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PETROCHEMICAL SUPPLY CHAIN'S SHARE IN EMISSION OF GREEN HOUSE GASES, CASE STUDY: SHAZAND PETROCHEMICAL COMPLEX

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ABSTRACT

In this study petrochemical supply chain shares in global warming is studied by monitoring carbon footprint during manufacturing and distribution phase. For identification and measurement of carbon emissions in petrochemical supply chain, at first step necessary data are collected. Then carbon footprint is calculated in manufacturing process. So GHG is measured during fossil fuel use for chemical productions and electricity production in exclusive power plant in production phase. Also carbon emissions are calculated during chemical process (non-energy use of fossil fuels). The other activity that has an impact on GHG emissions is transportation. In this study Intergovernmental Panel for Climate Change (IPCC) methodology was employed. For conducting this research Shazand petrochemical complex in Iran is selected as a case study. The calculations and monitoring GHG will help to greening the petrochemical supply chain.The result shows GHG emissions in Shazad petrochemical complex supply chain is 6108960.35 tons per year. 6100434.9 tones CO_2equ per year emit from manufacturing phase and 8525.4 tones CO_2equ per year emit from distribution phase. Based on a comparison with statistics from United Nation Statistics division reports contribution of manufacturing phase of Shazand Petrochemical supply chain in global warming is about 0.020% and Based on a comparison with statistics from Iranian fuel Conservation Company and energy balance reports the contribution of distribution phase of Shazand Petrochemical supply chain in global warming is about 0.004%.

Keywords: Green House Gases, Green Supply Chain, Petrochemical Industry

1. INTRODUCTION

Carbon management is the main issue in greening the supply chain. A green supply chain is a new concept appearing in recent literatures.Green Supply Chain Management (GSCM) has emerged as a key approach for enterpriser seeking to make their businesses environmentally sustainable. The notion of GSCM implies the insertion of environmental criteria within the decision-making context of the traditional supply chain management (Emmett and Vivek, 2010). Companies using environmental supply chain management or GSCM are managing tehir supply chian by supplying materials and information systems requirements, designing new methods for performance evolution, applying enviornmnetal goals and supply chian strategies (Naini *et al*., 2010).

Carbon management could help to greening the supply chain. Integrating carbon footprint into supply chain management can help companies identify the source of carbon impacts in their supply chain. A number of companies in different industry sectors are beginning

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to recognize the carbon issue as one of the critical factors in supply chain management so started to accounting and monitoring their carbon footprint.

Two main reasons exist for companies to exert effort on carbon emission abatement: The first one is voluntary commitment, as a response to pressure from customer preferences, environmental groups and initiatives such as the carbon disclosure project. The second reason is to respond to emission regulations (Hoen *et al*., 2012). Having quantified the emissions, the important sources of emissions can be identified and areas of emission reductions and increasing efficiencies can be prioritized. This provides the opportunity for environmental efficiencies and cost reductions.

One of the industrial parts that cause CO_2 emissions is petrochemical industry. In 2008 about 1.2 billion tons of petrochemical products were produced. In Iran petrochemical production capacity is 2.5% of world petroleum production and 27% of Middle East petroleum production IHBS, 2010.

Chemical and petrochemical manufactures are the second largest energy-consuming manufacturing sector in the world and accounts for almost 5% of global GHG emissions. It is include direct (on-site) CO_2 emissions from fossil fuel combustion, indirect emissions from electricity consumed during production and release of non-CO_2 gases from various industrial processes (Baumert *et al*., 2005).

In the context of greenhouse gas emissions, so far most attention has been paid to CO_2 emissions from the combustion of fossil fuels. But a significant fraction of fossil fuels is used for non energy applications. Non-energy use is here defined as the consumption of fossil feedstocks for the manufacture of synthetic organic materials and chemical products (Patel *et al*., 2000; 2003).

