IDEC DP² Series Vol. 2 No. 15

Developmnet Discussion Policy Paper

Estimation of sectoral energy and energy-related CO2 emission intensities in Iran: An energy IO approach

Hossein Mirshojaeian Hosseini and Shinji Kaneko

November, 2012

Department of Development Policy
Division of Development Science
Graduate School for International Development and Cooperation (IDEC)
Hiroshima University
1-5-1 Kagamiyama, Higashi-Hiroshima
739-8529 JAPAN

Estimation of sectoral energy and energy-related CO2 emission intensities in Iran: An energy IO approach

Hossein Mirshojaeian Hosseini[ab1]

Shinji Kaneko[a]

[a] *Graduate School for International Development and Cooperation, Hiroshima University, 1-5-1 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8529 Japan.*

[b] *Faculty of Economics, University of Tehran, Kargar Shomali Ave., Tehran 141556445 Iran IR.*

Abstract:

Iran is experiencing ever-increasing domestic energy consumption and CO2 emissions, mostly due to its price control policy. The first step in designing any conservation policy is the quantification of sectoral total, direct and indirect energy intensities to track the sectors or commodities responsible for increasing energy consumption and CO2 emissions. Energy input–output (E-IO) analysis is a frontier method for assessing resource and pollutant embodiments in goods and services on a macroeconomic scale that is popular among researchers. This paper is the first attempt to apply this approach to quantify energy and energy-related CO2 emissions in Iran. Based on the results, the sectors with the highest potentials for conservation, which are simultaneously the main consumers of energy and have the highest energy intensities, are the road transportation sector, the sectors that produce basic mineral, metal and chemical products, the construction sector, the food industry and the agricultural and livestock sectors. Although the energy consumption pattern is distorted by cheap energy prices, our study shows that the energy theory of value still applies in Iran.

Keywords: Energy input–output, Iran, energy intensity, energy-related CO2 intensity

JEL classification: C67, Q43, Q58

[1] Corresponding author, E-mail: mirshojaeian@hiroshima-u.ac.jp, mirshojaeian@ut.ac.ir, Tel.:+98-9126509760.

1. Introduction

Like most of the oil-exporting countries, Iran is experiencing ever-increasing domestic energy consumption and CO_2 emissions, mostly due to its price control policy. In 1967, final energy consumption was 49.58 MBOE[1], but by 2008 it had reached 993.65 MBOE (Fig. 1). This translates to the Iranian economy experiencing, on average, a 7.73% increase in final energy consumption per year over the last four decades. The same pattern exists for CO_2 emissions. CO_2 emissions rose 5.61% annually over the same period, from 67.94 MT[2] in 1967 to 537.40 MT in 2008 [1–2].

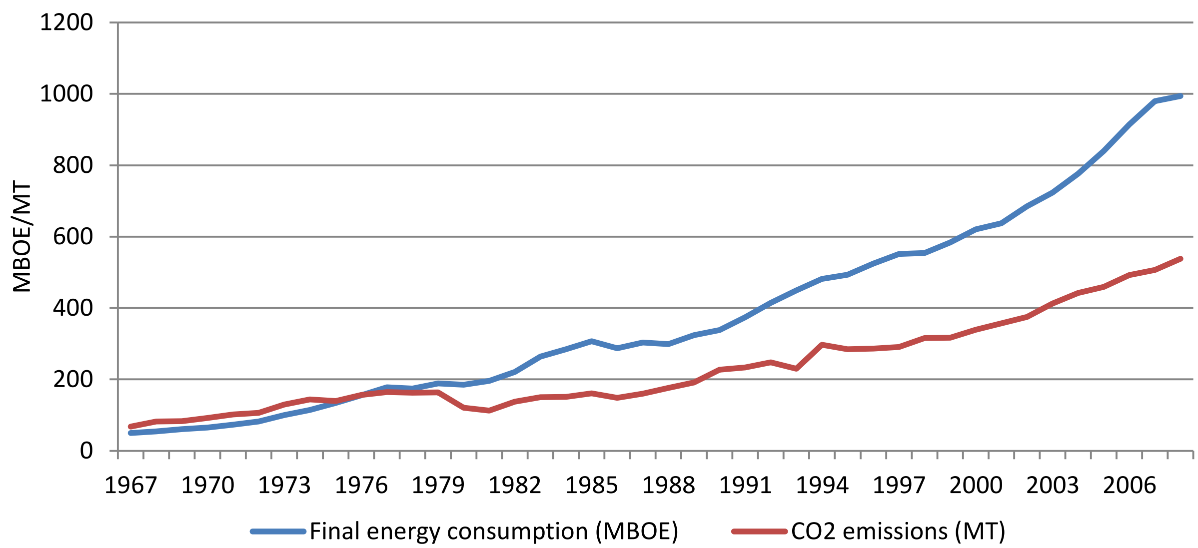

Fig. 1. The trend in final energy consumption and CO2 emissions in Iran (1967–2008)

Since the 1980s, the main contributors to total energy consumption have been the residential, public and commercial (RPC) sector and the transportation sector. As Fig. 2 shows, the energy consumption pattern has not altered in Iran in terms of the main contributors over the last few decades. The RPC and transportation sectors accounted for 39% and 29% of final energy consumption in 1980, respectively; by 2009, their respective shares were 41% and 30%. Indeed, the main change occurred as a result of a change in fuel consumption from refined petroleum to natural gas, especially in the RPC and industrial

[1] Million Barrels Oil Equivalent
[2] Million Tons

sectors. Whereas refined petroleum comprised 80% of total energy consumption in the RPC and industrial sectors in 1980, it accounted for only 17% and 25%, respectively, of the required energy for these sectors in 2009. On the other hand, the share of natural gas used by these sectors increased from 7% (for both) to 68% and 61%, respectively, over the same period [1].

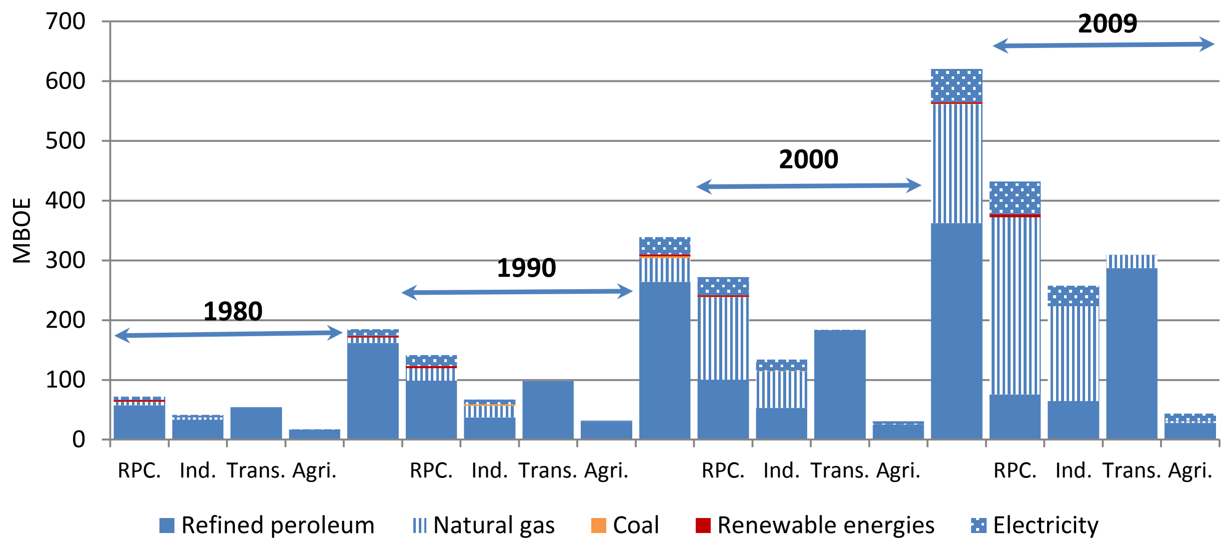

Fig. 2. Decomposition of final energy consumption by sector and fuel type in Iran (1980, 1990, 2000 and 2009)

An international comparison of patterns of energy consumption shows that one of the main reasons for the tremendous and seemingly uncontrollable upward trend in energy consumption and CO2 emissions in Iran is high energy intensity. When the average global primary and final energy intensities were 189 and 118 TOE[1]/million USD (PPP) in 2009, the respective energy intensities in the same year were about 374 and 245 in Iran, almost twice the global averages [3]. Fig. 3 depicts the trend in energy and CO2 intensities in Iran over the period 1980–2008. It is obvious that energy and CO2 intensities have risen rapidly, from 1.12 BOE[2]/million IRR and 0.73 tons/million IRR in 1980, respectively, to 2.20 and 1.26, respectively, by the middle of the 1990s, and so far they remain unchanged. It is noteworthy that in the

[1] Tons Oil Equivalent
[2] Barrels Oil Equivalent

calculation of the above intensities, the value addition of the oil and natural gas sector was deducted from GDP to provide a more realistic picture of the Iranian economy [1, 4].

