH3 |
|---|---|---|---|---|
| **Original case** | Agri., Hunting, Forest,Fishing | Coke, Ref. Petrol. & Nuclear | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Inland Transport | Construction | Food & beverages |
| | Food & beverages | Basic Metals & Fabricated Metals | Food & beverages | Hotels & Restaurants |
| **With 10% replace.** | Agri., Hunting, Forest,Fishing | Coke, Ref. Petrol. & Nuclear | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Basic & fab. Metals | Construction | Food & beverages |
| | Construction | Construction | Basic Metals & Fabricated Metals | Chemicals & chem. products |
| **With 20% replace.** | Agri., Hunting, Forest,Fishing | Coke, Ref. Petrol. & Nuclear | Coke, Ref. Petrol. & Nuclear | Agri., Hunting, Forest,Fishing |
| | Electricity,Gas & Water Sup. | Basic Metals & Fabricated Metals | Construction | Food & beverages |
| | Construction | Construction | Basic Metals & Fabricated Metals | Chemicals & chem. products |

Forward linkages can be found with the formula $\mathbf{P'*(I-B)^{-1}}$. As the name suggests, they refer to the effect of the activities at the later stage in the chain. And thus, they imply the higher (or lower) energy-intensity embedded at the further stages of the economic activity. In the table, we have provided the list of three industries for each pollutant at each scenario, with the largest forward linkages. And hence, in order to achieve lower levels of emissions in the future, we have to concentrate on these industries. (The industries highlighted are the industries for which the rank is changed than the original scenario). Thus, as was the case regarding backward linkages, the 'agriculture, logging, forestry & fishing' sector should be given more attention in the future.

**Table: 11 Pollutant-wise highest values for 'forward linkages'**

| | CO2 | CH4 | N2O | NOX | SOX | CO | NMVOC | NH3 |
|---|---|---|---|---|---|---|---|---|
| **FL(99)** | 1065124 | 22549166 | 1006109 | 3165839 | 7557339 | 28079444 | 4044321 | 3547154 |
| **FL1(99)** | 986573.3 | 22472144 | 1004715 | 2923623 | 7007235 | 28018978 | 4033503 | 3544973 |
| **FL2(99)** | 724755.1 | 22465637 | 1002561 | 2134856 | 5164680 | 26674066 | 3774922 | 3539136 |
| **FL(04)** | 1377782 | 26216180 | 1194869 | 5131578 | 6240064 | 17023581 | 4802646 | 4281702 |
| **FL1(04)** | 757671.7 | 25909777 | 1184488 | 4876823 | 5745633 | 15925127 | 4580881 | 4257370 |
| **FL2(04)** | 749449 | 25972905 | 1184055 | 4848640 | 5703302 | 15786206 | 4543001 | 4253752 |
| **FL(08)** | 918984.698 | 20500510 | 946662.4 | 4091892 | 6506123 | 14035801 | 4269714 | 3436247 |
| **FL1(08)** | 929321.7949 | 26494633 | 1229673 | 5754044 | 8554704 | 36093836 | 10955962 | 4415873 |
| **FL2(08)** | 1125676.066 | 26480315 | 1231364 | 5829112 | 8731574 | 36288302 | 11011862 | 4419037 |

*Source: Calculated by the author*

The highest values for the forward linkages for the industries stated in Table: 8, 9 & 10 are provided in Table: 11. We find a downward change at two scenarios than the original scenario. In 2007-08, we have found that the lowest values for the forward linkages are found at the original scenario. This might have happened due to non-scalability or inefficiency at the larger scale. Transmission losses, storage-problem & the problem of distribution also lead to the inefficiency & non-viability. If we want to curb these high levels of forward linkages in future, we have to decide a policy that would assure R&D in the field of solar, which would concentrate on the processes that would cause lower emissions in the future.

