Review Article

Review of Life Cycle Assessment and Environmental Impacts from The Oil & Gas Sector

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Abstract

Introduction: The oil and gas sector is the subject of key interest and concern because of its increasing demand, the dependency of various sectors on it and its high environmental impacts. The life cycle assessment of this sector will give us the idea to enumerate the various emissions, energy use, fuel usage, raw material requirement, resource consumption, material requirement related to each life cycle stages. Based on the literature analysis, we have presented some discussions on recent trends in the oil and gas sector, cleaner technologies and propose future research directions.

Methodology: A detailed literature review was done by identifying the research papers focusing on the LCA in oil and gas sector. The database referred were EBSCOhost, Science Direct, Google Scholar, Web of science. The literature search is limited to academic search from 1990 to 2018.

Findings: In India despite a regulatory lid on polluting fuels, the overall fuel demand showed a healthy trend in 2017-18 on the back of strong growth in transportation fuels. The total consumption of petrol was increased from 10.14 percent to 26.17 MT, while diesel consumption grew by 6.63 percent to 81 MT in 2018. Various studies have confirmed that the main environment polluting hotspot identified in the supply chain was the refining activity, the maximum CO_2 emissions is from the exploration and drilling stage i.e., 60%-65% and the local pollutant emission is maximum in the oil usage phase which is approx. SOx emissions is 5.45 MT, NOx is 6.88 MT and black carbon 8.5 MT.

Contributions: The results can be used in the comparative assessment of different crudes, by the government and the industry for decision making, by the various stakeholders and researchers who are conducting LCA and proposing models for systems that are using the petrochemical products in different context.

Introduction

The oil and gas sector is an important aspect of the world economy. It has the potential to cause severe environmental degradation, not only to the physical environment, but also to the health, culture, and economic and social structure of local and indigenous communities [1]. Since this sector is growing drastically over a period of time, it is their foremost duty to make necessary changes in its supply chain. Oil and gas companies are representing a considerable portion of wealth in the midst of the world's major industries.

According to the 2015 United Nations Climate Change Conference, India is the third largest GHG (Green House Gas) emitter in the world. India and other developing countries are focusing more on the alternate fuels, but the transportation sector is still dependent on conventional fuels. This is due to the reason that alternate fuels which are assumed to be cleaner are emitting more carbon dioxide as compared to conventional fuels per unit production of energy and the extraction of energy from these renewable sources require high initial costs, lack of social acceptance and severe competition from current fossil fuels [2]. Therefore the existing oil and gas industry requires a lot of attention for the implementation of sustainable and green practices [3].

Life Cycle Analysis (LCA) is a technique to assess environmental impacts associated with all the stages of a product's life from cradle to grave, that is, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling (US Environmental Protection Agency, 2010). But according to the recent literature LCA can be used as a tool for assessment of processes and can be used to study the supply chain and make it more sustainable [4] (Figure 1).

The oil and gas sector is divided into three major components i.e., upstream, midstream and downstream. The upstream is also known as Exploration and Production (E&P) and is responsible for the searching of natural oil fields and drilling underground wells. The midstream
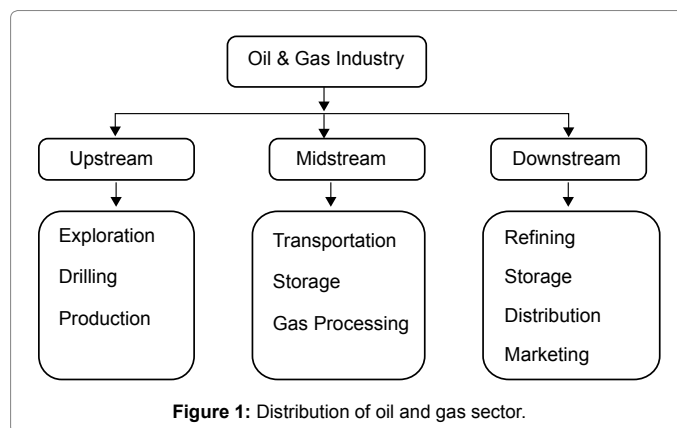

Figure 1: Distribution of oil and gas sector.

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sector is the storage and transportation of crude oil; it links the upstream and downstream sector. The downstream sector is of refining the crude oil, storage distribution, and marketing. Emissions through direct combustion of fossil fuels are easily recognized as part of the fuel process chain, but the emissions associated with other links in the supply chain is less understood.

