

**Controlling Greenhouse Gases Emissions via Natural Gas Substitution:
An Input-Output Study for Turkey**

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Abstract

On the growing concern of the world over the issues of global warming and unfavorable climate changes, Turkey is being pressurized by EU and other international agencies to reduce GHGs emissions by ratifying Kyoto Protocol. Recognizing the importance of above problems, this paper aims to offer reduction of GHGs emissions by 100 percent substitution of natural gas for other fossil fuel types. Using agriculture focused environmental input-output model, this paper finds that natural gas substitution has produced incredible reduction in GHGs emissions - CO₂, N₂O, CH₄, CO, SO_x, NO_x and NMVOC emissions decreased by 30.74, 88.02, 45.27, 89.44, 99.99, 29.01 and 96.61 percent respectively. These results points out that Turkey can meet her economic and social goals at very low costs of environmental damage.

Key words: Agriculture focused Input-Output Model, GHGs Emissions, and Natural Gas.

1. Introduction

Today world is facing serious challenges; on one side is the problem of food security and poverty and on other side is the problem of global warming and climate changes. High temperatures, melting of glaciers and ice caps, rise in sea level, floods, droughts, loss of biodiversity, disturbed ecosystem, water contamination, deforestation, desertification, and loss of soil fertility are prominent. These problems are not God gifted but humans have themselves produced these problems through their unsustainable production and consumption patterns. The trade-off between economic and social goals and environmental issues have driven the attention of the nations of the world to think on this very much serious concern and to find out the possible solution with least costs. Sustainable development has become hot agenda in the policies of the developed countries specially, as well as for developing countries.

Turkey is a developing country and she has shown the average growth of about 7 percent since last four years. Economic and social goals are at the top priority of the country's macroeconomic policies so as to improve the living standard of the people.

Turkish manufacturing and transportation sectors are growing rapidly since last four years. As a matter of fact, these sectors have significantly contributed to GHGs emissions in the atmosphere. Turkey is facing huge pressure from EU and other international agencies to ratify Kyoto Protocol. Turkey is already member of Annex I of UNFCCC and Turkey has to prepare annual inventories on GHGs emissions as required by UNFCCC.

Basing on the above this paper aims to seek such solution which can meet the economic and social goals and as well as environmental goals. The second part of the paper describes the various data sources and methodology. The third part is about policy analysis that is hundred percent natural gas substitutions for other fossil fuel types. The last part concludes the paper along with policy recommendations and suggestions.

2. Methodology & Data

Environmental discharges can be calculated by using extended input-output model of Leontief (1970) which includes both environmental pollution and abatement activities. The advantage of using input-output model is that it measures direct and indirect changes in total production caused by changes in final demand. The total output in input-output technique is:

$$O = Bo + F \quad (1)$$

Where O is the vector of total output of all sectors and Bo is the matrix of intermediate demand of all sectors and F is the vector of final demand of all sectors. B is the matrix of technical coefficients which can be obtained by:

$$B = \frac{o_{ij}}{O_j} \quad (2)$$

where o_{ij} is the sale of i th sector to j sector and O_j is the total outlay of sector j . Take the intermediate demand term to the left-side in equation (1):

$$O - Bo = F \quad (3)$$

Simplifying the equation (3) we get:

$$O(I - B) = F \quad (4)$$

To solve for O , $(I - B)$ has to be non-singular.

$$O = (I - B)^{-1} F \quad (5)$$

where $(I - B)^{-1}$ is the famous Leontief Inverse. The total sectoral output can be found out with the help of equation (5) when exogenous variable F changes.

Following equation adds the environmental component in the input-output technique:

$$Qi = \hat{P}iO \quad (6)$$

where Qi is the vector of environmental pollution of type i and $\hat{P}i$ is the diagonal matrix of environmental pollution of type i per monetary unit of sector's output. To solve for Qi simply put the value of O from equation (5) into equation (6):

$$Qi = \hat{P}i(I - B)^{-1} F \quad (7)$$

Equation (7) measures the total (direct and indirect) pollution caused by changes in the final demand of the sectors.