**Table: 12 'Change in various emission coefficients'**

| | CO2 | CH4 | N2O | NOX | SOX | CO | NMVOC | NH3 |
|---|---|---|---|---|---|---|---|---|
| **Scenario2-10%replacement** | | | | | | | | |
| Change in Pe1 from Pe (99) | -0.0198 | -0.0066 | -0.00215 | -0.00976 | -0.02303 | 0.000345 | -0.002606 | -0.00073 |
| Change in TP1 from TP (99) | -0.04086 | -0.06484 | -0.02393 | -0.02475 | -0.04701 | 0.005114 | -0.00544 | -0.00937 |
| Change in TPone1 from TPone (99) | -0.040349 | -0.048061 | -0.01947 | -0.0264 | -0.0459 | -0.00202 | -0.01007 | -0.00874 |
| Change in BL1 from BL (99) | -0.08352 | -0.00179 | -0.00046 | -0.09062 | -0.07983 | -0.0034 | -0.0115 | -9.8E-05 |
| Change in FL1 from FL (99) | -0.07375 | -0.00342 | -0.00139 | -0.07651 | -0.07279 | -0.00215 | -0.00267 | -0.00061 |
| Change in Pe1 from Pe (04) | -0.10905 | 0.023255 | 0.020689 | -0.00076 | -0.02289 | 0.001305 | 0.020373 | 0.020644 |
| Change in TP1 from TP (04) | -0.30568 | -0.11237 | -0.08195 | -0.15548 | -0.24029 | -0.11066 | -0.07306 | -0.06014 |
| Change in TPone1 from TPone (04) | -0.27105 | -0.08997 | -0.07116 | -0.13606 | -0.20415 | -0.10624 | -0.07519 | -0.05387 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Change in BL1 from BL (04) | -0.47889 | -0.00187 | -0.00116 | -0.00418 | -0.00713 | -0.09092 | -0.00363 | -0.00074 |
| Change in FL1 from FL (04) | -0.45008 | -0.01169 | -0.00869 | -0.04964 | -0.07923 | -0.06453 | -0.04618 | -0.00568 |
| Change in Pe1 from Pe (08) | -0.0458023 | -0.00072 | -0.00306 | -0.00725 | -0.01646 | -0.00197 | -0.00382 | -0.00181 |
| Change in TP1 from TP (08) | -0.11163372 | -0.01513 | -0.02611 | -0.03986 | -0.09435 | -0.01273 | -0.0144 | -0.02083 |
| Change in TPone1 from TP (08) | -0.0812517 | -0.00785 | -0.0169 | -0.02461 | -0.06582 | -0.00515 | -0.00853 | -0.01287 |
| Change in BL1 from BL (08) | -0.25618324 | -0.00031 | -0.00047 | -0.00108 | -0.00331 | -0.01098 | -0.01305 | -0.00027 |
| Change in FL1 from FL (08) | 0.011248388 | 0.292389 | 0.298956 | 0.406206 | 0.31487 | 1.571555 | 1.565971 | 0.285086 |
| **Scenario3-20%replacement** | | | | | | | | |
| Change in Pe2 from Pe (99) | -0.23462 | -0.0082 | -0.0096 | -0.13043 | -0.27673 | -0.0705 | -0.04651 | -0.00556 |
| Change in TP2 from TP (99) | -0.18771 | -0.01908 | -0.04151 | -0.13793 | -0.2112 | -0.07175 | -0.05944 | -0.03669 |
| Change in TPone2 from TPone (99) | -0.25142 | -0.04255 | -0.05827 | -0.1871 | -0.28178 | -0.10345 | -0.09385 | -0.04806 |
| Change in BL2 from BL (99) | -0.50103 | -0.00053 | -0.00097 | -0.52284 | -0.48532 | -0.04174 | -0.0536 | -0.00067 |
| Change in FL2 from FL (99) | -0.31956 | -0.0037 | -0.00353 | -0.32566 | -0.3166 | -0.05005 | -0.06661 | -0.00226 |
| Change in Pe2 from Pe (04) | -0.10662 | 0.0383 | 0.022733 | -0.00325 | -0.02263 | -0.0053 | 0.015208 | 0.019643 |
| Change in TP2 from TP (04) | -0.31496 | 0.002843 | -0.06814 | -0.17634 | -0.25042 | -0.13839 | -0.09731 | -0.07314 |
| Change in TPone2 from TPone (04) | -0.2807 | -0.00672 | -0.06183 | -0.15409 | -0.21401 | -0.13055 | -0.09653 | -0.06499 |
| Change in BL2 from BL (04) | -0.49045 | -2.9E-05 | -0.00097 | -0.0048 | -0.00749 | -0.10559 | -0.0049 | -0.00091 |
| Change in FL2 from FL (04) | -0.45605 | -0.00928 | -0.00905 | -0.05514 | -0.08602 | -0.07269 | -0.05406 | -0.00653 |
| Change in Pe2 from Pe (08) | -0.02687148 | -0.01058 | -0.00432 | -0.00784 | -0.00743 | -0.01058 | -0.00754 | -0.00256 |
| Change in TP2 from TP (08) | -0.04421641 | -0.06003 | -0.02689 | -0.02741 | -0.0379 | -0.01753 | -0.01546 | -0.0176 |
| Change in TPone2 from TPone (08) | -0.04123379 | -0.04803 | -0.02448 | -0.02619 | -0.03388 | -0.01978 | -0.01831 | -0.01689 |
| Change in BL2 from BL (08) | -0.09810481 | -0.0021 | -0.00082 | -0.00145 | -0.00173 | -0.01054 | -0.01113 | -0.00045 |
| Change in FL2 from FL (08) | 0.224912742 | 0.291691 | 0.300742 | 0.424552 | 0.342055 | 1.58541 | 1.579063 | 0.286007 |