Literature Review

The LCA approach was not recognized by many industries but the methodology was gradually getting accepted. Few sectors such as soft drinks, plastics, personal care products, detergents, and automobiles were known to be pioneers investing in LCA. This was followed by other sectors like manufacturing industries, agriculture, mining, oil and gas extraction, construction/building material sector, and retailing, and more recently by infrastructure industries (electricity, gas and water supply, transport, storage, and communication) [4].

Various technologies used in the oil and gas sector

Oil and gas sector is one the most important sector in the country's economy. The main challenge faced by this sector is to satisfy the demands for safe, abundant and affordable petroleum products within the evolving regulatory environment (Report on Technology Vision 2020), the technology has the potential to achieve this demands over the coming decades. The changes in prospect are exciting and profound– such as digitization and artificial intelligence, the electrification of transport, and the scaling up of renewable energy. The required technology transition in this sector is discussed below.

From brownfield refinery to greenfield refinery: Most of the Indian refineries are the brownfield refinery; it is already constructed and is upgraded and expanded with time. Recently, three Indian downstream sector – IOCL (Indian Oil Corporation Limited), HPCL (Hindustan Petroleum Corporation Limited), and BPCL (Bharat Petroleum Corporation Limited) have recently signed a Joint Venture (JV) agreement to create the world's largest refinery-cum-petrochemicals complex Ratnagiri district at the cost of $ 40 billion and a refining capacity of 60 Million Tonnes Per Annum (MMTPA). It will be a Greenfield refinery.

From conventional refinery to bio refinery: The Go Green initiative is now applicable in Refineries too. The conventional petroleum refinery is now changed to a bio refinery by implying the eco fining technology. This pioneering idea will help to encourage the industrial application of the eco fining technology under green refinery project. The eco fining technology undergoes reaction in two stages: firstly the deoxygenating process is completed under hydrogen partial pressure and the product is processed in next stage where isomerization is done, which helps in improving the properties of the obtained products [5]. The eco fining process maximizes the green production which is esteemed as bio components for transportation fuels such as Green Diesel, Green Naphtha, Green LPG and Green Jet.

Moving from desulphurization to bio desulfurization (BDS): Indian refineries have started DHDS (Diesel Hydrodesulphurization) process to bring down the sulfur content which is a threat to public health and corrodes the engine which minimizes its life. This technology has brought down the sulfur content from 10000 PPM to 10 PPM (HPCL Sustainability Report, 2017).

As we are moving towards green processing of fossil fuel, the Bio Desulfurization (BDS) has drawn wide attention for removal of sulfur compounds. Various bacterial species which are able to bio-transform DBT or grow independently as a sole sulfur has been recognized [6].

From wastewater treatment to Zero Liquid Discharge (ZLD) system: ZLD systems help in treating 100 percent wastewater (internal/process wastewater, fire/storm water, utility wastewater) and effluents [7]. The Zero Liquid Discharge System consistently producing treated effluent (pH 6-8.5, sulphide <0.5 ppm, COD <50 ppm, oil and grease <5 ppm, phenol <0.35 ppm) meeting guarantee parameters for reuse for various effluents.

Other existing clean technologies

Tail gas treating unit: The tail gas treating unit converts the small number of sulfur compounds (<5%), which were not converted in the Sulfur Recovery Unit (SRU), into hydrogen sulfide (H_2S) and recycles it back to the SRU for additional processing.

Fluid catalytic cracking (FCC): Fluid Catalytic Cracking (FCC) is an essential component in the petroleum refinery. It converts the long-chain hydrocarbons into the gasoline precursors which can be used in different industries such as fuels, plastics, and lubricants. The FCC minimizes the energy consumption in the processing phase and maximizes the premium gasoline production.

Flare gas recovery unit: Flare Gas Recovery (FGR) is the process of recovering the waste gases that would normally be flared, so they can be used as fuel gas elsewhere in the facility. This results in reduced emissions and cost savings.

Vapour recovery system (VRS): It is the process to recover the vapours of petrochemical fuels and stop them from escaping into the atmosphere. This is generally installed at filling stations which help in reducing pollution.

Inspite of major developments in the oil industry in India, we still depend on developed countries for oil. The main obstacle in technology transfer is firstly the major economic factors. Such as low saving rate, lack of economic growth, lack of investment in R&D, lack of developed manufacturing, management and quality control systems, lack of necessary technical, engineering, and science skill in industry section to improve product technology and process of imported technology [8].

