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Life Cycle Assessment of Libyan Crude Oil

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Abstract. Petroleum products such as petrol and diesel are fossil fuels and have a high environmental impact. There is a demand to minimize these impacts especially in the upstream and midstream oil operations, i.e. exploration, production and refining processes, due to current and upcoming environmental regulations/policies and increased environmental consumer awareness. Thus, integration of the tools, methods and techniques for sustainability into products is becoming essential to comply with environmental regulations. The Libyan petroleum industry appears to be very slow in approaching modern concepts of approaches of sustainability including Life Cycle Assessment and studies. Therefore, this paper presents a novel environmental Life Cycle assessment of Libyan petroleum refining processes conducted with the support of Life Cycle Assessment methods and related tools including Software SimaPro. The refining processes from the Azzawya Oil refinery, are analyzed and used in the assessment and the data for the assessments was collected through fieldwork conducted in Feb 2013 in both El-Sharara oil field (Repsol Oil Company) and Azzawya Oil refinery in Libya. The results show that the first significant environmental impacts are associated with fossil fuels and the second major impacts are the respiratory inorganic impacts.

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Introduction. Life Cycle Assessment (LCA) is a method used to evaluate the potential impacts on the environment of a product, process, or activity throughout its life cycle (Gillani *et al*, 2010). The LCA analysis begins from raw material extraction, materials processing, manufacture, distribution, use, maintenance and disposal or recycling. So, the crude oil product (diesel) LCA was completed based on the framework established by ISO standards 14040. The framework embraces four phases: goal and scope definition, inventory analysis, impact assessment and interpretation (ISO, 2006).

There are many studies that have investigated the LCA of crude oil and its products (See Garg *et al*, 2013; Ghazi *et al*, 2011; Mata *et al*, 2003; and Keeson *et al*, 2009). These studies focus on data provided based on specific refineries and databases. Libyan crude oil and its products have never been investigated from a Life cycle perspective. It is the intention of this paper to analyze the environmental impacts of crude oil produced in the Murzueq basin, and transported to the Azzawya Oil refinery for distillation. The analysis considers the crude oil exploration and production, transportation and the refining processes to produce diesel fuel. In other words, it is concerned with the upstream oil and gas operations (exploration and production) and the midstream oil and gas operations (refining and transportation) (Nooman and Curtis, 2013).

LCA Methodology

The methodology of this LCA assessment follows the requirements of ISO standards14040. This LCA is carried out for Libyan crude oil (well to wheel) to produce diesel. A LCA software-based tool (SimaPro PHD version) was used for the assessment. Following the ISO4040 LCA Framework (Fig 1), the following sections present the goal and scope of the LCA, Life Cycle inventory, environmental impact assessment and the interpretation stage. Data used for the analysis was gained from both Ecoinvent databases, in addition to data collected from the Azzawya Oil refinery in which the database was modified for the changes based on the company data. The analysis method used is the Eco-indicator 99. The Eco-indicator 99 method was selected due to the fact that Libyan petroleum refineries use European made refinery which follows the European standards and systems. Another reason is that the eco-indicator 99 method uses the damage-oriented approach.

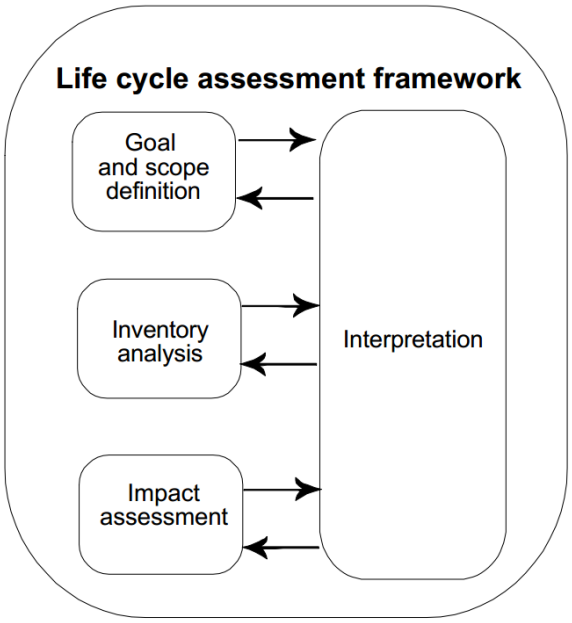

Figure 1: LCA framework (ISO 14044:2006)

2.1 Product system

The crude oil production and distillation is analyzed to produce diesel. The analysis considers 1 kg of crude oil for the upstream operations (exploration and production) from the ground, transported from the Murzueq basin in the south of Libya to the Azzawya Oil refinery which is around 800 KM. The analysis considers the distillation processes in the refinery. Fig (2) shows the system boundary for the LCA analysis.