*Source: Calculated by the author*

Table: 12 is the consolidated table of changes in all emission coefficients, viz. Pe (total impact of changed technology on pollution emission), TP (weighted sum of pollution, weight=A), TPone (weighted sum of pollution, weight=L), BL (Backward Linkages for the industry with highest BL levels) & FL (Forward Linkages for the industry with highest FL levels). These changes depict impact of change in energy-technology for our two scenarios- first of 10% & second of 20% replacement. Good changes in order to have a cleaner environment are marked green. Results not expected i.e. no positive effect on environment (values are positive), are marked red. All the other results are evident from previous tables.

# Section 5: Summary & Conclusions

## Summary

It can be concluded that the analysis for the years 1998-99, 2003-04 & 2007-08 for India confirms the expected result of the change in energy technology. Replacement of fossil fuels by solar energy would definitely lead to reduced quantum of pollution i.e. towards a cleaner environment.

In this paper, we analyzed the impacts of a new energy technology, viz. the renewable energy technology which is varying the energy-mix by replacement of fossil fuels by solar energy. The results show that the replacement by 10% solar energy would lead to 0.5% to 30% reduction in the quantum of pollution emissions (It differs with the pollutant type). The replacement by 20% solar energy would lead to reduction in pollution emissions by 0.4% to 31%, which is lower than that of 10% replacement. (Refer Table: 12- TP values for weighted sum of pollution, weight=A).

We have assumed 'no change in the total output' and it is also verified by the results.

When we compare values for other emission coefficients and all the pollutants, values for 20% are seem to be more efficient than that for 10%. Thus it can be inferred that the replacement by solar by 20% is efficient than the replacement by 10%. But, even at the 10% replacement, pollution levels have come down significantly.

This implication justifies the targets by Solar Mission for 9.9% growth. The issue of scale of replacement should be wisely addressed for better results.

## Future scope of work

This study is made for the period prior to the implementation of the Solar Mission. Thus, we find the mission a right move by the Government in order achieve a cleaner environment. The exercise of estimating the impact is proved to be helpful. But for this study purpose, the duration was only for three years. We can increase the scope of this study for larger time-period. Again, as we had mentioned earlier, the solar costing for consequent years was not used, and hence it can also be edited further. We can add other renewable energy sources also to our model.

As mentioned earlier, this analysis is done on the basis of costing of solar energy sector in 2014-15, but the shortcoming is known. And thus, for revised calculations, we may refer to costs for consequent years.

In reality, the energy sector highly relies on the international trade i.e. imports & exports. So it is suggested that this study would be more significant if we club the import matrix with the domestic inter-industry transaction matrix.