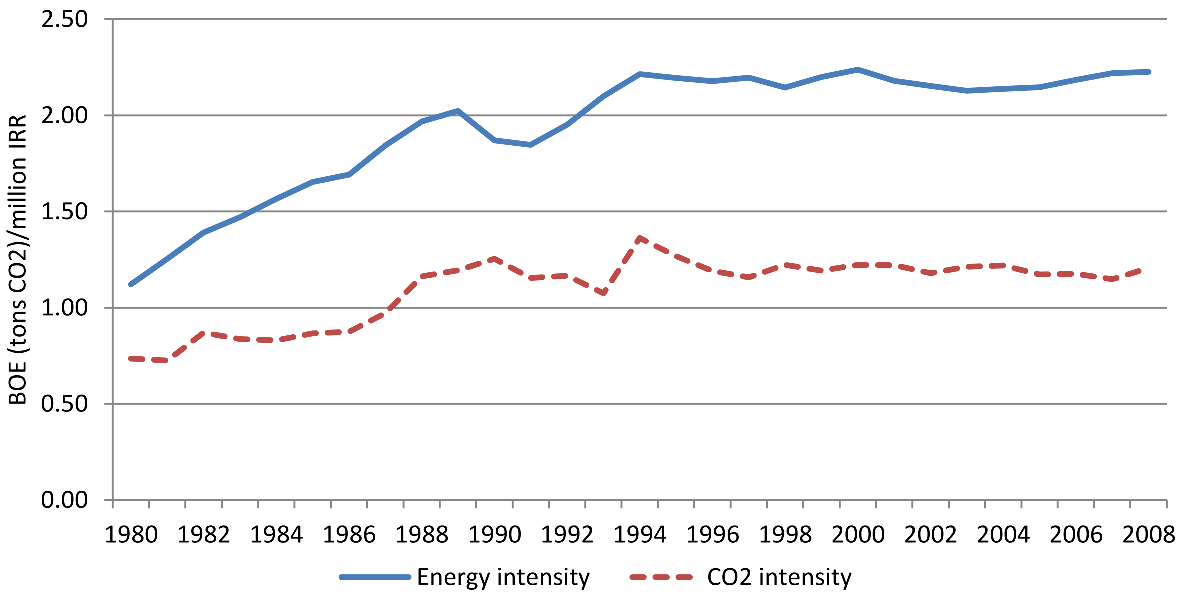

Fig. 3. Trend in energy and CO2 intensities in Iran (1980–2008)

Different studies have been carried out to find out the determinants of the high energy and CO2 intensities in Iran. Using an index decomposition analysis (IDA), Sharifi et al. [5] showed that structural changes have had little effect in decreasing the energy intensity in the manufacturing industries in Iran. Behboudi et al. [6] attempted to identify the key factors affecting energy intensity in Iran by applying an IDA over the period 1968–2006. Their results indicated that increasing energy intensity was the result of the reduction of productivity and changes in the structure of economic activities. In addition, they found that energy prices play a critical role in determining energy intensity in Iran. The results of the study of Fotros and Barati [7] indicated that economic activities have had the largest positive effect on CO2 emissions in the economy, with the exception of the industrial and transportation sectors. For these two sectors, structural changes have been the main driver of CO2 emissions. Sadeghi and Sojoodi [8] studied the determinants of energy intensity in Iranian manufacturing firms. A firm's size, ownership type, capital intensity and the wage level have significant impacts on energy intensity.

The first step in designing any conservation policy is the quantification of sectoral total, direct and indirect energy intensities to track the sectors or commodities responsible for increasing energy consumption and CO2 emissions. The energy consumed by each sector and the pollutants they emit are referred to as the direct energy and pollution requirements. When a sector consumes goods and services, it causes environmental pressures and resource depletion through indirect consumption of energy and the emission of pollutants to produce corresponding commodities. The sum of these direct and indirect requirements of resources and pollutants is referred to as the sector's total requirements [9]. By determining the direct and indirect requirements, the amounts of required direct and indirect energy use for producing one unit of value added can be measured in each sector, known as the direct and indirect energy intensity of that sector. Understanding energy and CO2 intensities paves the way to assessing the effectiveness of any conservation policies at national, regional, or firm levels.

Energy input–output (E-IO) analysis is a frontier method that is popular among researchers for assessing resource and pollutant embodiments in goods and services on a macroeconomic scale [9–23]. Using IO analysis, Lenzen [10] examined the direct and indirect primary energy and GHG requirements for a given set of Australian final consumption. Lababderira and Labeaga [11] used the IO method to obtain the energy-related CO2 intensity for the Spanish economy in 1992. Using the estimated CO2 intensities, they performed a structural decomposition and estimated the price effect of several hypothetical carbon taxes levied on fossil fuel consumption. Lenzen et al. [9] used IO analysis and detailed household expenditure data to yield comprehensive energy use breakdowns for the 14 statistical subdivisions of Sydney. They used multivariate regression and structural path analysis to interpret the results. Cohen et al. [12] used a generalized input–output model in order to calculate the energy embodied in goods and services purchased by Brazilian households of different income levels in 11 major cities in Brazil.

Using a uniform energy price, Park and Heo [13] transformed monetary IO tables to energy IO tables and studied the direct and indirect energy requirements of Korean households over the period 1980–2000. Limmeechokchai and Suksuntornsiri [14] quantified the embedded energy and total GHG emissions in final consumption in Thailand. Tarancón and González [15] and Tarancón and Río [16] proposed a combined IO and sensitivity analysis approach to determine the most CO2-emission-intensive productive relationships. Chung et al. [17] used a hybrid E-IO table to calculate sectoral energy and GHG emission intensities caused by energy use in Korea. Chung et al. [18] decomposed energy and emission factors derived from Korean E-IO tables into three affecting factors, i.e., an energy consumption effect, a social effect and a technological effect, over the period 1980–2005. Kerkhof et al. [19] employed an environmentally extended IO table for the Netherlands and combined it with household expenditure data to evaluate the relationships between household expenditures and multiple environmental impacts, i.e., climate change, acidification, eutrophication and smog formation. Zhou et al. [20] used an ecological IO table for Beijing to estimate the resource use and GHG emissions in the Beijing economy in 2002. Chen and Zhang [21] employed an inventory and IO analysis to measure the GHG emissions embodied in the final consumption and international trade of the Chinese economy in 2007. Using an ecological endowment inventory and ecological IO model, Chen and Chen [22] investigated GHG emissions and natural resources used in the global economy in 2000. Finally, Cellura et al. [23] introduced an energy and environmental extended IO model and combined it with a Life Cycle Assessment methodology to study the energy and environmental impacts of Italian households' consumption.

This paper is the first attempt to quantify sectoral energy and CO2 emission intensities for the Iranian economy, and to detect the sectors with the highest potential in terms of reducing energy consumption and CO2 emissions. The structure of the paper is as follows. In the second section, the methodology of E-IO analysis is explained. The third section explains the results and discusses the intensities from the fuel and sectoral standpoints. The last section concludes the paper, summarizes the main findings and explains the limitations of the research.

2. The methodology of energy input–output analysis

Increasing oil prices during the late 1960s and the 1970s drew the attention of researchers and policy makers to studying the role of energy in the economy. IO models were appropriate tools to study the role of energy and the impact of energy conservation policies at the macro level. The traditional approach to E-IO analysis was developed by Strout [24] and Bullard and Herendeen [25]. They included energy in the traditional IO analysis by defining a matrix of direct energy coefficients (D). Matrix D is the amount of energy type k required directly to produce a dollar's worth of each producing sector's output. This matrix could be derived by calculating $D=AP^{-1}$, where P is the implied energy price and A is the technical coefficient matrix. Therefore, total interindustry energy coefficients can be obtained from $D(I-A)^{-1}$. The deficiency of this approach is that it provides internally consistent results only when these energy prices are the same across all consuming sectors (including final energy) for each energy type [26]. It is obvious that the condition of uniform prices does not hold in most countries.

As Chapman [27] and Wright [28] pointed out, matrices expressed in purely monetary terms do not correctly reflect supplies from the energy industries if the energy prices vary across different industries. This problem can be overcome if the monetary values in the IO table rows for the energy sectors are replaced by values expressed in energy units. Therefore, the new E-IO table is composed of “hybrid units” whereby energy flows are expressed in convenient energy units (such as MBTU[1]) and nonenergy flows are expressed in monetary units (such as million IRR).

Our E-IO table in this study was constructed in four steps. First, the last monetary IO table in Iran, published in 2001, was obtained from the Statistical Center of Iran [29]. The IO table of 2001 is a commodity table consisting of 91 sectors, including five energy sectors, i.e., crude oil and natural gas, coal, electricity, natural gas and refined petroleum products. Using the use table, the energy sectors were extended to 10 sectors. When the energy prices have been set by the government in Iran, they can be used for our preliminary conversion of monetary units to energy units (million BTU) [1]. To obtain more accurate results, all available reports were used, such as the Energy Balances of Iran and Transportation Energy Data, to replace the more accurate energy flow data with energy flows obtained from unit conversion by average energy prices [1, 30–32]. Data for energy prices in 2001 are reported in Table 1.

Table 1

Domestic prices for different final energies in 2001

Row	**Energy type**	**Price in 2001**
1	Coal (IRR/Kg)	620
2	Electricity (IRR/kWh)	Residential: 72.93; Public: 99.59; Commercial: 273.86; Industrial: 133.58; Agricultural: 11.5
3	Natural gas (IRR/m3)	Power plant: 22; Commercial and public: 133; Industrial: 115; Education and sport: 81; Residential (average): 60.5; Transport: 60.5; Refinery plant: 22; Petrochemical plant: 66.66
4	Gasoline (IRR/Liter)	450
5	Kerosene (IRR/Liter)	120
6	Gas oil (IRR/Liter)	120
7	Fuel oil (IRR/Liter)	64.2
8	LPG (IRR/Liter)	150

[1] Million British Thermal Units

Note: The official and market exchange rates were 1755 and 7925 IRR/USD in 2001, respectively.