In this paper, data has been taken from four different sources; agriculture focused input-output table of Turkey for the year 1998 has been taken from Bhutto & Cagatay (2007). Sectoral GHGs emissions data for the year 1998 has been taken from Bhutto (2007); prices of fossil fuel types are taken from TURKSTAT (2001) and net calorific values and emissions factors of fossil fuel types are taken from IPCC (2006).

3. Policy Analysis

In this policy scenario, an effort has been made to offer clean development guideline relatively if natural gas is substituted completely in place of other fossil fuel types. In this policy scenario we will estimate and analyze the size of GHGs emissions from natural gas substitution and changes with respect to results of GHGs emissions in 1998 from fossil fuel consumptions.

In this policy scenario, we assume that all fuel types are perfect substitutes to each other. In Table 1 prices (Millions of TL per Tone) of fuels and net calorific values (NCVs) TJ/Gg are given.

<insert Table 1 here>

Lignite has the minimum price 10.9 Million TL per tone and minimum NCV 11.9 TJ/Gg; natural gas has the maximum NCV 48 TJ/Gg and price 40.83 Million TL per tone; and

gasoline has the maximum price 202.66 Million TL per tone with the NCV of 44.3. The rankings of emissions (Kgs/Tone) for three direct GHGs - CO₂, CH₄ and N₂O are given in Table 2. In terms of CO₂ emissions, lignite has the lowest emissions 1201.9 Kgs/Tone, natural gas 2692.8 Kgs/Tone and highest emissions by diesel oil 3186.3 Kgs/Tone. For CH₄, again lignite has the lowest emissions 0.0119 Kgs/Tone, natural gas 0.048 Kgs/Tone and highest value 0.1329 Kgs/Tone goes to gasoline. In case of N₂O, LPG has the lowest emissions 0.0047 Kgs/Tone, natural gas has the second lowest emissions 0.0048 Kgs/Tone and coking coal has the highest emissions 0.0432 Kgs/Tone.

<insert Table 2 here>

Here question arises, when lignite has the lowest emissions per tonne in two main GHGs (CO₂ and CH₄), as well as, the advantage of the minimum price per tone, then, why natural gas has been chosen as a substitution for fuel types that are mentioned in the above tables. This is the one side of the picture, on the other side of the picture; we see the NCV (the useful calorific value or heating value in boiler plant) which is one of the significant factors (emissions and prices of natural gas per tonne) that made us to choose natural gas for substitution of other fuel types. In simple words, lignite has the lowest NCV 11.9 TJ/Gg, in order to produce as much as heat that 1 Gg of natural gas (NCV 48 TJ/Gg) produces, more than 4Gg of lignite would be needed that would mean four times more emissions and more costly too. If natural gas is substituted for LPG, diesel oil, kerosene, gasoline and lignite, it will reduce costs significantly. But in terms of GHGs emissions minimization, natural gas will decrease emissions compared to all other fuel types mentioned in the above tables.

Substitution of natural gas for other fuel types takes place in the following manner:

1. Transform all the fuels into energy units (TJ) by simply multiplying quantity of fuels expressed in 1000 tonnes with their net calorific values (NCVs).
2. Divide each fuel type expressed in energy units TJ (step 1) with the NCV of natural gas 48 TJ/Gg that will give us the quantities of natural gas (1000 tonnes) equivalent to correspondent fuel types.

The following Table 3 reveals the mechanism described in above 2 steps. The 4th column of Table 3 is obtained multiplying column 2 with column 3 and 5th column is obtained by dividing column 4 with the NCV of natural gas 48 TJ/Gg.

<insert Table 3 here>

A 100 percent substitution of natural gas in 1998 produces incredible results useful in future policy priorities. In terms of CO₂, overall reduction is 30.74 percent in which highest reduction 42 percent takes place in manufacture of prepared animals feed sector, manufacture of sugar 38 percent, manufacture of ferrous, non-ferrous metals, various machinery, vehicles, etc sectors 35.24, energy production and distribution sectors 34.46 percent, transport sectors 21.38 percent, agriculture sectors on average above 21 percent and manufacture of fertilizers, pesticides, other agro-chemicals, paints, and varnishes sectors 9.67 percent. The results are given in Table 4.

