P Petrochemical Supply Chain’s Share in Emission of Green House Gases, Case Study: Shazand Petrochemical Complex

Naser Moharamned, Masoud Aghajani, Faride Atabi and Sahar Azarkamand

1Department of Environment Management, Graduate School of Environment and Energy, Islamic Azad University, Science and Research Campus, Tehran, Iran
2Faculty of Petroleum, Petroleum University of Technology Ahwaz, Iran

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\textsubscript{2} equivalent per year emit from manufacturing phase and 8525.4 tones CO\textsubscript{2} equivalent 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 their supply chain by supplying materials and information systems requirements, designing new methods for performance evolution, applying environmental goals and supply chain 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...
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. Shyu 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. Forerstl 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.
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:

\[
E = A_f \cdot F_{ox} \cdot F_{ca}
\]

Where:
- \( E \) = Mass emissions of \( \text{CO}_2 \) (short tons or metric tons)
- \( A_f \) = Volume of fuel consumed \( (m^3) \)
- \( F_{ox} \) = Oxidation factor to account for fraction of carbon in fuel that remains as soot or ash
- \( F_{ca} \) = Carbon content of fuel on a volume basis (metric tons \( C/m^3 \))

![Fig. 2. The location of Shazand petrochemical complex](image-url)
Table 1. Input and output of different process in Shazand petrochemical complex

| Process unit                              | Feedstock          | Amount (tone/year) | Product        | Amount (tone/year) |
|-------------------------------------------|--------------------|--------------------|----------------|-------------------|
| Olefin                                    | Naphtha            | 925000             | Ethylene       | 306400            |
|                                           |                    |                    | Propylene      | 124000            |
|                                           |                    |                    | Fuel oil       | 71000             |
|                                           |                    |                    | C4             | 77000             |
|                                           |                    |                    | Crude gasoline | 174000            |
|                                           |                    |                    | Hydrogenate pyrolysis gasoline | 168800 |
| Pyrolysis gasoline                        | Crude gasoline     | 174000             | Ethylene       | 306400            |
|                                           | Hydrogen           | 1600               | Propylene      | 124000            |
|                                           | Ethylene and Propylene | 61800         | Ethylene       | 70000             |
| Linear Low Density)                       | Ethylene and Hydrogen | 60                | Propylene      | 60000             |
| Polyethylene (LLDP)                       | Butene-1           | 60                 | Polyethylene   | 60000             |
|                                           | Hydrogen           | 60                 | Butene-1       | 70000             |
| High Density Polyethylene (HDPE)          | Ethylene           | 83000              | High density polyethylene | 85000 |
|                                           | Butene-1           | 18000              | Polypropylene  | 75000             |
|                                           | Hydrogen           | 20                 | Butadiene      | 27300             |
|                                           |                    |                    | Raffinate      | 1830              |
| Polypropylene                             | Propylene          | 75200              | Polypropylene  | 75000             |
| Butene-1 separation (BD)                  | C4                 | 52000              | Butadiene      | 27300             |
|                                           |                    |                    | Raffinate      | 1830              |
|                                           | Ethylene           | 7624               | Poly Butadiene rubber | 25000 |
|                                           | Poly Butadiene Rubber (PBR) | 26000     | Ethylene oxide | 105000            |
| Ethylene Oxide (EO)                       | Ethylene oxide     | 90420              | CO2            | 57600             |
|                                           | Oxygen              | 104000             | Ethylene Glycols | 105000 |
| Ethylene Glycols (EG)                     | Ethylene oxide     | 75000              | Ethanolamine   | 30000             |
| Ethanolamine (EA)                         | Ethylene oxide     | 25000              | Ethanolamine   | 30000             |
|                                           | Ammonia            | 6000               | Ethoxylated products | 30000 |
| Ethoxylated products (EX)                 | Ethylene oxide     | 10000              | Ethoxylated products | 30000 |
|                                           | Phenylalcohol      | 10000              | Nonylphenol    | 2000              |
|                                           | Butyraldehyde Synthesis gas | 27176  | Butyraldehyde | 63000             |
|                                           | Propylene          | 38400              | Acetic acid    | 30000             |
|                                           | Normal Butyraldehyde | 55500       | Acetic acid    | 30000             |
| 2 Ethyl Hexanol (2EH)                     | Hydrogen           | 1400               | Acetic acid    | 30000             |
|                                           | Ethylene           | 16500              | Acetic acid    | 30000             |
|                                           | Oxygen             | 19000              | Acetic acid    | 30000             |
| Acetic Acid (AA)                          | Ethylene           | 16500              | Vinyl Acetate  | 30000             |
|                                           | Oxygen             | 19000              | Vinyl Acetate  | 30000             |
|                                           | Ethylene           | 22000              | Vinyl Acetate  | 30000             |
|                                           | Acetic acid        | 10480              | Butanalysols   | 10700             |

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):  

\[
\text{TOTAL}_{ij} = A_j \times \text{EF}_{ij}
\]

Where:  
- \( \text{TOTAL}_{ij} \) = Process emission (tonnes) of gas i from industrial sector j  
- \( A_j \) = Amount of activity or production of process material in industrial sector j (tonnes/yr)  
- \( \text{EF}_{ij} \) = 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 raw material and distribution of product to customers. In Shazand petrochemical complex main raw 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 phase was not possible.