Most of the basic petrochemical productions depend on crude oil for energy and raw material supply. Basic petrochemical productions include two steps: feedstock production (from primary energy sources to feedstocks) and petrochemical productions. In feedstock production, primary energy sources (i.e., crude oil, natural gas, coal and biomass) are extracted and then converted into feedstocks (e.g., naphtha and methanol). In this step, it is possible for some processes to coproduce electricity and fuels. When applicable, primary energy sources can also be used as fuels here. In petrochemical productions, feedstocks are converted into basic petrochemicals, such as ethylene and aromatics, which are then separated from each other. In this step, it is possible for some processes to coproduce fuels (Ren, 2009). These two steps lead to emission of considerable amounts of GHG gases. **Figure 1** shows the two Process Steps in Basic Petrochemicals Routes.

The other source of CO_2 emission in petrochemical supply chain is distribution and transportation of raw material and products.

Literature reviews show many research have been done in the field of green supply chain. Zsidisin and Hendrick (1998) by investigating purchasing managers in Germany, the UK and the USA identified four green supply management factors, namely hazardous materials, Investment Recovery (IR), product design and supply chain relationships and determined the existence of these four factors with an exploratory factor analysis. Handfield *et al*. (2002) developed a decision model to measure environmental practice of suppliers using a multi attribute utility theory approach. Rao and Holt (2005) studied the relationship between the implementation of green supply chains and the economic performance and competitiveness of a sample of Asian firms. Zhu and Sarkis (2004) and Zhu *et al*. (2007) evaluated the effectiveness of green supply chain management in Chinese manufacturing enterprises and the automobile industry, respectively. De Brito *et al*. (2008) conduct a survey of stakeholder to explore how green initiatives impact the fashion retail supply chain organization and its performance. They found that green issues in the fashion industry were particularly sensitive due to intense competition, high resource use and concerns about labor practices. Sheu *et al*. (2005) developed a linear multi-objective programming model that optimized the operations of both forward and reverse logistics in a given green supply chain. These models and frameworks included and defined a variety of characteristics, attributes and scales for green supply chain management practices implementation.

Hugo and Pistikopoulos (2005) addressed the inclusion of Life Cycle Assessment (LCA) criteria as part of the strategic investment decisions. Kainumaa and Tawarab (2006) proposed the multiple attribute utility theory method for assessing a supply chain including re-use and recycling throughout the life cycle of products and services. Foerstl *et al*. (2010) and Pullman *et al*. (2009) integrate the supplier perspective to sustainable supply chain management. Gonzalez-Benito and Gonzalez-Benito (2006); Locke and Romis (2007); Collins *et al*. (2007) and Locke *et al*. (2007) studied green supply chain management downstream side, their results show that customers increasingly want to understand the conditions under which products have been produced and desire products that have been produced in an environmentally sustainable way. Testa and Iraldo (2010) investigated different factors that could have effect on implementation of green supply chain in 4000 company.