In the second step, and following the energy conservation condition, energy use of all energy sectors was set to zero to avoid double counting [33] and energy consumption of nonenergy sectors was multiplied by energy loss coefficients [26]. It is noteworthy that from the authors' point of view, knowing the sectors that are really responsible for energy consumption and CO2 emission is more important than determining those that directly consume energy and emit pollutants. As Labanderia and Labeaga [11] mentioned, for instance, electricity-related energy consumption and CO2 emissions should not be exclusively imputed to the electricity industry, because nonenergy sectors that are consumers of electricity are indeed responsible for production of electricity directly and, consequently, responsible for the consumption of primary energy and CO2 emissions indirectly. Calculating the energy and CO2 emission intensities of the final energies makes it possible to recognize actual responsibility for increasing energy consumption and CO2 emissions.

In the third step, the Hawkins–Simon (H-S) conditions should be checked [34]. The H-S conditions ensure that, to obtain a nonnegative solution in a Leontief model [35]: 1) all the diagonal elements in the matrix (I-A) must be positive, and all the off-diagonal elements must be nonpositive; and 2) the determinants of all leading principle submatrices (minors) in the matrix (I-A) should be positive [17]. The E-IO table constructed in our study satisfied both conditions.

In the last step, the E-IO analysis is performed to derive the energy intensity of each sector stemming from the direct and indirect domestic consumption of the energy carriers. Then, the CO2 intensities can be calculated by multiplying energy intensities of the sectors to their respective CO2 emissions factors. The procedure for estimating energy and CO2 emission intensities is described in the next section.

2.1 Estimation of energy and CO2 emission intensities

In this section, we first explain the basic and original procedure for estimation of energy and CO2 emission intensities, and then apply our modifications to it. Although monetary and energy units exist in an E-IO table simultaneously, we have to redefine the conventional IO matrices. The basic procedure for performing an E-IO analysis was introduced by Miller and Blair [35]. Whereas n is the number of all sectors and k is the number of energy sectors, Z^* $(n \times n)$, X^* $(n \times 1)$ and Y^* $(n \times 1)$ are the new transaction matrix, the new total output vector and the new final demand vector, respectively. F^* $(n \times 1)$ is an artificial vector that is used to isolate the energy rows during matrix manipulation. These matrices are defined as follows:

$$Z_i^* = \begin{cases} Z_j & \text{for nonenergy rows} \\ E_k & \text{for energy rows} \end{cases}$$
$$X_i^* = \begin{cases} X_j & \text{for nonenergy rows} \\ F_k & \text{for energy rows} \end{cases}$$
$$Y_i^* = \begin{cases} Y_j & \text{for nonenergy rows} \\ e_k & \text{for energy rows} \end{cases}$$
$$F_i^* = \begin{cases} 0 & \text{for nonenergy rows} \\ F_k & \text{for energy rows} \end{cases} \quad (1)$$

In Eq. (1), Z_j, X_j and Y_j are expressed in monetary terms and E_k, F_k and e_k are expressed in energy units. Therefore, the above matrices have the following format:

$$Z^* = \begin{bmatrix} MBTU & MBTU \\ Mil.IRR & Mil.IRR \end{bmatrix}; \quad X^* = \begin{bmatrix} MBTU \\ Mil.IRR \end{bmatrix}; \quad Y^* = \begin{bmatrix} MBTU \\ Mil.IRR \end{bmatrix}; \quad F^* = \begin{bmatrix} MBTU \\ 0 \end{bmatrix}. \quad (2)$$

The new technical coefficient matrix (A*) and the new Leontief matrix (L*) can be defined as usual:

$$A^* = Z^*(\hat{X}^*)^{-1} = \begin{bmatrix} \frac{MBTU}{MBTU} & \frac{MBTU}{Mil.IRR} \\ \frac{Mil.IRR}{MBTU} & \frac{Mil.IRR}{Mil.IRR} \end{bmatrix}; \quad L^* = (I - A^*)^{-1}. \quad (3)$$

By using the A* and L* matrices, the sectoral direct energy coefficients (EI_δ) and the sectoral total or embodied energy coefficients (EI_α) can be calculated by the following equations:

$$EI_\delta = \hat{F}^*(\hat{X}^*)^{-1} A^*; \quad EI_\alpha = \hat{F}^*(\hat{X}^*)^{-1}(I - A^*)^{-1}. \quad (4)$$

In the above coefficient matrices, the values of the energy sectors are expressed in terms of MBTU/MBTU, which is the energy ratio of k energy sectors. What are important for us are the values of the nonenergy sectors, expressed in terms of MBTU/million IRR, which are in fact the energy intensities in the nonenergy sectors. Using a symmetric matrix of CO_2 emission factors (M ($n \times n$)), the sectoral direct CO2 emission coefficients (GI_{δ}) and the sectoral total or embodied CO2 emission coefficients (GI_{α}) can be calculated as follows [17]:

$$GI_{\delta} = \hat{F}*(\hat{X}*)^{-1}MA*; \quad GI_{\alpha} = \hat{F}*(\hat{X}*)^{-1}M(I-A*)^{-1}. \tag{5}$$

We have made three modifications to the above procedure:

1- As mentioned before, one of our targets is recognizing the sources of ever-increasing energy consumption and CO2 emissions in Iran. Therefore, we made the above analysis for the final energies consumed by utilizers.

2- To avoid the double counting problem, the energy consumption of the energy sectors was set to zero. While the crude oil and natural gas products are consumed by all the other energy sectors or exported to the global market, this sector was dropped from the analysis.

3- The assumption behind Eqs. (4) and (5) is equal energy and CO2 intensities of domestic and imported commodities. A problem with this assumption is that many of the countries from which the imports originate face different energy and CO2 intensities [10]. To solve this problem, the energy coefficients are purified by using the import coefficient matrix ($\hat{M}* = I\hat{M}(\hat{X}*)^{-1}$) and calculating the direct and embodied domestic energy coefficients (EI_{δ}^{d} and EI_{α}^{d}) as follows:

$$EI_{\delta}^{d} = \hat{F}*(\hat{X}*-\hat{M}*)^{-1}(I-\hat{M}*)A*; \quad EI_{\alpha}^{d} = \hat{F}*(\hat{X}*-\hat{M}*)^{-1}(I-(I-\hat{M}*)A*)^{-1}. \tag{6}$$

The same analysis was carried out to calculate the domestic CO2 emission coefficients. All of the intensities that will be reported in this study are domestic intensities.

3. Results and discussion

As explained before, the E-IO analysis was applied to the 95×95 IO table for the 2001 Iranian economy. Table 2 presents the descriptions and categorization of sectors. In the IO table, the first nine sectors are energy sectors providing final energies for domestic utilizers. The agricultural and mining sectors contain six and five subsectors, respectively. The most elaborate sectors in the IO table are the industrial and service sectors, consisting of 29 and 46 subsectors, respectively.

In 2001, the gross domestic product (GDP) of Iran was 737,909 billion IRR (92.61 billion USD) including the oil sector or 614,177 billion IRR (77.50 billion USD) excluding the oil sector. Producing 10.40 billion USD, the agricultural sector accounted for 11.27% of total GDP. The share of the mining and industrial sector was 34.70%, while its production was valued at 32.01 billion USD. The biggest economic sector in Iran is the service sector, which produced 48.02 billion USD and accounted for 52.05% of the total economy in 2001.

Table 2

Description of the 95 sectors in the input–output table for Iran

Sector categories	Name and code of sectors		
Energy sectors	1- Coal	2- Electricity	3- Natural gas
	4- Gasoline	5- Kerosene	6- Gas oil
	7- Fuel oil	8- LPG	9- Other refined petroleum products
Agricultural sectors	10- Agricultural products	11- Horticulture and market gardening products	12- Live animals and animal products
	13- Products of bees and silkworms	14- Forestry and logging products	15- Fish and other fishing products
Mining and industrial sectors	16- Iron ores and concentrates	17- Copper, ores and concentrates	18- Stone, sand and clay
	19- Other minerals	20- Water	21- Animal and vegetable oils and fats
	22- Other foods and beverages	23- Tobacco products	24- Textiles
	25- Wearing apparel	26- Leather and leather products; footwear	27- Products of wood, cork, straw and plaiting materials
	28- Pulp, paper and paper products; printed matter and related articles	29- Basic chemicals and chemical products	30- Rubber and plastics products
	31- Glass and glass products	32- Other mineral products	33- Furniture
	34- Basic iron and steel and their products	35- Other metals	36- Metal products
	37- General-purpose machinery	38- Special-purpose machinery	39- Domestic appliances and parts thereof
	40- Office, accounting and computing machinery	41- Electrical machinery and apparatus	42- Radio, television and communication equipment and apparatus
	43- Medical and surgical equipment and orthopedic appliances	44- Optical and measurement instruments, watches and clocks	45- Motor vehicles, trailers and semi-trailers
	46- Other vehicles	47- Jewelry and other unclassified products	48- Residential construction
	49- Other constructions		
Service sectors	50- Wholesale and retail trade services	51- Lodging services	52- Food and beverage serving services
	53- Railway transport	54- Road passenger transport	55- Road freight transport
	56- Pipeline transport	57- Water transport	58- Air transport
	59- Supporting and auxiliary transport	60- Postal and telecommunication	61- Banking services

	services	services	
	62- Investment banking and financial intermediation services	63- Insurance and pension services	64- Renting services of own residential construction
	65- Renting services of rental residential construction	66- Renting services of rental nonresidential construction	67- Trade services of real states
	68- Leasing or rental services without operator	69- Research and development services	70- Computer and information services
	71- Other professional, technical and business services	72- Agriculture, raising livestock and mining services	73- Maintenance, repair and installation (except construction) services
	74- News agency services	75- Administrative services of the government	76- Military and civil defense services
	77- Police and fire protection services	78- Social security services	79- Public primary education services
	80- Private primary education services	81- Public secondary education services	82- Private secondary education services
	83- Public university education services	84- Private university education services	85- Other education and training services
	86- Hospital services	87- Medical and dental services	88- Other human health services
	89- Veterinary services	90- Social services	91- Religious services (Masjids, etc.)
	92- Arts-related services	93- Recreational and sporting services	94- Museum and library services
	95- Other services		