To deliver products to international markets, at first 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:

\[
\text{Emissions} = \Sigma \alpha \text{Fuela} \times \text{EFa}
\]

- Emission = Emissions of GHG (kg)
- Fuela = Fuel sold (TJ)
- EFa = Emission factor (kg/TJ)

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 Shazand 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 tons 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$_2$ equ per year. 6100434.95 tones CO$_2$ equ per year emit from manufacturing phase and 8524.4 tones CO$_2$ equ per year emit from distribution phase.

| Source ID | CO$_2$ | CH$_4$ | N$_2$O | All GHGs (tonnes CO$_2$e/year) |
|-----------|--------|--------|--------|-------------------------------|
| Olefin    | 312102.250 | 5.56   | 0.560  | 312407.120                    |
| Benzene pirolis | 59248.817  | 1.05   | 0.100  | 59306.963                    |
| 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                     |
| Butyaldehyde | 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$_2$e): | 622948.180 |        |        | 622948.180                   |
| Power plant | 2752.042  | 0.49   | 0.040  | 2754.730                     |
| Total GHG emissions due to fossil fuel consumption (tonnes CO$_2$e): | 625702.900 |        |        | 625702.900                   |
Table 3. Total GHG emissions from non-energy use of fossil fuels in production phase

| Source ID | CO₂ (mt/year) | CH₄ (Kg/year) | N₂O (Kg/year) | All GHGs (tonnes CO₂e/year) |
|-----------|---------------|----------------|----------------|----------------------------|
| Olefin    | 2773125.0     | 123.900        | 26.100         | 2773129.9                  |
| 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        | 0.600          | 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        | 0.000          | 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 CO₂e): 5474732.05

Table 4. GHG emissions during distribution phase

| Destination         | CO₂ (mt/year) | CH₄ (Kg/year) | N₂O (Kg/year) | All GHGs (tonnes CO₂e/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                      |

Total GHG emissions due to non-energy use of fossil fuel consumption (tonnes CO₂e): 8525.4

Table 5. GHG emissions in Shazand petrochemical complex supply chain

| Supply chain phase       | Total GHG emissions (metric tonnes CO₂e) |
|--------------------------|------------------------------------------|
| 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 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 international 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 an early attempt to monitor carbon emissions across chemical process and discusses carbon footprint in petrochemical industry. This study provides 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$_2$equ 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.

6. REFERENCES

Baumert, K.A., T. Herzog and J. Pershing, 2005. Navigating the Numbers: Greenhouse Gas Data and International Climate Policy. 1st Edn., World Resources Institute, Washington, ISBN-10: 1569735999, pp: 122.

Cheng, J., 2011. A web service framework for measuring and monitoring environmental and carbon footprint in construction supply chains. Proc. Eng., 14: 141-147. DOI: 10.1016/j.proeng.2011.07.016

Chohlette, S. and K. Venkat, 2009. The energy and carbon intensity of wine distribution: A study of logistical options for delivering wine to consumers. J. Cleaner Product., 17: 1401-1413. DOI: 10.1016/j.jclepro.2009.05.011

Collins, C.M., L. Steg and M.A.S. Koning, 2007. ‘Customers’ values, beliefs on sustainable corporate performance and buying behavior. Psychol. Market., 24: 555-577. DOI: 10.1002/mar.20173

De Brito, M.P., V. Carbone and C.M. Blanquart, 2008. Towards a sustainable fashion retail supply chain in Europe: Organisation and performance. Int. J. Product. Econ., 114: 534-553. DOI: 10.1016/j.ijpe.2007.06.012

Emmett, S. and S. Vivek, 2010. Green Supply Chains: An Action Manifesto. 1st Edn., John Wiley and Sons, Chichester, U.K., ISBN-10: 0470662336, pp: 316.

Foerstl, K., C. Reuter, E. Hartmann and C. Blome, 2010. Managing supplier sustainability risks in a dynamically changing environment-Sustainable supplier management in the chemical industry. J. Purchas. Supply Manage., 16: 118-130. DOI: 10.1016/j.pursup.2010.03.011

Hugo, A. and E.N. Pistikopoulos, 2005. Environmentally conscious long-range planning and design of supply chain networks. J. Cleaner Product., 13: 1471-1491. DOI: 10.1016/j.jclepro.2005.04.011

IPCC, 2006. Guidelines for national greenhouse gas inventories. International Organizations.