<insert Table 4 here>

Natural gas substitution has shown a great success in N₂O emissions reductions in which manufacture of prepared animals feeds sector 92.62 percent, manufacture of sugar 91 percent, energy production and distribution sectors 90 percent, transport sectors 80.33 percent, agriculture sectors on average 80 percent. CH₄ has shown an overall reduction of 45.27 better than CO₂ reductions. Manufacture of grain mill products, starches and starch products sector has shown a great response in reducing the emissions of CH₄ by 66.66 percent, manufacture of dairy products comes the second with 65 percent, transport sector 60 percent, energy production and distribution sectors 34.51 and agriculture sectors on average above 61 percent.

Natural gas substitution has produced much better results in four indirect GHGs compared to three GHGs. In SO_x, the results are unbelievable that is 99.99 percent overall and sectoral reductions; in CO, overall reduction is 89 percent but in some sectors CO emissions have increased with the natural gas substitution. Manufacture of grain mill

products, starches and starch products sectors and mining and quarrying sectors have shown great increase 198.33 and 167.3 percent respectively. But many sectors have shown significant reductions in CO whose shares in total emissions of CO in 1998 emissions table from natural gas substitution are very high i.e. transport sectors, private consumption and growing of cereals and other crops sectors n.e.c sector 65.81, 8.6 and 3.79 percent respectively. Increase in CO emissions in some sectors whose shares in total CO emissions are very low (0.00073 percent for manufacture of grain mill products, starches and starch products sectors and 0.146 percent for mining and quarrying sectors) can not affect the overall reduction of CO from the natural gas substitution.¹

NMVOG has shown overall reduction of 96.6 percent in which transport sector, private consumption and agriculture sectors have contributed a lot 99.34, 95.8 and 95.12 percent respectively, whereas, energy production and distribution and manufacture of grain mill products, starches and starch products sectors have no role in reducing the emissions. In all seven gases, NOx has produced the lowest reductions 29 percent overall and main contributors are private consumption, services, energy production and distribution, transport and agriculture sectors with the shares of 47.36, 43.85, 40, 16.87 and 19 percents respectively.

4. Conclusion and Recommendations

Sustainable development has become an urgent need in today's world. Extreme weathers and global warming are the main concerns that have raised the seriousness of the collective action of both the developed and the developing countries to combat these problems. From the environmental perspective, the increased consumption of fossil fuels raises the problems of climate change, acid rain, damage to eco-system from the extraction of fossil fuels and impact of oil spills on marine eco-system.

Natural gas substitution puts the baseline for framing future policy frameworks for sustainable development of Turkey. Estimation of GHGs emissions for the year 1998 from natural gas substitution produces extra ordinary results compared to fossil fuel

¹ For the details of individual shares in tonnes and % for each sector in total emissions of GHGs from natural gas consumption and percentage changes in GHGs emissions from all fossil fuel types to natural gas substitution in 1998, see Appendix 2

consumption, CO₂ and N₂O emissions decreased by 30.74 and 88.02 percent respectively, whereas, CH₄, CO, SO_x, NO_x and NMVOC emissions decreased by 45.27, 89.44, 99.99, 29.01 and 96.61 percent respectively. It is obvious from the above results if Turkey ratifies Kyoto Protocol, Turkey can successfully reduce GHGs emissions without compromising the economic and social goals - high output, full employment and equity etc. This study strongly recommends natural gas substitution should be given first priority in the future policies for clean development-development with the least cost of environmental damage of Turkey.