3.1 Direct and indirect energy intensities by sector

Fig. 4 represents the energy intensities of the Iranian nonenergy sectors in 2001. Furthermore, Table 3 shows the energy intensities of the top 20 sectors. As is obvious, the highest energy intensity belongs to the "pipeline transport" sector, which consumes 90.26 BTU/IRR (or 715,310 BTU/USD). This sector is a relatively small sector that contributes less than 1% to the total GDP. However, the importance of this sector is due to its strong backward linkage (the backward linkage multiplier is about 1.89), in particular, the role of the sector in transportation of raw crude oil, natural gas and refined petroleum products in this energy exporting country. The second-highest energy intensity is for the "other mineral products" sector. This sector, producing ceramic ware, clay products, cement, lime, plaster, concrete, building stone, nonmetallic mineral products and prefabricated buildings, consumes 22.54 BTU for production of one rial of value added in this sector (or 178,629 BTU/USD). As for the transportation sector, the "other mineral products" sector consumes most of its required energy directly. The third place is owned by the "road freight transport" sector, which has an energy intensity of around 15.51 BTU/IRR (or 122,916 BTU/USD). The size of the last two sectors is substantial, accounting for 1.96% and 2.49% of total GDP in 2001, respectively. This means there is an opportunity for the Iranian economy to mitigate the energy consumption of the corresponding sectors by reducing their direct energy intensities. A list of the direct and indirect energy intensities of the sectors can be found in Appendix A.1.

As Fig. 4 shows, most of the nonenergy sectors consumed their required energy directly. The main exceptions are some service and industrial sectors. The services of rental own, residential and nonresidential constructions have negligible direct energy consumption and thus consume energy mostly through their nonenergy inputs. The next main exclusions are the construction sectors, which consume close to 95% of their required energy indirectly. Out of a total of 86 nonenergy sectors, 32 sectors have indirect energy intensities that exceed their direct intensities. The sectors “office, accounting and computing machinery”, “insurance and pension services” and “radio, television and communication equipment and apparatus” had the lowest energy intensities of all the sectors. The total energy intensities of these sectors were 0.14, 0.56 and 0.65 BTU/IRR, respectively.

Generally, taking a macro view, most of the fuels (except coal) were being consumed directly in the nonenergy sectors in 2001. As shown in Table 4, 59.88% of total energy was consumed directly by sectors, while 40.12% was consumed through the consumption of nonenergy inputs. Kerosene has the highest share of direct consumption, with 66.59% of total kerosene consumed directly, mostly by “basic chemicals and chemical products” (20.28%), “pipeline transport” (8.60%) and “maintenance, repair and installation services” (7.35%). The ratio of direct consumption for gasoline was 63.21%, with the main direct sectoral consumers being “road freight transportation” (42.77%) and road passenger transportation (30.12%). Electricity had a direct consumption share of 62.56%. The main sectoral direct utilizers of electricity were “agricultural products” (16.33%), “horticulture and market gardening products” (16.08%) and “wholesale and retail trade services” (11.08%). The share of direct consumption for natural gas is 60.17%, with the sectors “basic chemicals and chemical products” (21.21%), “basic iron and steel and their products” (18.16%) and “wholesale and retail trade services” (14.30%) being the main direct consumers. In terms of the total sectoral consumption of gas oil, 57.84% of it is consumed directly. The main consumers are “road freight transport” (55.61%), “wholesale and retail trade services” (7.65%) and “road passenger transport” (6.68%). The share of direct consumption of fuel oil is 54.46%. The major part of this fuel was directly consumed by “other mineral products” (61.51%).

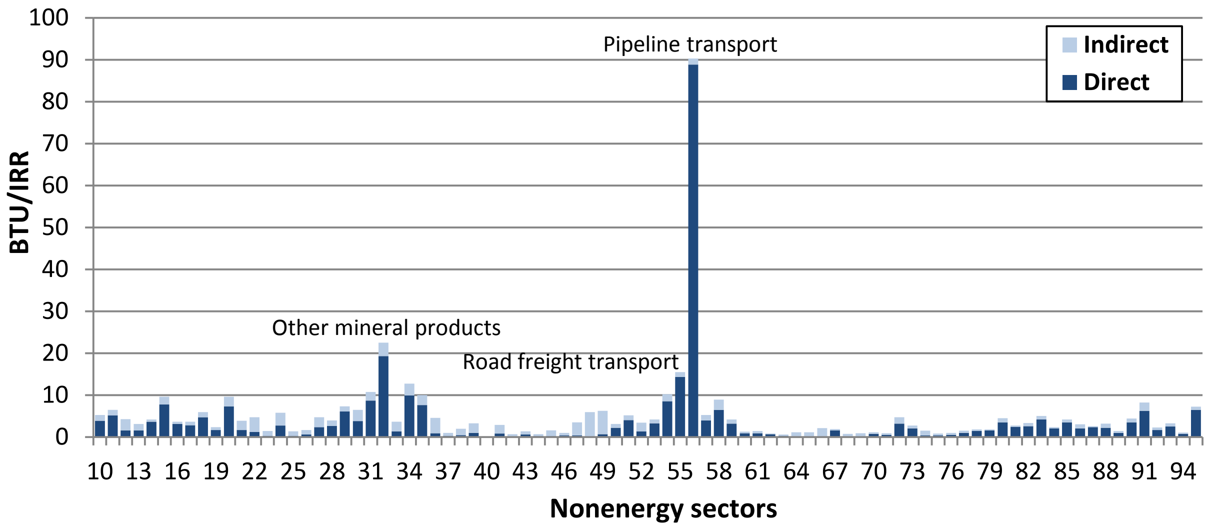

Fig. 4. Direct and indirect energy intensities of nonenergy sectors in Iran

Table 3

Top 20 sectors in terms of energy intensities in the Iranian economy

Code	Sector name	Category	Energy intensity (BTU/IRR)		
			Total	Direct	Indirect
56	Pipeline transport	Ser.	90.26	88.80	1.45
32	Other mineral products	Ind.	22.54	19.27	3.27
55	Road freight transport	Ser.	15.51	14.33	1.17
34	Basic iron and steel and their products	Ind.	12.70	9.88	2.82
31	Glass and glass products	Ind.	10.77	8.67	2.10
54	Road passenger transport	Ser.	10.22	8.57	1.65
35	Other metals	Ind.	9.96	7.59	2.36
20	Water	Min.	9.60	7.31	2.29
15	Fish and other fishing products	Agri.	9.59	7.79	1.80
58	Air transport	Ser.	8.92	6.46	2.46
91	Religious services (Masjids, etc.)	Ser.	8.25	6.21	2.03
29	Basic chemicals and chemical products	Ind.	7.33	6.09	1.24
95	Other services	Ser.	7.22	6.48	0.74
30	Rubber and plastics products	Ind.	6.51	3.77	2.73
11	Horticulture and market gardening products	Agri.	6.46	5.20	1.26

49	Other constructions	Ind.	6.27	0.70	5.58
48	Construction of residential buildings	Ind.	5.97	0.08	5.89
18	Stone, sand and clay	Min.	5.97	4.69	1.28
24	Textiles	Ind.	5.83	2.71	3.12
57	Water transport	Ser.	5.24	3.93	1.31

Note: Agri. = Agricultural, Min. = Mining, Ind. = Industrial, Ser. = Service

3.2 Total energy intensities by fuel type

Fig. 5 depicts the composition of sectoral energy intensities in Iran by their fuels. The main contributors to the energy consumption of the pipeline transportation sector are natural gas (37% of the sector's energy intensity), fuel oil (26%), electricity (15%) and kerosene (12%). The energy consumption pattern of the "other mineral products" sector is simpler, with 54% of total energy consumption in this sector due to the consumption of fuel oil. The next main energy carriers are electricity, natural gas and gas oil, accounting for 18%, 11% and 9% of the total energy intensity of this sector, respectively. Gas oil and gasoline are the main energies consumed in the "road freight transport" sector.