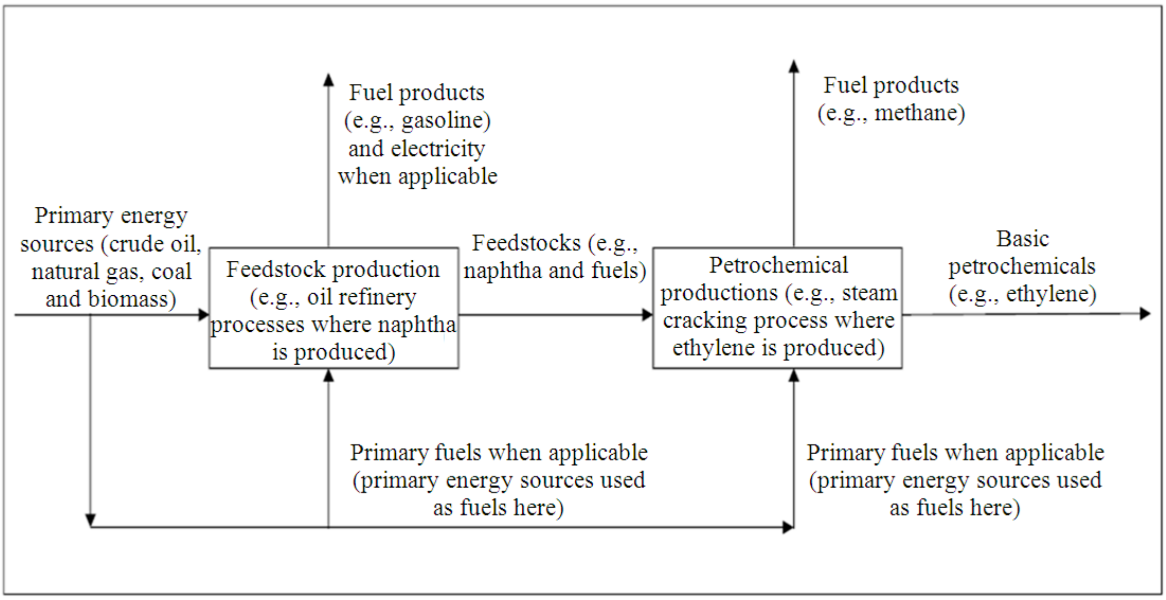

Fig. 1. The two process steps in basic petrochemicals routes

Despite the researches in the area of green supply chain management, literature is scare with respect to monitoring and control carbon emissions. Chohlette and Venkat (2009) calculate the energy and carbon emissions in transportation and warehousing activities in wine industry. Sundarakani *et al.* (2010) modeling carbon footprint across the supply chain network for electric power. Lee (2011) integrated carbon footprint into automobile supply chain management. Cheng (2011) presents a web service collaborative framework for measuring, monitoring and integrating environmental and carbon footprint data in construction supply chains. Tjian *et al.* (2010) discusses a new application of graphical technique based on pinch analysis for company-level visualization and analysis of carbon footprint improvement. The technique is based on the decomposition of total carbon footprint into material- and energy-based components, or alternatively, into internal and external components. Larsen *et al.* (2012) discuss how to reduce energy/climate footprint Supply chain management through the use of Environmentally Extended Input-Output Analysis (EEIOA) and Life Cycle Assessment (LCA). Results show that for most sectors a majority of the energy/environmental loads are located in the upstream supply chain, both nationally and abroad.

Despite these researches of modeling carbon footprint across supply chains, there isn't any attempt on monitoring carbon footprint across petrochemical supply chain. So in this study petrochemical supply chain shares in global warming and its role in greening supply chain is studied by monitoring carbon footprint during manufacturing and distribution phase.

2. MATERIALS AND METHODS

As mentioned above the aim of this study is calculation of GHG in petrochemical supply chain by monitoring carbon footprint in manufacturing chemical products and distribution of these products. Necessary data gathered by doing interviews, using internal reports, published data source and company records. Although suppliers and consumers can influence the carbon footprint, they are not included in this study due to complications the supply phase and due to limited extent to which final consumers can effect carbon emissions occurring in the supply chain.

2.1. Introduction to Shazand Petrochemical Company

Shazand petrochemical company as an affiliation of National Petrochemical Company of Iran-Ministry of Oil was founded in 1987. This company has established as a petrochemical Complex for the production of different Petrochemical products such as polyethylene, polypropylene, butadiene, poly-butadiene, acetic acid, vinyl acetate, oxide ethylene and ethylene glycol, 2ethyl hexanol and butanols, ethanol amines from Naphtha feedstock (totally 17 presses unit). **Table 1** shows Input and output of different process in Shazand petrochemical complex. This tabel shows the amout af input and producs of each unit.