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Appendix 1

Table 1. Prices and Net Calorific Values of Fuels

Fuel Type	Prices Millions TL per Tonne	NCVs TJ/Gg
Lignite	10.90	11.9
Sulphur	12.00	40.2
Coke powder	13.72	25.0
Hard coal	14.16	26.7
Petroleum coke	16.62	32.5
Coking coal	21.23	28.2
Fuel oil	31.64	40.4
Natural gas	40.83	48.0
LPG	88.36	47.3
Diesel oil	129.54	43.0
Kerosene	151.20	43.8
Gasoline	202.66	44.3

Source: (TURKSTAT, 2001) and (IPCC, 2006)

Table 2. Rankings of Emissions in Ascending Order for Three GHGs

Fuel Type	CO ₂ Emissions Kgs per Tonne	Fuel Type	CH ₄ Emissions Kgs per Tonne	Fuel Type	N ₂ O Emissions Kgs per Tonne
Lignite	1201.9	Lignite	0.0119	LPG	0.00473
Coke powder	2449.165	Coke powder	0.025	Natural gas	0.0048
Hard coal	2624.61	Hard coal	0.0267	Lignite	0.01785
Coking coal	2667.72	Coking coal	0.0282	Petroleum coke	0.0195
Natural gas	2692.8	LPG	0.0473	Sulphur	0.02412
Sulphur	2946.66	Natural gas	0.048	Fuel oil	0.02424
LPG	2984.63	Petroleum coke	0.0975	Diesel oil	0.0258
Gasoline	3069.99	Sulphur	0.1206	Kerosene	0.02628
Fuel oil	3126.96	Fuel oil	0.1212	Gasoline	0.02658
Kerosene	3149.22	Diesel oil	0.129	Coke powder	0.0375
Petroleum coke	3168.75	Kerosene	0.1314	Hard coal	0.04005
Diesel oil	3186.3	Gasoline	0.1329	Coking coal	0.0423

Source: Author's Calculations

Table 3. Conversion of Fuel Types into Natural Gas in Manufacturing Industries

Energy Type	Quantity in 1000 Tonnes	NCVs TJ/Gg	Energy Type in TJ	NG Equivalent in 1000 Tonnes
Natural gas	2667.632	48.0	128046.30	2667.632
Fuel oil	3780.943	40.4	152750.10	3182.294
LPG	362.545	47.3	17148.38	357.258
Kerosene	6.866	43.8	300.73	6.265
Sulphur	144.705	40.2	5817.14	121.190
Diesel oil	129.533	43.0	5569.92	116.040
Gasoline	18.634	44.3	825.49	17.198
Petroleum coke	1443.449	32.5	46912.09	977.335
Coking Coal	828.289	28.2	23357.75	486.619
Coke Powder	419.814	25.0	10495.35	218.653
Hard coal	4891.877	26.7	130613.10	2721.107
Lignite	5050.529	11.9	58081.08	1210.023

Source: Author's Calculations

Table 4. Change in GHGs Emissions from Fossil Fuel Consumption to 100 Percent Natural Gas Substitution in 1998

GHGs Emissions in Tones	CO2	N2O	CH4	CO	SOx	NOx	NMVOC
1998 from Fossil Fuels	240084750.05	2475.25	5418.24	2643732.82	2815676.37	844237.38	437213.38
1998 from Natural Gas Substitution	166288061.27	296.52	2965.20	279073.25	28.47	599340.86	14826.01
% Change	-30.74	-88.02	-45.27	-89.44	-100.00	-29.01	-96.61

Source: Author's Calculations

Appendix 2

Table 5. GHGs Emissions 1998 (in 1000 Tonnes)