The main energy carriers consumed in the nonenergy sectors were electricity, gas oil and natural gas. The total amount of sectoral electricity consumption was 1,326.55 TBTU, which accounted for 27.46% of total energy consumption by the nonenergy sectors in 2001. When the sectors consumed 1,272.85 TBTU, they covered 26.35% of their total energy requirements by consumption of gas oil directly and indirectly. Natural gas is the third most used energy carrier consumed by different nonenergy sectors. In 2001, the amount of natural gas consumption reached 886.82 TBTU, accounting for 18.36% of total energy consumption by the sectors.

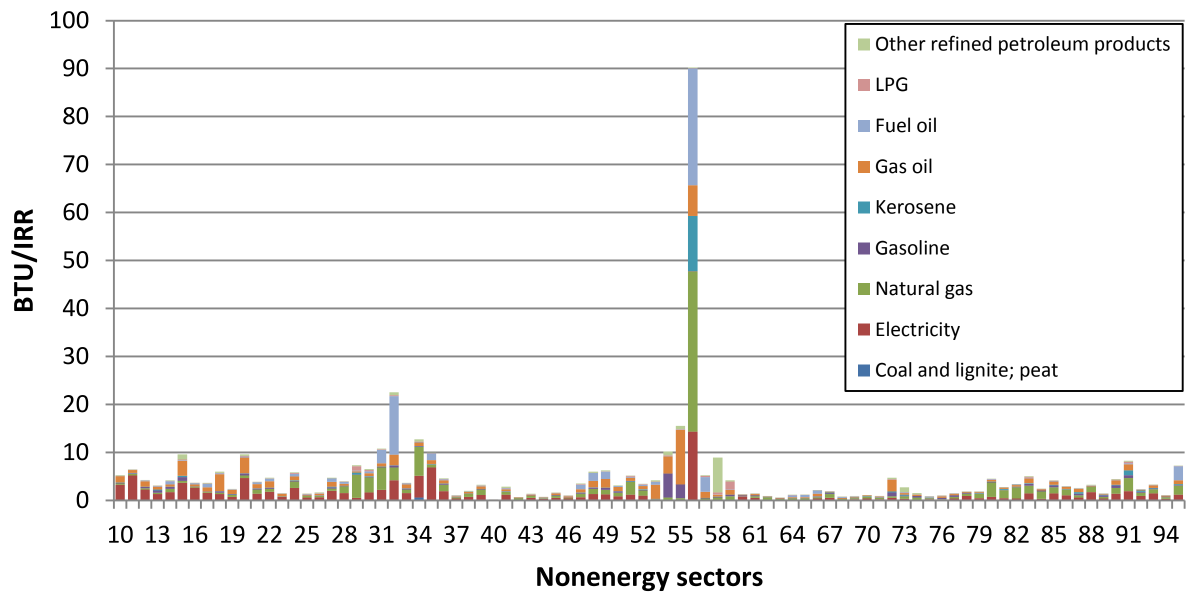

Fig. 5. Total energy intensity of the nonenergy sectors by fuel types

Table 4

Direct and indirect energy consumption and CO2 emissions by fuel type and their shares in Iran (2001)

Energy type	Direct energy consumption		Indirect energy consumption		Total energy consumption		Shares of direct and indirect energy consumption			Direct CO2 emissions		Indirect CO2 emissions		Total CO2 emissions		Shares of direct and indirect CO2 emissions		
	Direct (TBTU)	Share of fuel (%)	Indirect (TBTU)	Share of fuel (%)	Total (TBTU)	Share of fuel (%)	Direct (%)	Indirect (%)	Total (%)	Direct (MT)	Share of fuel (%)	Indirect (MT)	Share of fuel (%)	Total (MT)	Share of fuel (%)	Direct (%)	Indirect (%)	Total (%)
Coal and lignite; peat	9.36	0.32	9.80	0.51	19.16	0.40	48.85	51.15	100.00	0.93	0.48	0.98	0.74	1.91	0.58	48.85	51.15	100.00
Electricity	829.84	28.69	496.71	25.63	1,326.55	27.46	62.56	37.44	100.00	50.40	25.74	30.17	22.85	80.57	24.58	62.56	37.44	100.00
Natural gas	533.57	18.45	353.25	18.23	886.82	18.36	60.17	39.83	100.00	31.85	16.26	21.09	15.98	52.94	16.15	60.17	39.83	100.00
Gasoline	239.89	8.29	139.62	7.21	379.51	7.86	63.21	36.79	100.00	17.76	9.07	10.20	7.73	27.96	8.53	63.52	36.48	100.00
Kerosene	47.19	1.63	23.68	1.22	70.88	1.47	66.59	33.41	100.00	3.34	1.71	1.68	1.27	5.02	1.53	66.59	33.41	100.00
Gas oil	736.16	25.45	536.68	27.70	1,272.85	26.35	57.84	42.16	100.00	54.42	27.79	39.67	30.05	94.09	28.70	57.84	42.16	100.00
Fuel oil	313.77	10.85	262.42	13.54	576.19	11.93	54.46	45.54	100.00	22.82	11.65	19.09	14.46	41.90	12.78	54.46	45.54	100.00
LPG	47.49	1.64	36.32	1.87	83.81	1.74	56.66	43.34	100.00	3.21	1.64	2.44	1.85	5.65	1.72	56.76	43.24	100.00
Other refined petroleum products	135.09	4.67	79.25	4.09	214.34	4.44	63.03	36.97	100.00	11.11	5.67	6.70	5.07	17.81	5.43	62.39	37.61	100.00
Total	2,892.36	100.00	1,937.74	100.00	4,830.11	100.00	59.88	40.12	100.00	195.85	100.00	132.01	100.00	327.86	100.00	59.74	40.26	100.00

3.3 CO2 emission intensities and the contribution of fuels

Table 5 shows the top 20 sectors that had the largest CO2 emission intensities in 2001. The sectors are virtually identical to the top 20 sectors with the highest energy intensities, with only small differences in the ranking. This is a reasonable finding given that most final energies in Iran have a hydrocarbon base. Out of a total nominal capacity of 34,222 MW of electricity production in 2001, the capacity of the hydropower plants was only 1,999 MW, about 5.84% of the total capacity. The remainder belonged to diesel, natural gas and steam power plants, all of which consume hydrocarbon fuels.

The “pipeline transport”, “other mineral products” and “road freight transport” sectors have the highest sectoral CO2 emission intensities. “Pipeline transport” emits 5.94 tons of CO2 for production of one million IRR. In other words, for production worth one USD, it emits 47.12 kg of CO2. The intensities for “other mineral products” and “road freight transport” sectors are 1.56 and 1.15 tons CO2/million IRR, respectively, or 12.38 and 9.11 kg CO2/USD, respectively. In a similar pattern to the sectoral ranking for energy intensities, the sectors “office, accounting and computing machinery”, “insurance and pension services” and “radio, television and communication equipment and apparatus” have the lowest CO2 emission intensities, i.e., 0.009, 0.037 and 0.042 tons CO2/million IRR, respectively. The list of CO2 emission intensities of the Iranian nonenergy sectors can be found in Appendix A.2.

Table 5

Top 20 sectors in terms of CO2 emission intensities in the Iranian economy

Code	Sector name	Category	CO2 emission intensity (kg/million IRR)		
			Total	Direct	Indirect
56	Pipeline transport	Ser.	5,945.90	5,844.35	101.55
32	Other mineral products	Ind.	1,563.26	1,332.32	230.94
55	Road freight transport	Ser.	1,150.22	1,068.33	81.89
34	Basic iron and steel and their products	Ind.	811.98	625.10	186.88
54	Road passenger transport	Ser.	756.04	638.76	117.28
31	Glass and glass products	Ind.	696.79	556.76	140.03
15	Fish and other fishing products	Agri.	663.05	539.95	123.10
58	Air transport	Ser.	650.47	477.27	173.21
20	Water	Min.	641.65	486.19	155.45
35	Other metals	Ind.	636.44	478.40	158.04
91	Religious services (Masjids, etc.)	Ser.	542.98	406.76	136.21

95	Other services	Ser.	488.20	438.46	49.75
29	Basic chemicals and chemical products	Ind.	457.63	377.37	80.26
49	Other constructions	Ind.	435.31	51.07	384.24
18	Stone, sand and clay	Min.	421.70	332.92	88.77
30	Rubber and plastics products	Ind.	413.89	234.40	179.50
48	Construction of residential buildings	Ind.	410.93	6.09	404.85
11	Horticulture and market gardening products	Agri.	403.35	318.54	84.81
57	Water transport	Ser.	380.41	286.67	93.74
24	Textiles	Ind.	375.23	173.74	201.49

Note: Agri. = Agricultural, Min. = Mining, Ind. = Industrial, Ser. = Service

Fig. 6 shows the contribution of fuels to the emissions of CO2 pollutants in Iran in 2001. As is obvious, the main sources of CO2 emissions across the sectors are gas oil, electricity, natural gas, fuel oil and gasoline. In total, 29% of CO2 pollutants were emitted as a result of the consumption of gas oil. About 58% of this amount was produced by direct gas oil consumption, with the remainder emitted through the consumption of nonenergy inputs for which gas oil was a production input. Following gas oil, electricity is the second-highest contributor to emissions of total CO2, accounting for 25% of total emissions. From a primary energies perspective, the role of gas oil and natural gas should be given more consideration, given that the main primary energies used for generation of electricity are gas oil and natural gas. However, as we mentioned before, one of the main reasons for substituting final energies with primary energies is to find the sectors and fuels responsible for the increasing trend in energy consumption and CO2 emissions in Iran. Therefore, the role of electricity is similar to that of gas oil. In terms of total CO2 produced by electricity, 62.56% was emitted through direct electricity consumption and 37.44% emitted via the consumption of electricity to produce other nonenergy inputs. The share of natural gas in total emissions is about 16%, with 60.17% of these emissions due to direct consumption and 39.83% due to indirect use. Consumption of fuel oil and gasoline account for 13% and 8%, respectively, of the total sectoral CO2 emissions. As for the other energies, the largest proportion of emitted pollutants is due to direct consumption of them.