Shazand petrochemical complex is located in Iran, Markazi province, near to city of Shazand, next to the 7th Refinery. It is constructed on the land with surface area of 523 hectares (**Fig. 2**).

2.2. Manufacturing Phase

In a manufacturing phase in petrochemical supply chain green house gases emit from fossil fuel consumption during chemical production and electricity production. Also GHG emit from Non-energy use of fossil fuels. Calculation based methods typically entail the collection of (a) activity data, in the form of the quantity of fuel consumed for combustion purposes and(b) emission factor data, in the form of information on the characteristics of the fuel combusted and the efficiency of the oxidation process (IPCC, 2006).

In order to calculate GHG emissions due to fossil fuels combustion in 17 processes the following equations is applied base on GHG protocol methodology:

$$E = A_{f,v} \cdot F_{c,v} \cdot F_{ox}$$

Where:

- E = Mass emissions of CO_2 (short tons or metric tons)
- $A_{f,v}$ = Volume of fuel consumed (m^3)
- F_{ox} = Oxidation factor to account for fraction of carbon in fuel that remains as soot or ash
- $F_{c,v}$ = Carbon content of fuel on a volume basis (metric tons C/m^3)

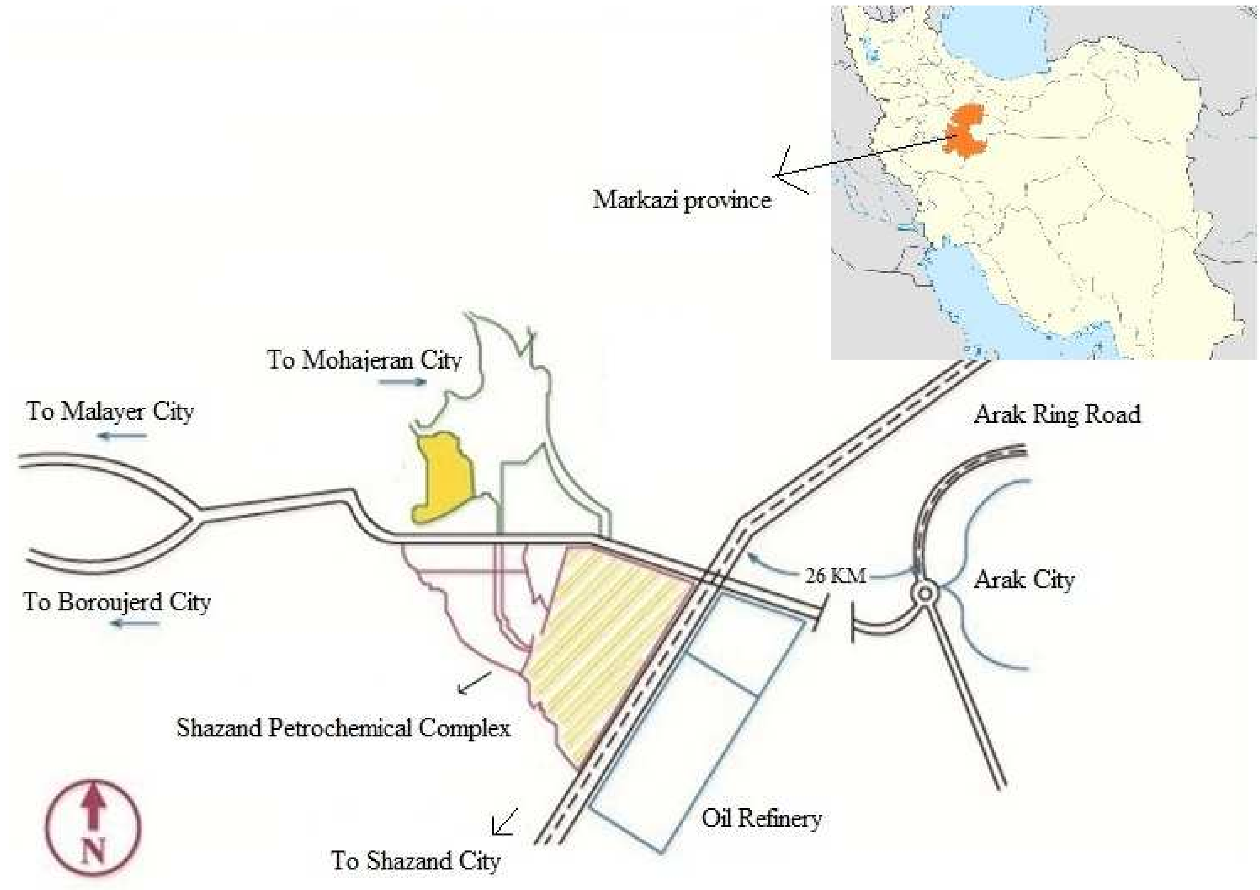

Fig. 2. The location of Shazand petrochemical complex

Table 1. Input and output of different process in Shazand petrochemical complex

	Input		Output	
Process unit	Feedstock	Amount(tone/year)	Product	Amount (tone/year)
Olefin	Naphtha	925000	Ethylene	306400
			Propylene	124000
			Fuel oil	70000
			C_4	77000
			Crude gasoline	174000
Pyrolysis gasoline	Crude gasoline	174000	Hydrogenate pyrolysis gasoline	168800
	Hydrogen	1600		
Linear Low Density) Polyethylene (LLDP	Ethylene and Buthene-1	61800	Polyethylene	60000
	Hydrogen	60		
High Density Polyethylene (HDPE)	Ethylene	83000	High density polyethylene	85000
	Buthene-1	18000		
	Hydrogen	20		
Polypropylene	Propylene	75200	Polypropylene	75000
Butadiene separation (BD)	C_4	52000	Butadiene	27300
			Raffinate	1830
Buthene-1	Ethylene	7624	Buthene-1	7000