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# Appendix

## The Scheme for Consolidation- 115 to 33 sectors

| WIOD Classification Scheme | No. of industries from CSO classifi-cation | CSO Classification Scheme |
|---|---|---|
| Agriculture, Hunting, Forestry and Fishing | 22 | Paddy, Wheat, Jowar, Bajra, Maize, Gram, Pulses, Sugarcane, Groundnut, Coconut, Jute, Cotton, Tea, Coffee, Rubber, Tobacco, Other crops, Milk & Milk Products, Animal services(agricultural), Other li.st.produ., Forestry and logging, Fishing |
| Mining and Quarrying | 10 | Coal and lignite, Natural gas & Crude petroleum, Iron ore, Manganese ore, Bauxite, Copper ore, Other metallic minerals, Limestone, Other non-metallic minerals, Mica |
| Food, Beverages and Tobacco | 8 | Sugar, Khandsari & boora, Hydrogenated oil (vanaspati), Edible oils other than vanaspati, Tea and coffee processing, Miscellaneous food products, Beverages, Tobacco products |
| Textiles and Textile Products | 9 | Khadi & cotton textiles(handlooms), Cotton textiles, Woolen textiles, Silk textiles , Art silk & synthetic fiber textiles, Jute & hemp & mesta textiles, Carpet weaving, Readymade garments, Miscellaneous textile products |
| Leather, Leather and Footwear | 2 | Leather footwear, Leather and leather products |
| Wood and Products of Wood and Cork | 2 | Furniture and fixtures-wooden, Wood and wood products |
| Pulp, Paper, Paper , Printing and Publishing | 2 | Paper, paper prods. & newsprint, Printing and publishing |
| Coke, Refined Petroleum and Nuclear Fuel | 2 | Petroleum products, Coal tar products |
| Chemicals and Chemical Products | 9 | Inorganic heavy chemicals, Organic heavy chemicals, Fertilizers, Pesticides, Paints & varnishes and lacquers, Drugs and medicines, Soaps & cosmetics & glycerine, Synthetic fibers & resin, Other chemicals |
| Rubber and Plastics | 2 | Rubber products, Plastic products |
| Other Non-Metallic Mineral | 3 | Other non-metallic mineral prods., Structural clay products, Cement |
| Basic Metals and Fabricated Metal | 6 | Iron, steel and ferro alloys, Iron and steel -casting & forging, Iron and steel foundries, Non-ferrous basic metals, Hand tools & hardware, Miscellaneous metal products |
| Machinery, Nec | 7 | Tractors and agri. Implements, Industrial machinery(F & T), Industrial machinery(others), Machine tools, Other non-electrical machinery, Office computing machines, Electrical industrial Machinery |

| | | |
|---|---|---|
| Electrical and Optical Equipment | 5 | Electrical wires & cables, Batteries, Electrical appliances, Communication equipments, Other electrical Machinery |
| Transport Equipment | 6 | Ships and boats, Rail equipments, Motor vehicles, Motor cycles and scooters, Bicycles & cycle-rickshaw, Other transport equipments |
| Manufacturing, Nec; Recycling | 3 | Electronic equipments(incl.TV), Watches and clocks, Miscellaneous manufacturing |
| Electricity, Gas and Water Supply | 3 | Electricity, Water supply, Gas |
| Construction | 1 | Construction |
| Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel | 0 | NA |
| Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles | 0 | NA |
| Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods | 1 | Trade |
| Hotels and Restaurants | 1 | Hotels and restaurants |
| Inland, Water and Air Transport | 2 | Railway transport services, Other Transport Services |
| Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies | 1 | Storage and warehousing |
| Post and Telecommunications | 1 | Communication |
| Financial Intermediation | 2 | Banking, Insurance |
| Real Estate Activities | 1 | Ownership of dwellings |
| Renting of M&Eq and Other Business Activities | 0 | NA |
| Public Admin and Defence; Compulsory Social Security | 1 | Public Administration |
| Education | 1 | Education and Research |
| Health and Social Work | 1 | Medical and Health |
| Other Community, Social and Personal Services | 1 | Other services |
| Private Households with Employed Persons | 0 | NA |