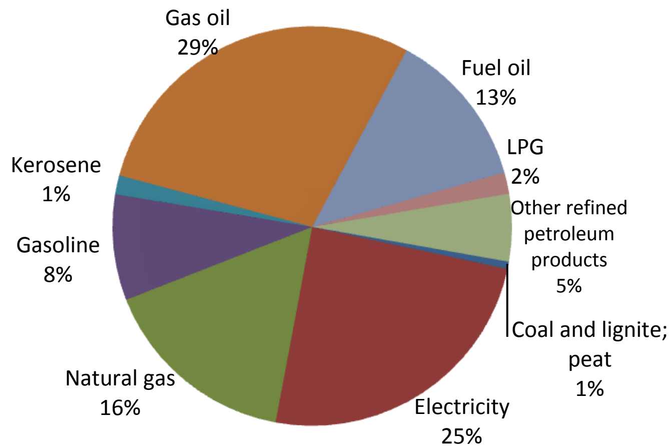

Fig. 6. Contribution of the final energy carriers to CO2 emissions across the nonenergy sectors

3.4 Opportunities to reduce sectoral energy and CO2 emission intensities

Having gained an understanding of the size of the energy and CO2 emission intensities in Iran, we next need to determine which sectors can be targeted to reduce energy consumption and CO2 emissions. Undoubtedly, the sectors that are simultaneously the main consumers of energy and have the highest energy intensities should be considered first. Because identifying the sectors in terms of energy consumption or CO2 emissions gives us the same policy implications, we just explain the potential for CO2 emission mitigation in this section.

Fig. 7 depicts the volume of CO2 emissions in each sector against their CO2 emission intensities. To ensure plausibility, we assumed that a conservation policy could mitigate the sectoral CO2 emission intensities by 10%. Applying this assumption into the model, we calculated the total mitigation of CO2 emissions that would occur in each sector. The sectors that could experience significant reductions in CO2 emissions, e.g., more than 1 MT, are listed in descending order as follows: “road freight transport”, “other mineral products”, “wholesale and retail trade services”, “other constructions”, “other foods and beverages”, “agricultural products”, “basic iron and steel and their products”, “construction of residential buildings”, “live animals and animal products”, “basic chemicals and chemical products”, “road passenger transport” and, finally, “horticulture and market gardening products”. From the above list, three subsectors are from the agricultural sector, three are in the service sector and the remaining six are in the industrial sector.

Undoubtedly, conservation policies and plans should target transportation first, given that it is the main consumer of gas oil and gasoline. Increasing the share of public transportation, reducing the price gap between Iranian and international markets for gas oil and gasoline, and renovation fleet vehicles are the key policies that can strongly affect the energy consumption pattern in this sector. A reduction of only 10% in the CO2 intensities of the road freight and passenger transportation sectors could mitigate total CO2 emissions by close to 4.5 MT. The next target for conservation policies and plans should be the producers of basic products, such as basic mineral, metal and chemical products. Most of these sectors were developed under the import substitution policy and they were fundamentally established and developed in an inefficient manner. The target of the import substitution policies influencing these industries was to make the country independent of imports of such strategic products. To attain this goal in an oil-exporting country, the energy efficiency criterion had the lowest importance. A 10% reduction in the CO2 emissions intensities of the sectors “other mineral products”, “basic iron and steel and their products” and “basic chemicals and chemical products” would reduce CO2 emissions by about 2.5 MT, 1.5 MT and 1.2 MT, respectively. The construction and trade sectors are the other energy intensive activities in Iran. If any policy can mitigate 10% of the total CO2 intensities of these sectors, the amount of CO2 emissions would be reduced by 3.8 MT in the construction sector and by 2.5 MT in the trade sector. The food industry is also an energy inefficient industry in Iran, because applying the same policy would reduce CO2 emissions by 2.4 MT in this sector. Agricultural and livestock could experience a 3.9 MT reduction in CO2 emissions under such a policy.

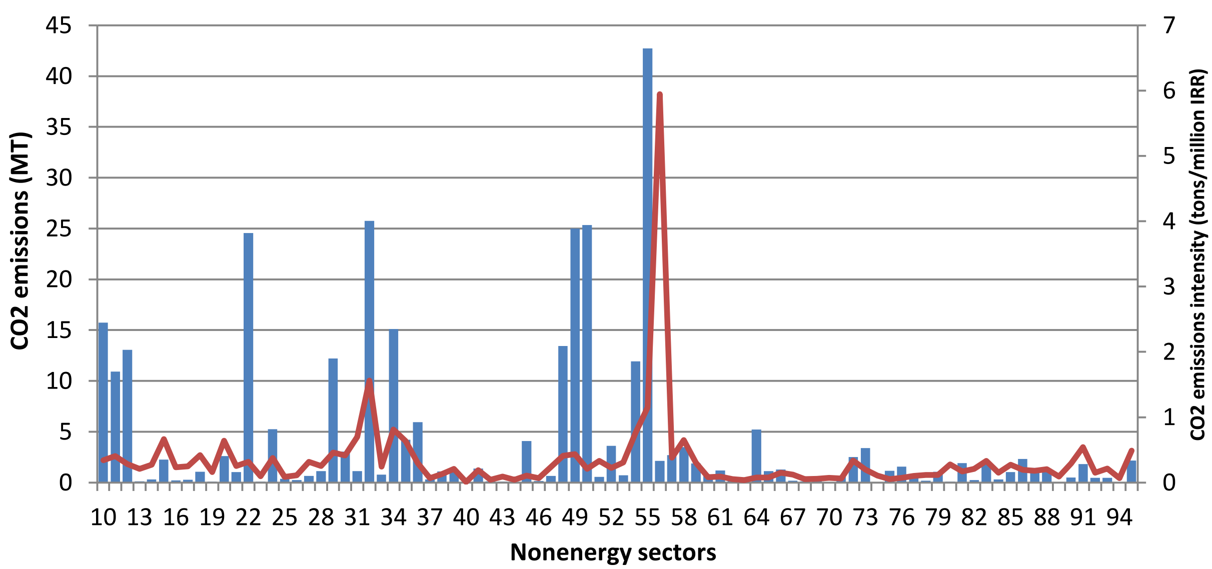

Fig. 7. Total sectoral CO2 emissions against sectoral emissions intensities in Iran

3.5 Energy consumption and economic value in Iran

Following Costanza and Herendeen [36], in this section, we will test the energy theory of value in Iran. An economy can be said to operate on an energy theory of value if economic value can be shown to be proportional to an appropriate energy indicator. Costanza and Herendeen [36] show that one of the best indicators is sectors' direct plus indirect (embodied) energy consumption. To examine the theory, the logarithms of the embodied energy consumption of 86 Iranian nonenergy sectors are plotted and regressed against the logarithms of their total output. The results are depicted in Fig. 8. As the figure shows, there is a relatively strong relationship between sectoral embodied energy consumption and the sectors' production. While the simple regression results in a relatively high R^2 (0.75), the covariance and Pearson's r of these two variables are also high, i.e., 2.32 and 0.86, respectively. The results of our study confirm the results of previous studies regarding the strong cross-sectional relationship between embodied energy and economic value.

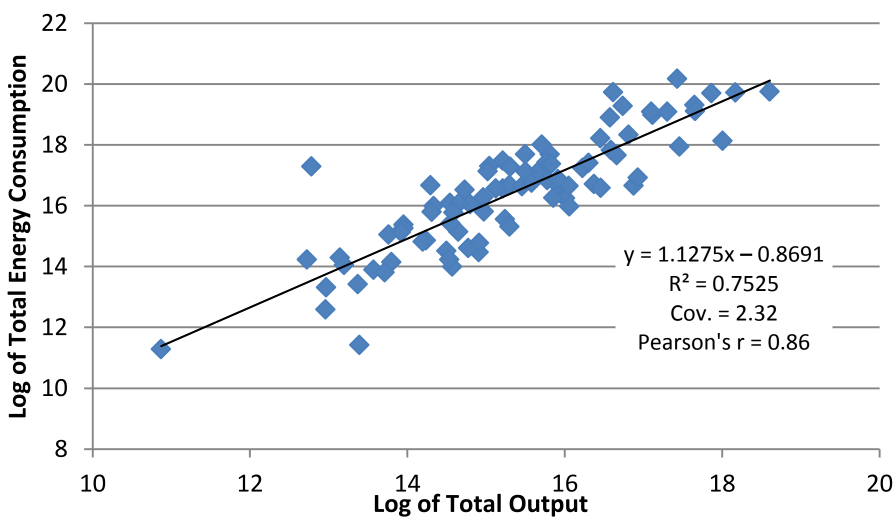

Fig. 8. Log-log plot of total energy consumption vs. total output of 86 nonenergy sectors in Iran

4. Conclusion

The aim of this paper was to quantify the energy and CO_2 emissions intensities across the nonenergy sectors in the Iranian economy. For this purpose, E-IO analysis was applied to the 95×95 IO table of Iran in 2001. Then, the sectors that had the potential to experience a significant reduction in energy consumption and CO_2 emissions were identified. As explained above, the sectors with the highest potential to reduce energy consumption and emissions are the road transportation sectors, the sectors which produce basic mineral, metal and chemical products, the construction sectors, the food industry and the agricultural and livestock sectors. Although the energy consumption pattern is distorted by cheap energy prices, our study shows that the energy theory of value still applies in Iran. The next step should be to identify the policies that reduce energy and CO_2 emissions intensities in these sectors. While the price gap between domestic and international markets is immense in Iran, removing the energy subsidies should be considered first.