Poly Butadiene Rubber (PBR)	Butadiene	26000	Poly Butadiene rubber	25000
Ethylene Oxide (EO)	Ethylene	90420	Ethylene oxide	105000
	Oxygen	104000	CO_2	57600
Ethylene Glycols (EG)	Ethylene oxide	75000	Ethylene Glycols	105000
Ethanolamine (EA)	Ethylene oxide	25000	Ethanolamine	30000
	Ammonia	6000		
Ethoxylated products (EX)	Ethylene oxide	10000	Ethoxylated products	30000
	Phenyalcohol	10000		
	Nonylphenol	2000		
	Mono Ethylene Glycol	2000		
Butyraldehyde	Synthesis gas	27176	Butyraldehyde	63000
	Propylene	38400		
2 Ethyl Hexanol (2EH)	Normal Butyraldehyde	55500	2 Ethyl Hexanol	45000
	Hydrogen	1400		
Acetic Acid (AA)	Ethylene	16500	Acetic acid	30000
	Oxygen	19000		
Vinyl Acetate (VA)	Acetic acid	22000	Vinyl Acetate	30000
	Oxygen	8800		
	Ethylene	11000		
Buthanols	Butyraldehydes	10480	Buthanols	10700
	Hydrogen	270		

In Shazand petrochemical complex GHG emissions also release during production processes in where hydrocarbon feedstock are used as input. The general methodology employed to estimate this part of emissions associated with each industrial process involves the product of activity level data, e.g., amount of material produced or consumed and an associated emission factor per unit of consumption/production according to the following method (IPCC, 2006):

$$TOTAL_{ij} = A_j x\ EF_{ij}$$

Where:

$TOTAL_{ij}$ = Process emission (tonnes) of gas i fromIndustrial sector j

A_j = Amount of activity or production of processMaterial in industrial sector j (tonnes/yr)

EF_{ij} = Emission factor associated with gas i per unit of Activity in industrial sector j (tonne/tonne)

2.3. Distribution Phase

In a supply chain distribution phase consist of distribution of row material and distribution of product to customers. In Shazand petrochemical complex main row material is naphtha and naphtha is transferred by pipeline. At the downstream side product transferred to the domestic and international markets. Due to the dispersion and diversity of the roots of domestic market transport data collection in this p was not possible.