Sectors	CO2	N2O	CH4	CO	SOx	NOx	NMVOc
Growing of cereals and other crops n.e.c.	3345.56	0.0235	0.1222	23.9775	30.578	30.559	4.819
Wheat	660.17	0.0046	0.0241	4.7314	6.034	6.030	0.951
Maize	115.34	0.0008	0.0042	0.8266	1.054	1.054	0.166
Sunflower	145.43	0.0010	0.0053	1.0423	1.329	1.328	0.209
Cotton	89.94	0.0006	0.0033	0.6446	0.822	0.822	0.130
Growing of vegetables, horticultural specialties and nursery products	122.29	0.0009	0.0045	0.8764	1.118	1.117	0.176
Growing of fruit, nuts, beverage and spice crops	130.20	0.0009	0.0048	0.9331	1.190	1.189	0.188
Farming of animals	41.87	0.0003	0.0015	0.3007	0.382	0.382	0.060
Agricultural and animal husbandry service activities, except veterinary activities	11.50	0.0001	0.0004	0.0824	0.105	0.105	0.017
Forestry, logging and related service activities	174.87	0.0019	0.0042	2.2715	2.227	0.946	0.295
Fishing	369.01	0.0027	0.0131	2.8221	3.483	3.257	0.539
Mining and quarrying [08-12]	970.81	0.0069	0.0351	0.1527	8.943	2.730	0.070
Production, processing and preserving of meat and meat products	74.55	0.0007	0.0015	0.0658	1.020	0.205	0.010
Processing and preserving of fish and fish products	7.97	0.0000	0.0001	0.0037	0.076	0.019	0.001
Processing and preserving of fruit and vegetables	143.85	0.0011	0.0054	0.0216	1.277	0.372	0.009
Manufacture of vegetable and animal oils and fats	324.34	0.0034	0.0068	0.2830	4.064	0.907	0.044
Manufacture of dairy products	57.55	0.0005	0.0021	0.0140	0.563	0.150	0.004
Manufacture of grain mill products, starches and starch products	5.22	0.0000	0.0002	0.0007	0.047	0.014	0.000
Manufacture of prepared animal feeds	5.25	0.0001	0.0001	0.0069	0.092	0.015	0.001
Manufacture of bakery products	86.27	0.0003	0.0020	0.0366	0.565	0.221	0.007
Manufacture of sugar	2444.74	0.0316	0.0363	2.9900	36.032	7.120	0.419
Manufacture of cocoa, chocolate, sugar confert.& other food products n.e.c.	643.48	0.0065	0.0154	0.4985	5.977	1.798	0.082
Manufacture of alcoholic, soft drinks and mineral waters[23-24]	144.37	0.0010	0.0049	0.0332	1.136	0.376	0.010
Manufacture of tobacco products	41.84	0.0003	0.0014	0.0117	0.303	0.112	0.003
Manufacture of textiles [26-32]	2334.60	0.0135	0.0584	1.1464	15.256	6.212	0.216
Wood, furniture, paper, publishing [33-37, 67]	2569.66	0.0192	0.0916	0.6293	22.285	6.868	0.193
Manufacture of fertilizers, pesticides, other agro-chemicals, paints, and varnishes [40-41]	2001.75	0.0083	0.0488	0.8817	7.234	5.355	0.171
Manufacture of coke, refined petroleum prod, basic chemicals, rubber, plastics, glass, ceramic prod., non-metallic minerals, etc. [38-39, 42-49]	19053.87	0.1719	0.4730	12.0256	196.546	50.024	2.095
Manufacture of ferrous, non-ferrous metals, various machinery, vehicles, etc. [50-66, 68]	18983.49	0.2302	0.3072	21.6770	180.115	55.079	3.094
Energy production and distribution [69-70]	84171.95	0.9904	1.5016	18.0471	1144.228	245.396	4.917
Water and Construction [71-72]	3156.53	0.0210	0.1090	0.7926	26.633	8.762	0.250
Transport [73, 78-81]	32764.54	0.2334	1.1729	1851.8286	301.267	331.402	347.603
Services [74-77, 82-97]	11249.75	0.1082	0.2485	99.7687	125.134	12.903	10.171
PrC	41683.77	0.5028	0.7200	569.4289	580.912	45.603	57.393
Pb C	6768.60	0.0501	0.1995	22.9420	60.226	8.532	2.490
Goods and services exports	5189.82	0.0365	0.1886	1.9379	47.424	7.272	0.411
Total	240084.75	2.4753	5.4182	2643.7328	2815.676	844.237	437.213

Source: Bhutto (2007)