However, it is of course necessary to note that we should interpret the results of this analysis with some caution. First, the input–output table used is from 2001. This raises concerns about the rigidity of the economic structure in Iran after a decade. Second, as for other quantitative approaches, E-IO has some limitations, such as price distortion during the process of unit conversion, aggregation errors in composing sectors and missing necessary products or services in the candidate sectors. However, it is widely used, especially because it provides reliable results from a macroeconomic perspective.

References

[1] Ministry of Energy (MOE) (2010), Energy balance of Iran 2009, Division of Electricity and Energy, Tehran (In Persian).

[2] World Bank (2012), World Development Indicators (WDI), Available at http://data.worldbank.org/data-catalog/world-development-indicators.

[3] International Energy Agency (IEA) (2011), Energy Balances of NonOECD Countries, Organization for Economic.

[4] Statistical Center of Iran (2012), Iran Statistical Yearbook 2009, Tehran, Available at http://amar.sci.org.ir/EPlanList.aspx.

[5] Sharifi, A., Sadeghi, M., Nafar, M., Dehghan Shaabani, Z. (2008), Decomposition of energy intensity in the Iranian manufacturing industries, Iranian Economic Research, Volume 10, pp. 79–109 (In Persian).

[6] Behboudi, D., Aslaninia, N.M., Sojoodi S. (2010), Decomposition and determinants of energy intensity in Iran, Quarterly Energy Economics Review, Volume 7, pp. 105–130 (In Persian).

[7] Fotros, M.H., Barati, J. (2011), Decomposition of Iranian energy consumption-related CO2 emissions in economic sectors, an index decomposition analysis, Quarterly Energy Economics Review, Volume 8, pp. 49–73 (In Persian).

[8] Sadeghi, K., Sojoodi, S. (2011), A study of the determinants of energy intensity in Iranian manufacturing firms, Quarterly Energy Economics Review, Volume 8, pp. 163–180 (In Persian).

[9] Lenzen, M., Dey, C., Foran, B. (2004), Energy requirements of Sydney households, Ecological Economics, Volume 49, Issue 3, pp. 375–399.

[10] Lenzen, M. (1998), Primary energy and greenhouse gases embodied in Australian final consumption: an input–output analysis, Energy Policy, Volume 26, Issue 6, pp. 495–506.

[11] Labandeira, X., Labeaga J.M. (2002), Estimation and control of Spanish energy-related CO2 emissions: an input–output approach, Energy Policy, Volume 30, Issue 7, pp. 597–611.

[12] Cohen, C., Lenzen, M., Schaeffer, R. (2005), Energy requirements of households in Brazil, Energy Policy, Volume 33, Issue 4, pp. 555–562.

[13] Park, H., Heo, E. (2007), The direct and indirect household energy requirements in the Republic of Korea from 1980 to 2000 — An input–output analysis, Energy Policy, Volume 35, Issue 5, pp. 2839–2851.

[14] Limmeechokchai, B., Suksuntornsiri, P. (2007), Embedded energy and total greenhouse gas emissions in final consumptions within Thailand, Renewable and Sustainable Energy Reviews, Volume 11, Issue 2, pp. 259–281.

[15] Tarancón Morán, M.A., González, P.R. (2007), A combined input–output and sensitivity analysis approach to analyze sector linkages and CO2 emissions, Energy Economics, Volume 29, Issue 3, pp. 578–597.

[16] Tarancon Morán, M.A., Río, P.D. (2012), Assessing energy-related CO2 emissions with sensitivity analysis and input–output techniques, Energy, Volume 37, Issue 1, pp. 161–170.

[17] Chung, W., Tohno, S., Shim, S.Y. (2009), An estimation of energy and GHG emission intensity caused by energy consumption in Korea: An energy IO approach, Applied Energy, Volume 86, Issue 10, pp. 1902–1914.

[18] Chung, W., Tohno, S., Choi, K. (2011), Socio-technological impact analysis using an energy IO approach to GHG emissions issues in South Korea, Applied Energy, Volume 88, Issue 11, pp. 3747–3758.

[19] Kerkhof, A.C., Nonhebel, S., Moll, H.C. (2009), Relating the environmental impact of consumption to household expenditures: An input–output analysis, Ecological Economics, Volume 68, Issue 4, pp. 1160–1170.

[20] Zhou, S.Y., Chen, H., Li, S.C. (2010), Resources use and greenhouse gas emissions in urban economy: Ecological input–output modeling for Beijing 2002, Communications in Nonlinear Science and Numerical Simulation, Volume 15, Issue 10, pp. 3201–3231.

[21] Chen, G.Q., Zhang, B. (2010), Greenhouse gas emissions in China 2007: Inventory and input–output analysis, Energy Policy, Volume 38, Issue 10, pp. 6180–6193.

[22] Chen, G.Q., Chen, Z.M. (2011), Greenhouse gas emissions and natural resources use by the world economy: Ecological input–output modeling, Ecological Modeling, Volume 222, Issue 14, pp. 2362–2376.

[23] Cellura, M., Longo, S., Mistretta, M. (2011), The energy and environmental impacts of Italian households' consumptions: An input–output analysis, Renewable and Sustainable Energy Reviews, Volume 15, Issue 8, pp. 3897–3908.

[24] Strout, A.M. (1967), Technological change and the United States' energy consumption, 1939–1954, PhD Dissertation, University of Chicago.

[25] Bullard, C.W., Herendeen, R.A. (1975), Energy impact of consumption decisions, Proceedings of the IEEE, Volume 63, Issue 3, pp. 484–493.

[26] Miller, R.E., Blair, P.D. (2009), Input–output analysis: foundations and extensions, Cambridge University Press, Cambridge.

[27] Chapman, P.F. (1974), Energy costs: a review of methods. Energy Policy, Volume 2, Issue 2, pp. 91–103.

[28] Wright, D.J. (1974), Goods and services: an input–output analysis, Energy Policy, Volume 2, Issue 4, pp. 307–315.

[29] Statistical Center of Iran (2005), Iran's national input–output table 2001, Available at http://www.amar.org.ir/nationalaccount/default-486.aspx (In Persian).

[30] Ministry of Energy (MOE) (2003), Energy balance of Iran 2001, Division of Electricity and Energy, Tehran (In Persian).

[31] Ministry of Petroleum (MoP) (2009), Hydrocarbon balance of Iran 2008, Institute of International Energy Studies (IIES), Tehran (In Persian).

[32] Ministry of Petroleum (MoP) (2010), Transportation energy data book, Iranian Fuel Conservation Company, Tehran (In Persian).

[33] Kok, R., Benders, R., Moll, H.C. (2006), Measuring the environmental load of household consumption using some methods based on input–output energy analysis: A comparison of methods and a discussion of results, Energy Policy, Volume 34, Issue 17, pp. 2744–2761.

[34] Hawkins, D., Simon, H.A. (1949), Some conditions of macroeconomic stability, Econometrica, Volume 17, pp. 245–248.

[35] Miller, R.E., Blair, P.D. (1985), Input–output analysis: foundations and extensions, Englewood Cliffs, New Jersey: Prentice-Hall.

[36] Costanza, R., Herendeen, R.A. (1984), Embodied energy and economic value in the United States economy: 1963, 1967, 1972, Resource and Energy, Volume 6, pp. 129–163.