Kainumaa, Y. and N. Tawarab, 2006. A multiple attribute utility theory approach to lean and green supply chain management. Int. J. Product. Econ., 101: 99-108. DOI:10.1016/j.ijpe.2005.05.010

Larsen, H.N., C. Solli and J. Pettersen, 2012. Supply chain management-How can we reduce our energy/climate footprint? Energy Proc., 20: 354-363. DOI: 10.1016/j.egypro.2012.03.035

Lee, K.H., 2011. Integrating carbon footprint into supply chain management: The case of Hyundai Motor Company (HMC) in the automobile industry. J. Cleaner Product., 19: 1216-1223. DOI: 10.1016/j.jclepro.2011.03.010

Locke, R. and M. Romis, 2007. Improving Work Conditions in a Global Supply Chain. MIT Sloan Manage. Rev., 48: 54-62.

Locke, R.M., Q.I.N. Fei and A. Brause, 2007. Does monitoring improve labor standards-Lessons from Nike. Indus. Labor Relat. Rev., 61: 3-31.

Naini, S.G.J., A.R. Alijahmadi and M. Jafari-Eskandari, 2010. Designing a mixed performance measurement system for environmental supply chain management using evolutionary game theory and balanced scorecard: A case study of an auto industry supply chain. Resources, Conservat. Recycl., 55: 593-603.

Gonzalez-Benito, J. and O. Gonzalez-Benito, 2006. The role of stakeholder pressure and managerial values in the implementation of environmental logistics practices. Int. J. Product. Res., 44: 1353-1373. DOI: 10.1080/00207540500435199

Handfield, R., S. Walton and R. Sroufe, 2002. Applying environmental criteria to supplier assessment: A study in the application of the analytical hierarchy process. Eur. J. Operat. Res., 141: 70-87. DOI:10.1016/S0377-2217(01)00261-2

Hoen, K.M.R., T. Tan, J.C. Fransoo and G.J.V. Houtum, 2012. Effect of carbon emission regulations on transport mode selection under stochastic demand. Flexible Services Manufact. J. DOI: 10.1007/s10696-012-9151-6
Patel, M., M. Neelis, D. Gielen and T. Simmons, 2000. International Network Non energy use and CO2 emissions (NEU-CO2). An Activity within the European Commission's ENRICH Programme, DG RTD, “Environment and Climate”. Final Report of the First Phase of the Network. Institute system and innovation research.

Patel, M., M. Neelis, D. Gielen, T. Simmons and J. Theunin, 2003. Summary of the International Network “Non-Energy Use and CO2 Emissions (NEU-CO2). Conclusions of Phase II.

Pullman, M.E., M.J. Maloni and C.R. Carter, 2009. Food for thought: Social versus environmental sustainability practices and performance outcomes. J. Supply Chain Manage., 45: 38-54. DOI: 10.1111/j.1745-493X.2009.03175.x

Rao, P. and D. Holt, 2005. Do green supply chains lead to competitiveness and economic performance? Int. J. Operat. Product. Manage., 25: 898-916. DOI: 10.1108/01443570510613956

Ren, T., 2009. Petrochemicals from Oil, Natural gas, Coal and Biomass: Energy Use, Economics and Innovation. 1st Edn., Proefschrift Universiteit Utrecht, ISBN-10: 9039350191, pp: 219.

Sheu, J.B., Y.H. Chou and J.J. Hu, 2005. An integrated logistics operational model for green supply chain management. Transportat. Res. Part E, 41: 287-313. DOI: 10.1016/j.tre.2004.07.001

Sundarakani, B., R. de Souza, M. Goh, S.M. Wgner and S. Mnikandan, 2010. Modeling carbon footprints across the supply chain. Int. J. Product. Econ., 128: 43-50. DOI: 10.1016/j.ijpe.2010.01.018

Testa, F. and F. Iraldo, 2010. Shadows and lights of GSCM (Green Supply Chain Management): determinants and effects of these practices based on a multi-national study. J. Cleaner Product., 18: 953-962. DOI: 10.1016/j.jclepro.2010.03.005

Tjian, W., R.R. Tan and D.C.Y. Foo, 2010. A graphical representation of carbon footprint reduction for chemical processes. J. Cleaner Product., 18: 848-856. DOI: 10.1016/j.jclepro.2009.12.002

Zhu, Q. and J. Sarkis, 2004. Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. J. Operat. Manage., 22: 265-289. DOI: 10.1016/j.jom.2004.01.005

Zhu, Q., J. Sarkis and K.H. Lai, 2007. Green supply chain management: Pressures, practices and performance within the Chinese automobile industry. J. Cleaner Product., 15: 1041-1052. DOI: 10.1016/j.jclepro.2006.05.021

Zsidisin, G.A. and T.E. Hendrick, 1998. Purchasing’S involvement in environmental issues: A multi-country perspective. Indus. Manage. Data Syst., 7: 313-320. DOI: 10.1108/02635579810241773