# The Scheme for Consolidation- 130 to 35 sectors

| WIOD Classification Scheme | No. of industries from CSO classifi-cation | CSO Classification Scheme |
|---|---|---|
| Agriculture, Hunting, Forestry and Fishing | 26 | Paddy, Wheat, Jowar, Bajra, Maize, Gram, Pulses, Sugarcane, Groundnut, Coconut, Oilseeds, Jute, Cotton, Tea, Coffee, Rubber, Tobacco, Fruits, Vegetables, Other crops, Milk & Milk Products, Animal services(agricultural), Poultry & Eggs, Other li.st.produ., Forestry and logging, Fishing |
| Mining and Quarrying | 11 | Coal and lignite, Natural gas, Crude petroleum, Iron ore, Manganese ore, Bauxite, Copper ore, Other metallic minerals, Limestone, Other non-metallic minerals, Mica |
| Food, Beverages and Tobacco | 8 | Sugar, Khandsari & boora, Hydrogenated oil (vanaspati), Edible oils other than vanaspati, Tea and coffee processing, Miscellaneous food products, Beverages, Tobacco products |
| Textiles and Textile Products | 9 | Khadi & cotton textiles(handlooms), Cotton textiles, Woolen textiles, Silk textiles , Art silk & synthetic fiber textiles, Jute & hemp & mesta textiles, Carpet weaving, Readymade garments, Miscellaneous textile products |
| Leather, Leather and Footwear | 2 | Leather footwear, Leather and leather products |
| Wood and Products of Wood and Cork | 2 | Furniture and fixtures-wooden, Wood and wood products |
| Pulp, Paper, Paper , Printing and Publishing | 2 | Paper, paper prods. & newsprint, Printing and publishing |
| Coke, Refined Petroleum and Nuclear Fuel | 2 | Petroleum products, Coal tar products |
| Chemicals and Chemical Products | 9 | Inorganic heavy chemicals, Organic heavy chemicals, Fertilizers, Pesticides, Paints & varnishes and lacquers, Drugs and medicines, Soaps & cosmetics & glycerine, Synthetic fibers & resin, Other chemicals |
| Rubber and Plastics | 2 | Rubber products, Plastic products |
| Other Non-Metallic Mineral | 3 | Other non-metallic mineral prods., Structural clay products, Cement |
| Basic Metals and Fabricated Metal | 6 | Iron, steel and ferro alloys, Iron and steel -casting & forging, Iron and steel foundries, Non-ferrous basic metals, Hand tools & hardware, Miscellaneous metal products |
| Machinery, Nec | 6 | Tractors and agri. Implements, Industrial machinery(F & T), Industrial machinery(others), Machine tools, Other non-electrical machinery, Electrical industrial Machinery |
| Electrical and Optical Equipment | 5 | Electrical wires & cables, Batteries, Electrical appliances, Communication equipments, Other electrical Machinery |

| | | |
|---|---|---|
| Transport Equipment | 7 | Ships and boats, Rail equipments, Motor vehicles, Motor cycles and scooters, Bicycles & cycle-rickshaw, Other transport equipments ,Aircraft & spacecraft |
| Manufacturing, Nec; Recycling | 5 | Electronic equipments(incl.TV), Watches and clocks, Jems & jewelry, Medical & precision &optical instru.s, Miscellaneous manufacturing |
| Electricity, Gas and Water Supply | 2 | Electricity, Water supply |
| Construction | 1 | Construction |
| Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel | 0 | NA |
| Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles | 0 | NA |
| Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods | 1 | Trade |
| Hotels and Restaurants | 1 | Hotels and restaurants |
| Inland Transport | 2 | Railway transport services, Land tpt including via pipeline |
| Water Transport | 1 | Water Transport |
| Air Transport | 1 | Air Transport |
| Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies | 2 | Supporting and aux. tpt activities, Storage and warehousing |
| Post and Telecommunications | 1 | Communication |
| Financial Intermediation | 2 | Banking, Insurance |
| Real Estate Activities | 2 | Ownership of dwellings, Real estate activities |
| Renting of M&Eq and Other Business Activities | 4 | Renting of machinery & equipment, Computer & related activities, Legal services, Business services |
| Public Admin and Defence; Compulsory Social Security | 1 | Public Administration |
| Education | 1 | Education and Research |
| Health and Social Work | 1 | Medical and Health |
| Other Community, Social and Personal Services | 2 | O.com, social & personal services, Other services |
| Private Households with Employed Persons | 0 | NA |

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