Appendix A.1

Energy intensities of sectors in the Iranian economy (BTU/IRR)

Code	Sector name	Energy intensity			Code	Sector name	Energy intensity		
		Total	Direct	Indirect			Total	Direct	Indirect
10	Agricultural products	5.23	3.85	1.38	53	Railway transport	4.16	3.26	0.90
11	Horticulture and market gardening products	6.46	5.20	1.26	54	Road passenger transport	10.22	8.57	1.65
12	Live animals and animal products	4.25	1.60	2.65	55	Road freight transport	15.51	14.33	1.17
13	Products of bees and silkworms	3.15	1.56	1.59	56	Pipeline transport	90.26	88.80	1.45
14	Forestry and logging products	4.17	3.65	0.52	57	Water transport	5.24	3.93	1.31
15	Fish and other fishing products	9.59	7.79	1.80	58	Air transport	8.92	6.46	2.46
16	Iron ores and concentrates	3.64	3.15	0.49	59	Supporting and auxiliary transport services	4.18	3.21	0.96
17	Copper, ores and concentrates	3.68	2.83	0.85	60	Postal and telecommunication services	1.28	0.93	0.35
18	Stone, sand and clay	5.97	4.69	1.28	61	Banking services	1.40	0.93	0.47
19	Other minerals	2.36	1.68	0.68	62	Investment banking and financial intermediation services	0.85	0.69	0.16
20	Water	9.60	7.31	2.29	63	Insurance and pension services	0.56	0.26	0.31
21	Animal and vegetable oils and fats	3.85	1.66	2.19	64	Renting services of own residential construction	1.14	0.00	1.14
22	Other foods and beverages	4.70	1.20	3.49	65	Renting services of rental residential construction	1.14	0.00	1.14
23	Tobacco products	1.42	0.31	1.10	66	Renting services of rental nonresidential construction	2.14	0.00	2.14
24	Textiles	5.83	2.71	3.12	67	Trade services of real states	1.86	1.56	0.30
25	Wearing apparel	1.36	0.28	1.08	68	Leasing or rental services without operator	0.74	0.09	0.64
26	Leather and leather products; footwear	1.64	0.57	1.08	69	Research and development services	0.87	0.15	0.72
27	Products of wood, cork, straw and plaiting materials	4.72	2.39	2.33	70	Computer and information services	1.10	0.72	0.38

28	Pulp, paper and paper products; printed matter and related articles	3.99	2.69	1.30	71	Other professional, technical and business services	0.92	0.53	0.39
29	Basic chemicals and chemical products	7.33	6.09	1.24	72	Agriculture, raising livestock, and mining services	4.70	3.16	1.53
30	Rubber and plastics products	6.51	3.77	2.73	73	Maintenance, repair and installation (except construction) services	2.70	2.06	0.64
31	Glass and glass products	10.77	8.67	2.10	74	News agency services	1.51	0.37	1.14
32	Other mineral products	22.54	19.27	3.27	75	Administrative services of the government	0.81	0.37	0.44
33	Furniture	3.68	1.37	2.31	76	Military and civil defense services	0.99	0.54	0.45
34	Basic iron and steel and their products	12.70	9.88	2.82	77	Police and fire protection services	1.49	0.97	0.52
35	Other metals	9.96	7.59	2.36	78	Social security services	1.85	1.41	0.44
36	Metal products	4.57	0.93	3.63	79	Public primary education services	1.82	1.60	0.21
37	General-purpose machinery	1.01	0.33	0.68	80	Private primary education services	4.48	3.49	0.99
38	Special-purpose machinery	2.00	0.47	1.53	81	Public secondary education services	2.74	2.44	0.30
39	Domestic appliances and parts thereof	3.24	0.97	2.28	82	Private secondary education services	3.37	2.56	0.81
40	Office, accounting and computing machinery	0.14	0.03	0.11	83	Public university education services	5.03	4.15	0.88
41	Electrical machinery and apparatus	2.87	0.80	2.07	84	Private university education services	2.38	2.04	0.35
42	Radio, television and communication equipment and apparatus	0.65	0.13	0.52	85	Other education and training services	4.21	3.48	0.73
43	Medical and surgical equipment and orthopedic appliances	1.37	0.60	0.78	86	Hospital services	3.02	2.04	0.98
44	Optical and measurement instruments, watches and clocks	0.69	0.20	0.49	87	Medical and dental services	2.61	2.32	0.29

45	Motor vehicles, trailers and semi-trailers	1.63	0.24	1.38	88	Other human health services	3.23	2.24	0.99
46	Other vehicles	1.01	0.34	0.67	89	Veterinary services	1.41	0.98	0.43
47	Jewelry and other unclassified products	3.50	0.39	3.11	90	Social services	4.45	3.48	0.97
48	Construction of residential buildings	5.97	0.08	5.89	91	Religious services (Masjids, etc.)	8.25	6.21	2.03
49	Other construction	6.27	0.70	5.58	92	Arts-related services	2.30	1.66	0.65
50	Wholesale and retail trade services	3.13	2.20	0.93	93	Recreational and sporting services	3.29	2.51	0.78
51	Lodging services	5.19	4.03	1.17	94	Museum and library services	1.05	0.72	0.33
52	Food and beverage serving services	3.44	1.36	2.09	95	Other services	7.22	6.48	0.74

Appendix A.2

CO2 emission intensities of sectors in the Iranian economy (kg/million IRR)

Code	Sector name	CO2 emissions intensity			Code	Sector name	CO2 emissions intensity		
		Total	Direct	Indirect			Total	Direct	Indirect
10	Agricultural products	340.28	245.39	94.89	53	Railway transport	306.05	242.47	63.58
11	Horticulture and market gardening products	403.35	318.54	84.81	54	Road passenger transport	756.04	638.76	117.28
12	Live animals and animal products	280.25	100.75	179.50	55	Road freight transport	1150.22	1068.33	81.89
13	Products of bees and silkworms	211.23	102.00	109.22	56	Pipeline transport	5945.90	5844.35	101.55
14	Forestry and logging products	274.93	237.81	37.12	57	Water transport	380.41	286.67	93.74
15	Fish and other fishing products	663.05	539.95	123.10	58	Air transport	650.47	477.27	173.21
16	Iron ores and concentrates	231.17	198.21	32.96	59	Supporting and auxiliary transport services	300.13	229.03	71.10
17	Copper, ores and concentrates	249.22	190.94	58.28	60	Postal and telecommunication services	83.38	58.89	24.50
18	Stone, sand and clay	421.70	332.92	88.77	61	Banking services	92.49	59.98	32.52
19	Other minerals	159.57	112.76	46.81	62	Investment banking and financial intermediation services	53.75	43.26	10.49
20	Water	641.65	486.19	155.45	63	Insurance and pension services	37.77	17.07	20.70
21	Animal and vegetable oils and fats	253.30	106.32	146.98	64	Renting services of own residential construction	78.69	0.00	78.69
22	Other foods and beverages	315.51	81.98	233.53	65	Renting services of rental residential construction	79.05	0.00	79.05
23	Tobacco products	94.50	20.78	73.72	66	Renting services of rental nonresidential construction	148.85	0.00	148.85
24	Textiles	375.23	173.74	201.49	67	Trade services of real states	118.44	97.90	20.54
25	Wearing apparel	88.06	17.16	70.90	68	Leasing or rental services without operator	50.55	6.99	43.56
26	Leather and leather products; footwear	109.56	38.25	71.31	69	Research and development services	58.28	10.43	47.85
27	Products of wood, cork, straw and plaiting materials	314.69	157.62	157.07	70	Computer and information services	70.66	44.83	25.83

28	Pulp, paper and paper products; printed matter and related articles	254.82	168.63	86.19	71	Other professional, technical and business services	60.57	33.80	26.77
29	Basic chemicals and chemical products	457.63	377.37	80.26	72	Agriculture, raising livestock, and mining services	336.65	230.50	106.15
30	Rubber and plastics products	413.89	234.40	179.50	73	Maintenance, repair and installation (except construction) services	198.07	154.81	43.26
31	Glass and glass products	696.79	556.76	140.03	74	News agency services	105.60	24.87	80.72
32	Other mineral products	1563.26	1332.32	230.94	75	Administrative services of the government	53.63	23.64	29.99
33	Furniture	242.38	88.03	154.34	76	Military and civil defense services	69.58	38.80	30.78
34	Basic iron and steel and their products	811.98	625.10	186.88	77	Police and fire protection services	99.98	64.47	35.51
35	Other metals	636.44	478.40	158.04	78	Social security services	117.98	87.77	30.21
36	Metal products	297.20	58.52	238.68	79	Public primary education services	114.18	99.80	14.38
37	General-purpose machinery	66.45	21.63	44.82	80	Private primary education services	279.43	211.20	68.23
38	Special-purpose machinery	132.34	31.72	100.63	81	Public secondary education services	171.83	151.61	20.22
39	Domestic appliances and parts thereof	210.80	60.88	149.92	82	Private secondary education services	210.62	155.46	55.16
40	Office, accounting and computing machinery	9.20	1.82	7.38	83	Public university education services	330.88	270.73	60.16
41	Electrical machinery and apparatus	191.66	55.79	135.88	84	Private university education services	150.45	127.19	23.26
42	Radio, television and communication equipment and apparatus	42.54	8.27	34.26	85	Other education and training services	274.04	223.60	50.43
43	Medical and surgical equipment and orthopedic appliances	89.33	38.02	51.31	86	Hospital services	192.94	128.39	64.55
44	Optical and measurement instruments, watches and clocks	44.51	12.69	31.82	87	Medical and dental services	177.64	158.22	19.43
45	Motor vehicles, trailers and	107.44	15.29	92.15	88	Other human health services	201.98	136.60	65.38

	semi-trailers								
46	Other vehicles	67.84	22.45	45.39	89	Veterinary services	93.77	64.97	28.79
47	Jewelry and other unclassified products	238.69	27.57	211.12	90	Social services	293.64	227.30	66.34
48	Construction of residential buildings	410.93	6.09	404.85	91	Religious services (Masjids, etc.)	542.98	406.76	136.21
49	Other construction	435.31	51.07	384.24	92	Arts-related services	148.28	103.75	44.53
50	Wholesale and retail trade services	210.63	144.01	66.62	93	Recreational and sporting services	211.75	158.28	53.47
51	Lodging services	330.17	250.54	79.63	94	Museum and library services	68.84	46.47	22.37
52	Food and beverage serving services	225.94	84.30	141.64	95	Other services	488.20	438.46	49.75