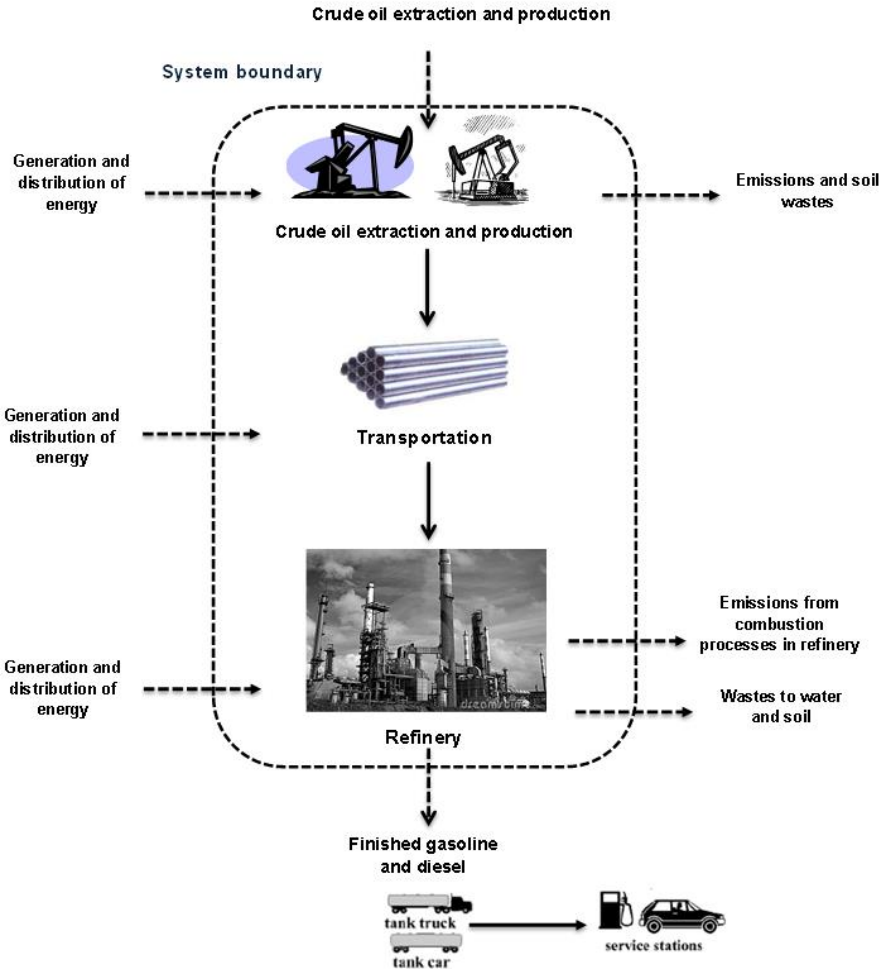

Figure 2: System boundary

2.2 Goal and Scope

The goal of this study is to investigate the potential environmental impact of diesel fuel production from well to wheel. The well is from the El-Sharara Oil field pumping oil to the Azzawya Oil refinery, where it is refined into multiple products including diesel fuel. In the analysis, all life cycle data including energy consumption, material uses, emissions and environmental impacts are ultimately presented in terms of the functional unit (km). The LCA study represents the situation of the 1990s, and considers the situation did not change much. Azzawya Oil refinery was built in the 1970s and the technology used in very outdated, therefore the situation of the 1990s in SimaPro fits well to gain accurate estimated data. The study is intended for policymakers and stakeholders in the field of environmental protection at the upstream company and Azzawya Oil refinery in order to assist environmental protection policies and measures to reduce impacts.

2.3 Inventory

An inventory is calculated for the transport, up-stream energy production and midstream treatments. All the inventory data in the materials extraction stage are using cradle to grave data from the SimaPro database. Fig (3) shows the process tree of the crude oil production and distillation.