**Table 6.GHG Emissions in Tonnes for 1998 from 100 Percent Natural Gas
Substitution**

Sectors	CO2	N2O	CH4	CO	SOx	NOx	NMVOG
Growing of cereals and other crops n.e.c.	2637519.86	4.70	47.01	10578.29	0.45	24682.67	235.07
Wheat	520450.88	0.93	9.28	2087.37	0.09	4870.53	46.39
Maize	90929.10	0.16	1.62	364.69	0.02	850.94	8.10
Sunflower	114651.68	0.20	2.04	459.83	0.02	1072.94	10.22
Cotton	70905.34	0.13	1.26	284.38	0.01	663.55	6.32
Growing of vegetables, horticultural specialties and nursery products	96407.10	0.17	1.72	386.66	0.02	902.21	8.59
Growing of fruit, nuts, beverage and spice crops	102644.59	0.18	1.83	411.68	0.02	960.58	9.15
Farming of animals	33014.84	0.06	0.59	132.41	0.01	308.96	2.94
Agricultural and animal husbandry service activities, except veterinary activities	9067.15	0.02	0.16	36.37	0.00	84.85	0.81
Forestry, logging and related service activities	119634.34	0.21	2.13	479.82	0.02	1119.57	10.66
Fishing	287719.21	0.51	5.13	1153.95	0.05	2692.56	25.64
Mining and quarrying [08-12]	763202.90	1.36	13.60	408.13	0.13	2040.65	68.02
Production, processing and preserving of meat and meat products	51178.88	0.09	0.91	27.42	0.01	137.09	4.57
Processing and preserving of fish and fish products	7040.47	0.01	0.13	3.77	0.00	18.86	0.63
Processing and preserving of fruit and vegetables	105889.16	0.19	1.89	56.73	0.02	283.63	9.45
Manufacture of vegetable and animal oils and fats	221789.16	0.40	3.96	118.82	0.04	594.08	19.80
Manufacture of dairy products	41788.94	0.07	0.75	22.39	0.01	111.93	3.73
Manufacture of grain mill products, starches and starch products	3790.36	0.01	0.07	2.03	0.00	10.15	0.34
Manufacture of prepared animal feeds	3043.72	0.01	0.05	1.63	0.00	8.15	0.27
Manufacture of bakery products	74776.92	0.13	1.34	40.06	0.01	200.30	6.68
Manufacture of sugar	1509162.23	2.69	26.95	808.48	0.26	4042.40	134.75
Manufacture of cocoa, chocolate, sugar confert.& other food products n.e.c.	446506.78	0.80	7.97	239.20	0.08	1196.00	39.87
Manufacture of alcoholic, soft drinks and mineral waters[23-24]	111190.34	0.20	1.99	59.57	0.02	297.83	9.93
Manufacture of tobacco products	34090.43	0.06	0.61	18.26	0.01	91.31	3.04
Manufacture of textiles [26-32]	1933153.63	3.45	34.52	1035.62	0.33	5178.09	172.60
Wood, furniture, paper, publishing [33-37, 67]	1975974.43	3.53	35.29	1058.56	0.34	5292.79	176.43
Manufacture of fertilizers, pesticides, other agro-chemicals, paints, and varnishes [40-41]	1807742.81	3.23	32.28	968.43	0.31	4842.17	161.41
Manufacture of coke, refined petroleum prod, basic chemicals, rubber, plastics, glass, ceramic prod., non-metallic minerals, etc. [38-39, 42-49]	12881976.19	23.00	230.04	6901.06	2.21	34505.29	1150.18
Manufacture of ferrous, non-ferrous metals, various machinery, vehicles, etc. [50-66, 68]	12292575.06	21.95	219.51	6585.31	2.11	32926.54	1097.55
Energy production and distribution [69-70]	55165478.37	98.33	983.34	19666.84	9.44	147501.28	4916.71
Water and Construction [71-72]	2537951.70	4.52	45.24	1370.98	0.43	6717.05	226.20
Transport [73, 78-81]	25758696.49	45.92	459.16	183662.72	4.41	275494.08	2295.78
Services [74-77, 82-97]	8128942.95	14.49	144.90	7245.05	1.39	7245.05	724.50
PrC	26932103.62	48.01	480.07	24003.66	4.61	24003.66	2400.37
Pb C	5326459.98	9.49	94.95	4747.29	0.91	4747.29	474.73
Goods and services exports	4090611.66	7.29	72.92	3645.82	0.70	3645.82	364.58
Total	166288061.27	296.52	2965.20	279073.25	28.47	599340.86	14826.01

Source: Author's Calculations.

