

“Impact of Cleaner Energy in I-O framework with reference to India”

(Topic: ‘Energy Input-Output Modeling’)

Author- Medhavinee Watve¹

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.

1. Ph.D. student at Gokhale Institute of Politics and Economics, Pune, India.

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

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

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

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

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 ($1 \times m$), of coefficients for the industrial emission intensity per unit of fossil fuel burnt. L_1 is a matrix ($m \times n$) 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:

$$\mathbf{X} = \mathbf{Ax} + \mathbf{F} \dots\dots\dots (1)$$

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

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{F} \dots\dots\dots (2)$$

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

$$\mathbf{B} = \hat{\mathbf{x}}^{-1} \mathbf{Z} \dots\dots\dots (3)$$

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

$$(\mathbf{I} - \mathbf{B})^{-1} = \mathbf{G} \quad \text{Ghosh Inverse} \dots\dots\dots (4)$$

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

1) Let \mathbf{P} be ($n \times m$) 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

$$\mathbf{Pe} = \mathbf{P}' * (\mathbf{I} - \mathbf{A})^{-1} * \mathbf{F} \dots\dots\dots (5)$$

2) $\sum a_{ij} p_i$ (Say, Total Pollution, \mathbf{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 \mathbf{A} will change to \mathbf{A}_1 , and so will cause the changes in \mathbf{Pe} and backward-forward linkages. The sum, \mathbf{TP} will also change consequently on the account of changes in \mathbf{A} .

3) $\sum l_{ij} p_i$ (Say, \mathbf{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 \mathbf{L} changes, and causes further changes in \mathbf{Pe} , backward & forward linkages, as well as \mathbf{TPone} .

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

5) The matrix $\mathbf{FL} = \mathbf{P}' * (\mathbf{I} - \mathbf{B})^{-1}$ 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, CO₂ 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 NO_x (nitrogen oxides) in tonnes
- Emissions of SO_x (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	CO ₂	CH ₄	N ₂ O	NO _x	SO _x	CO	NMVOC	NH ₃
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 $Pe = P * (I - A)^{-1} * F$. 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	NM VOC	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	NM VOC	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 $(I-A)^{-1} * P$. 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	NMVOG	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 NMVOG, no value is recognised as 'least' as 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	NM VOC	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	NM VOC	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 $P^*(I-B)^{-1}$. 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 classification	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 classification	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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