To deliver products to international markets, at fist products transfer to ports at the north and south of Iran (depending to the destination).

For exporting products annually 2600 truck travel to Bandarabas port, 4097 truck travel to Bandare-emam Khomeini port and 7079 truck travel to northern ports. Total loading weight is 145000000 kg.

IPCC methodology is employed to calculate transport emissions:

Emissions = Σα Fuela * EFa
Emission = Emissions of GHG (kg)
Fuela = Fuel sold (TJ)
EFa = Emission factor (kg/TJ).
a = Type of fuel (e.g., petrol, diesel, natural gas, LPG)

3. RESULTS

Table 2 shows the result of calculation of GHG emissions in 17 process units and power plant due to fossil fuels consumption. As can be seen total GHG emission in Shazanad petrochemical complex in this part of manufacturing phase of supply chain is 625702.9 tons per year.

According the result of **Table 3** 5474732.05 tons per year GHG emitted during non-energy use of fossil fuels. Totally 6100434.95 tones of GHG per year emitted during production phase in Shazand petrochemical supply chain.

Table 4 show the result of GHG emission in distribution phase of supply chain. Total GHG emissions in this phase 8525.4 tone co_2 equ per year.

As can be seen in **Table 5** total GHG emissions in Shazad petrochemical complex supply chain is 6108960.35 tones CO_2equ per year. 6100434.95 tones CO_2equ per year emit from manufacturing phase and 8524.4 tones CO_2equ per year emit from distribution phase.

Table 2. Total GHG emissions from energy use of fossil fuels in production phase

Source ID	CO_2	CH_4	N_2O	All GHGs (tones CO_2e/year)
Olefin	312102.250	5.56	0.560	312407.120
Benzene pirolis	59248.817	1.05	0.100	59306.693
Linear Low Density Polyethylene (LLDPE)	20872.049	0.37	0.030	20892.437
High Density Polyethylene (HDPE)	34084.940	0.60	0.060	34118.235
Polypropylene (pp)	25373.070	0.45	0.040	25397.855
Butadiene	17545.208	0.31	0.030	17562.346
Buten 1	2572.397	0.04	0.004	2574.910
Poly Butadiene Rubber (PBR)	8772.604	0.15	0.010	8781.173
Ethylene Oxide (EO)	35260.853	0.62	0.060	35295.297
Ethyleneglycols (EG)	25305.588	0.45	0.040	25330.307
Ethanolamine (EA)	2071.571	0.03	0.003	2073.595
Butyraldehyde	22125.857	0.39	0.030	22147.470
2Ethyl Hexanol (2EH)	19198.506	0.34	0.030	19217.260
Acetic Acid (AA)	11977.978	0.21	0.020	11989.679
Vinyl Acetate Monomer (VAM)	14103.648	0.25	0.020	14117.425
Normal Butanol (NB)	3627.134	0.06	0.006	3630.677
Ethoxylated (ETX)	8097.788	0.14	0.010	8105.698
Total GHG emissions in process units (tonnes CO_2e):	622948.180			
Power plant	2752.042	0.49	0.040	2754.730
Total GHG emissions due to fossil fuel consumption (tonnes CO_2e):				625702.900

Table 3. Total GHG emissions from non-energy use of fossil fuels in production phase