Table 7. GHGs Emissions Sectoral Share for 1998 from 100 Percent Natural Gas Substitution

Sectors	CO2	N2O	CH4	CO	SOx	NOx	NMVOC
Growing of cereals and other crops n.e.c.	1.59	1.59	1.59	3.79	1.59	4.12	1.59
Wheat	0.31	0.31	0.31	0.75	0.31	0.81	0.31
Maize	0.05	0.05	0.05	0.13	0.05	0.14	0.05
Sunflower	0.07	0.07	0.07	0.16	0.07	0.18	0.07
Cotton	0.04	0.04	0.04	0.10	0.04	0.11	0.04
Growing of vegetables, horticultural specialties and nursery products	0.06	0.06	0.06	0.14	0.06	0.15	0.06
Growing of fruit, nuts, beverage and spice crops	0.06	0.06	0.06	0.15	0.06	0.16	0.06
Farming of animals	0.02	0.02	0.02	0.05	0.02	0.05	0.02
Agricultural and animal husbandry service activities, except veterinary activities	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Forestry, logging and related service activities	0.07	0.07	0.07	0.17	0.07	0.19	0.07
Fishing	0.17	0.17	0.17	0.41	0.17	0.45	0.17
Mining and quarrying [08-12]	0.46	0.46	0.46	0.15	0.46	0.34	0.46
Production, processing and preserving of meat and meat products	0.03	0.03	0.03	0.01	0.03	0.02	0.03
Processing and preserving of fish and fish products	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Processing and preserving of fruit and vegetables	0.06	0.06	0.06	0.02	0.06	0.05	0.06
Manufacture of vegetable and animal oils and fats	0.13	0.13	0.13	0.04	0.13	0.10	0.13
Manufacture of dairy products	0.03	0.03	0.03	0.01	0.03	0.02	0.03
Manufacture of grain mill products, starches and starch products	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manufacture of prepared animal feeds	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manufacture of bakery products	0.04	0.05	0.05	0.01	0.05	0.03	0.05
Manufacture of sugar	0.91	0.91	0.91	0.29	0.91	0.67	0.91
Manufacture of cocoa, chocolate, sugar confert.& other food products n.e.c.	0.27	0.27	0.27	0.09	0.27	0.20	0.27
Manufacture of alcoholic, soft drinks and mineral waters[23-24]	0.07	0.07	0.07	0.02	0.07	0.05	0.07
Manufacture of tobacco products	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Manufacture of textiles [26-32]	1.16	1.16	1.16	0.37	1.16	0.86	1.16
Wood, furniture, paper, publishing [33-37, 67]	1.19	1.19	1.19	0.38	1.19	0.88	1.19
Manufacture of fertilizers, pesticides, other agro-chemicals, paints, and varnishes [40-41]	1.09	1.09	1.09	0.35	1.09	0.81	1.09
Manufacture of coke, refined petroleum prod, basic chemicals, rubber, plastics, glass, ceramic prod., non-metallic minerals, etc. [38-39, 42-49]	7.75	7.76	7.76	2.47	7.76	5.76	7.76
Manufacture of ferrous, non-ferrous metals, various machinery, vehicles, etc. [50-66, 68]	7.39	7.40	7.40	2.36	7.40	5.49	7.40
Energy production and distribution [69-70]	33.17	33.16	33.16	7.05	33.16	24.61	33.16
Water and Construction [71-72]	1.53	1.53	1.53	0.49	1.53	1.12	1.53
Transport [73, 78-81]	15.49	15.48	15.48	65.81	15.48	45.97	15.48
Services [74-77, 82-97]	4.89	4.89	4.89	2.60	4.89	1.21	4.89
PtC	16.20	16.19	16.19	8.60	16.19	4.01	16.19
Pb C	3.20	3.20	3.20	1.70	3.20	0.79	3.20
Goods and services exports	2.46	2.46	2.46	1.31	2.46	0.61	2.46
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Author's Calculations.