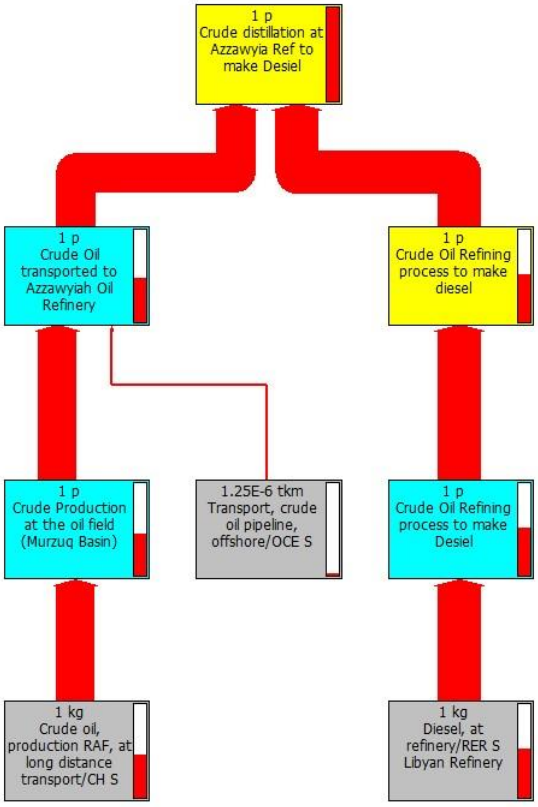

Figure 3

2.4 Impact assessment

The impact assessment of crude oil was carried out using Life Cycle Impact Assessment models (LCIA) incorporated in the SimaPro7 software (Pré Consultants, 2007). Numerous LCA practitioners have contributed to the progress and improvement of those models within several LCA methods such as Eco-indicator 99 (Goedkoop and Spriensma, 2000; Hauschild and Potting, 2004) In this paper, the whole life cycle stages include crude oil extraction, production, transportation, processing and distillation which are considered from well to wheel. The use phase and end of life are excluded from the analysis. The exclusion is due to the fact that impacts generated outside the refinery are out of the policy makers' control and, therefore, it cannot assist in environmental impact minimization.

Results

After life cycle inventories and modeling of the crude oil production system, the well to wheel life cycle of crude oil is modeled in SimaPro7 in all related flows, processing and plans. The LCA results are obtained using characterization and normalization features of SimaPro.

The environmental impacts of crude oil production and refining to produce diesel fuel have various impacts on the environment. Based on the LICA conducted, fig (4) shows the characterization of the impacts. The graph shows both the crude oil production and transportation to the refinery, highlighted in red, and crude oil refining processes at the refinery to make diesel fuel, highlighted in green.