Source ID	CO_2	CH_4	N_2O	All GHGs (tones CO_2e/year)
Olefin	2773125.0	123.900	26.100	2773129.90
Benzene pirolis	510578.4	21.700	4.400	510579.20
Linear Low Density Polyethylene (LLDPE)	116757.0	5.190	1.030	116757.20
High Density Polyethylene (HDPE)	160836.6	7.150	1.140	160836.60
Polypropylene (pp)	139038.0	6.250	1.150	139038.25
Butadiene	344027.8	43.900	9.000	344080.70
Buten 1	236750.3	24.800	16.800	236792.30
Poly Butadiene Rubber (PBR)	94522.0	4.020	0.800	94522.10
Ethylene Oxide (EO)	227441.3	10.100	2.020	227441.70
Ethyleneglycols (EG)	167974.2	7.400	1.400	167974.50
Ethanolamine (EA)	71733.9	3.050	0.060	71733.90
Butyraldehyde	381120.1	16.200	3.300	381120.70
2Ethyl Hexanol (2EH)	130.7	0.005	0.001	130.80
Acetic Acid (AA)	69203.8	2.940	0.600	69203.90
Vinyl Acetate Monomer (VAM)	77724.4	3.030	0.600	77724.50
Normal Butanol (NB)	32284.4	1.300	0.280	32284.40
Ethoxylated (ETX)	71381.1	3.030	0.600	71381.20
Total GHG emissions due to non-energy use of fossil fuel consumption (tonnes CO_2e):				5474732.05

Table 4. GHG emissions during distribution phase

Destination	CO_2	CH_4	N_2O	All GHGs (tones CO_2e/year)
Bandarabbas port	2567.9	3.14	0.135	2686.6
Bandare emam khomeini port	2475.5	3.03	0.130	2589.9
Northern port	3106.3	3.80	0.160	3248.9
Total	8149.7	9.90	0.420	8525.4

Table 5. GHG emissions in Shazand petrochemical complex supply chain

Supply chain phase	Total GHG emissions (metric tones CO_2e)
Manufacturing (energy use of fossil fuels)	625702.90
Manufacturing (Non-energy use of fossil fuels)	5474732.05
Distribution	8525.40
Total	6108960.35

4. DISCUSSION

The main aim of is this study has been to show the share of petrochemical industry in global warming. To find out the Shazand petrochemical complex share in global warming, results of calculation compared to intenational statistics.

Table 6 shows the contribution of manufacturing phase of Shazand Petrochemical supply chain in global warming Based on a comparison with statistics from United Nation Statistics division reports and **Table 7** shows the contribution of distribution phase of Shazand Petrochemical supply chain in global warming Based on a comparison with statistics from Iranian fuel conservation company and energy balance reports.

Table 6. Manufacturing phase of Shazand Petrochemicals complex contribution in global warming

	GHG emissions (mt/year)	Shazand Complex contribution (%)
World	29888.0	0.020
Iran	538.0	1.13
Manufacturing phase	6.1	-

Table 7. Distribution phase of Shazand Petrochemicals complex contribution in global warming

	GHG emissions (mt/year)	Shazand Complex contribution (%)
World	1889.4000	0.004
Iran	120.0700	0.007
Distribution phase	0.0085	-

This study is early attempt to monitor carbon emissions across chemical process and discusses carbon footprint in petrochemical industry. This study is provide some evidence on how to measure supply chain (manufacturing and distribution phase) carbon footprint. This study can be extended by measuring carbon footprint in entire supply chain of petrochemical company.

5. CONCLUSION

Results show total GHG emissions in Shazad petrochemical complex supply chain is 6108960.35 tones CO_2equ per year.Based on a comparison with statistics share of manufacturing phase of Shazand Petrochemical supply chain in global warming is about 0.020% and contribution of distribution phase of Shazand Petrochemical supply chain in global warming is about 0.004%.

This study is early attempt to monitor carbon emissions across petrochemical process and discusses carbon footprint in petrochemical industry. This study is provide some evidence on how to measure supply chain (manufacturing and distribution phase) carbon footprint. This study can be extended by measuring carbon footprint in entire supply chain of petrochemical company.

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