**Table 8. % Change Reduction in GHGs Emissions from Fossil Fuel Consumption to
100 Percent Natural Gas Substitution in 1998 (minus sign shows increment)**

Sectors	CO2	N2O	CH4	CO	SOx	NOx	NMVOc
Growing of cereals and other crops n.e.c.	21.16	80.00	61.54	55.88	99.99	19.23	95.12
Wheat	21.16	80.00	61.54	55.88	99.99	19.23	95.12
Maize	21.16	80.00	61.54	55.88	99.99	19.23	95.12
Sunflower	21.16	80.00	61.54	55.88	99.99	19.23	95.12
Cotton	21.16	80.00	61.54	55.88	99.99	19.23	95.12
Growing of vegetables, horticultural specialties and nursery products	21.16	80.00	61.54	55.88	99.99	19.23	95.12
Growing of fruit, nuts, beverage and spice crops	21.16	80.00	61.54	55.88	99.99	19.23	95.12
Farming of animals	21.16	80.00	61.44	55.97	99.99	19.11	95.11
Agricultural and animal husbandry service activities, except veterinary activities	21.16	80.00	61.54	55.88	99.99	19.23	95.12
Forestry, logging and related service activities	31.59	88.52	49.82	78.88	99.99	18.31	96.39
Fishing	22.03	81.03	60.89	59.11	99.99	17.34	95.24
Mining and quarrying [08-12]	21.38	80.28	61.27	167.31	99.99	25.26	2.44
Production, processing and preserving of meat and meat products	31.35	87.62	37.18	58.36	99.99	33.26	54.52
Processing and preserving of fish and fish products	11.71	13.78	6.01	-2.18	99.99	1.05	0.00
Processing and preserving of fruit and vegetables	26.39	82.32	65.06	163.14	99.99	23.69	0.05
Manufacture of vegetable and animal oils and fats	31.62	88.24	42.10	58.02	99.99	34.53	54.92
Manufacture of dairy products	27.38	83.60	63.61	-59.95	99.99	25.56	13.49
Manufacture of grain mill products, starches and starch products	27.33	83.29	66.60	198.33	99.99	24.95	0.00
Manufacture of prepared animal feeds	42.06	92.62	24.33	76.47	99.99	47.17	71.57
Manufacture of bakery products	13.33	60.58	33.42	-9.51	99.99	9.40	5.70
Manufacture of sugar	38.27	91.46	25.74	72.96	99.99	43.22	67.85
Manufacture of cocoa, chocolate, sugar confert.& other food products n.e.c.	30.61	87.80	48.14	52.02	99.99	33.47	51.11
Manufacture of alcoholic, soft drinks and mineral waters[23-24]	22.98	79.68	59.86	-79.26	99.99	20.78	3.96
Manufacture of tobacco products	18.53	76.98	55.62	-55.70	99.99	18.29	4.31
Manufacture of textiles [26-32]	17.20	74.42	40.88	9.66	99.99	16.64	20.20
Wood, furniture, paper, publishing [33-37, 67]	23.10	81.59	61.48	-68.21	99.99	22.94	8.66
Manufacture of fertilizers, pesticides, other agro-chemicals, paints, and varnishes [40-41]	9.69	61.05	33.91	-9.84	99.99	9.57	5.75
Manufacture of coke, refined petroleum prod, basic chemicals, rubber, plastics, glass, ceramic prod., non-metallic minerals, etc. [38-39, 42-49]	32.39	86.62	51.37	42.61	99.99	31.02	45.09
Manufacture of ferrous, non-ferrous metals, various machinery, vehicles, etc. [50-66, 68]	35.25	90.46	28.54	69.62	99.99	40.22	64.52
Energy production and distribution [69-70]	34.46	90.07	34.52	-8.97	99.99	39.89	0.00
Water and Construction [71-72]	19.60	78.50	58.50	-72.98	99.99	23.34	9.34
Transport [73, 78-81]	21.38	80.33	60.85	90.08	99.99	16.87	99.34
Services [74-77, 82-97]	27.74	86.61	41.68	92.74	99.99	43.85	92.88
PrC	35.39	90.45	33.33	95.78	99.99	47.36	95.82
Pb C	21.31	81.05	52.41	79.31	99.99	44.36	80.94
Goods and services exports	21.18	80.04	61.34	-88.13	99.99	49.87	11.22
Total	30.74	88.02	45.27	89.44	99.99	29.01	96.61

Source: Author's Calculations.