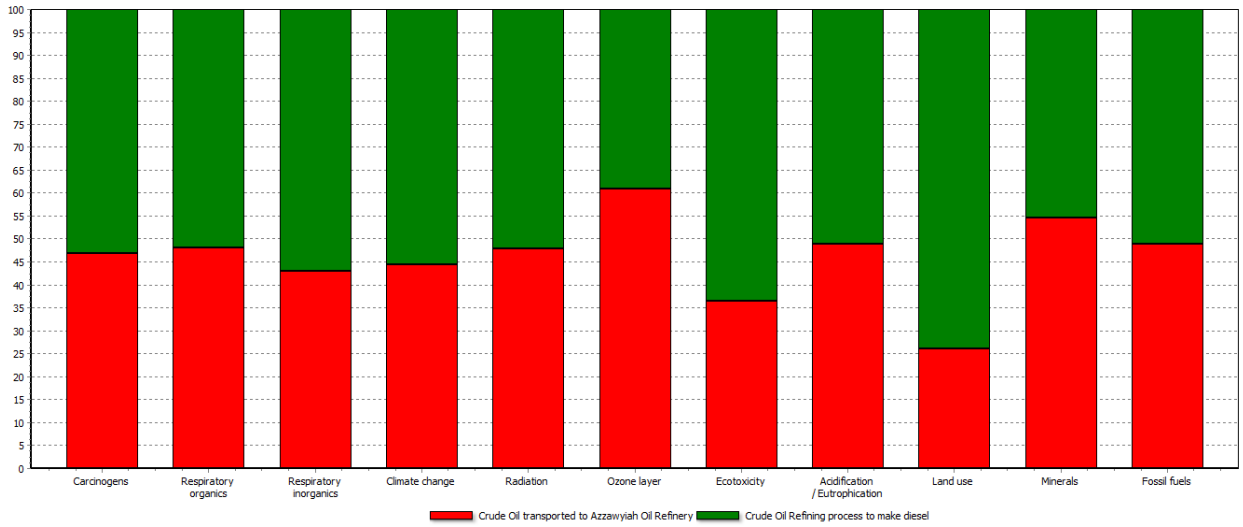

Figure 4 Characterization

Crude oil production takes a relatively similar share of crude oil distillation based on both the share of impacts and normalization results. Environmental impacts based on normalization as shown in fig (5) show that the highest impacts are associated with fossil fuels. These are due to the heavy duty machines, turbines, engines and pumps which produce, transport and generate energy for distillation. The amount of emissions from these processes is significant and almost equal in terms of upstream and midstream stages.

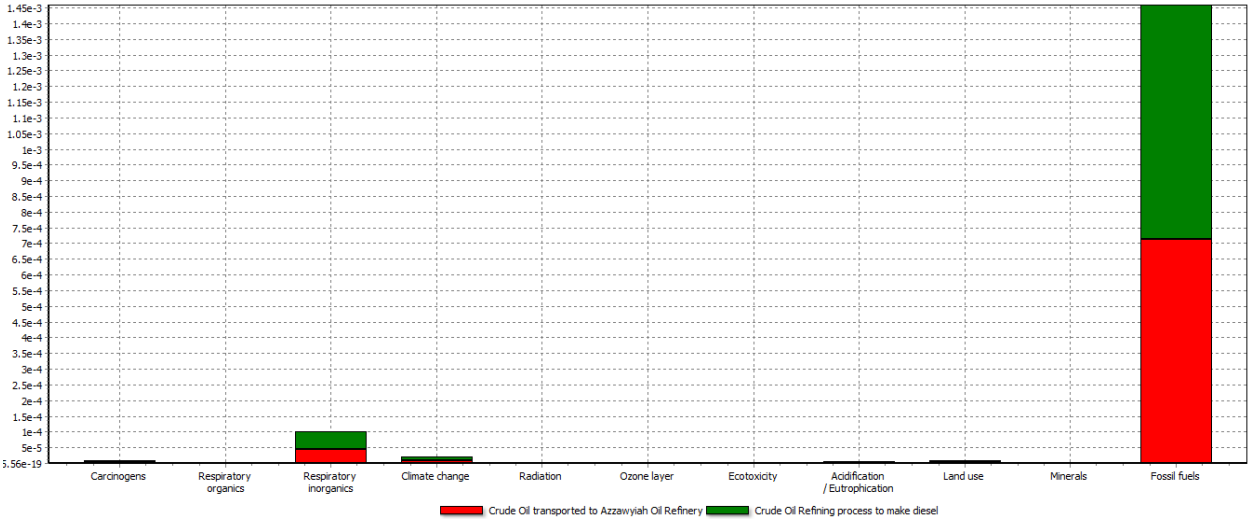

Figure 5 Normalization

Conclusion

Libyan crude oil and its products are very significant for the Libyan economy. However, their environmental impacts have never been investigated. This study provides a well to wheel life cycle assessment of crude oil to produce diesel. Based on the environmental impacts in the whole life cycle, crude oil extraction and processing dominate the whole life cycle impacts, which is mainly due to the high energy consumption in the preparing, producing, transporting, processing and handling of the crude oil.

The results of the assessment showed (Fig. 4 and 5) that crude oil production and distillation have first significant impacts (Fossil fuels). The assessment leads to the following main conclusions. The analysis demonstrates two major stages of crude oil life cycle and the red code is for crude oil extraction, production and transportation to the refinery, the green colour code is refinery processes to make diesel. It is evident from the analysis that the amount of environmental impacts at both stages is the same in regard to fossil fuels. The second major impacts are the respiratory inorganic impacts. Despite the limitation of a lack of actual industrial data, the results of this LCA show that measures must be taken to reduce the environmental impacts and the use of fossil fuels. This urges the Libyan petroleum refineries to consider minimising the fossil fuel consumption by replacing it with clean renewable energy sources. Flaring and venting issues must be reduced and gases should be used efficiently for preheating and energy generation.

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