Environmental impacts of oil and gas sector

The demand for oil is growing very rapidly with the economic expansion which is increasing the production. There are 3 main challenges faced by the oil & gas sector which is pollution, global climate change and impact on bio-diversity [9]. The increase in production cause environmental damage in each stage of its life cycle from exploration to refining to its final consumption which is generally referred as Well-to-Wheels (WTW). The effect of pollution is on the regional level as well as global level (Table 1). The majority of pollution is from the oil refineries which are consuming large amounts of energy and water, producing large quantities of wastewaters, releasing hazardous gases into the atmosphere and generating solid waste that is difficult both to treat and to dispose of [10]. Apart from environmental pollution, it also affects human health by causing respiratory diseases [11].

Review of existing life cycle models for oil and gas sector

The life cycle models have been proposed by various researchers working on LCA which can be easily understood by the readers. The models prepared must be verified by both expert and non-expert LCA users so that the proposed models can be made more perfect and user-friendly [12]. These models can be used for future exploration and to establish the relationship between methodologies which can result in more collaborative, in-depth assessments [12].

Process in oil	Waste Type	Effect on Environment
Transportation	Pipeline Explosion	Air and water pollution
	Oil spillage through pipelines	Ground water underground aquifers contamination,
	Oil spillage through ships	Marine pollution
	Oil spillage through tank trucks	Pollutes surrounding area
Crude Refinery Source: Steigerwald (1960) Atmospheric emission from petroleum refineries	Oily water	Affected nearby lagoon
	NOx Sox	Acid Rain
	CO_2	Climate Change
	Spent Caustic	Nearby lagoon
	Process Effluents	Nearby lagoon
	Leaked/Spilled oil	Polluted Surrounding rain
Bulk Oil Storage Source: Steigerwald (1960) Atmospheric emission from petroleum refineries	Waste Oil	Marshy Land and Stream
	Leaked/Spilled oil	Polluted Surrounding air
Final usage for transportation	Unburnt hydrocarbons	Photochemical smog
	CO	Global warming
	NOx	Acid Rain
	Lead Oxides	Toxic substance

Table 1: Effect on the environment of different processes of oil and gas sector.

Some of the models are described below:-

FUNNEL-GHG-CCO (Fundamental Engineering Principle based model for estimation of GHG in Conventional Crude Oil): This LCA model is based on the fundamental scientific principle to compute the GHG emission of all the life cycle stages of differently selected crudes. It is a bottom-up data-intensive model.

OPGEE (Oil Production Green House Gas Emission Estimator): It is an open source engineering based life cycle assessment model which is used to test the reproducibility from well to refinery inlet gate (WTR) GHG emissions. OPGEE (Oil Production Greenhouse Gas Emissions Estimator) is built with separate modules, including drilling, production, processing, and transport of crude. All sources of direct emissions are included in the model, including both combustion emissions and fugitive emissions [13].

Sengupta: This model was proposed for US petroleum refinery operations, which helps in estimating the impacts of refinery operations. The model describes the allocation factors, air emissions, and products and supports the emission modeling research carried by Sengupta and others at the Environmental Protection Agency (EPA) [12].

GHGenius: GHGenius model can estimate the air emissions for past, present, and future (through to 2050). It analyzes the Greenhouse Gas (GHG) emissions and other air emissions related to the production and usage of conventional and alternative transportation fuels [14]. This is done using the historical data and correlations that are stored in the model and changes with time. This model is much suitable for Canadian application [14].

LCA methods

Eco-indicator 99: It is one of the most widely used impact assessment methods in LCA. It is the successor of Eco-indicator 95, the first endpoint impact assessment method, which allowed an environmental load of a product to be expressed in a single score (Pre consultant). Garg uses eco-indicator 99 method to compare the life cycle impacts on ecosystem quality, human, and resources [15]. Nanaki

also used this method to compare the LCA of Diesel, Biodiesel, and gasoline and the various impact categories [16].

Impact 2002: The IMPACT 2002+ LCIA (London Court of International Arbitration) methodology implements the combined midpoint/damage a pproach, relating all types of life cycle inventory results (elementary flows and other interventions) *via* 14 midpoint categories to four damage categories [17].

CML 2002: CML 2001 is an impact assessment method which restricts quantitative modeling to early stages in the cause-effect chain to limit uncertainties. Results are grouped in midpoint categories according to common mechanisms (e.g. climate change) or commonly accepted groupings (e.g. ecotoxicity).

Shi has used CML2000 where 5 environmental impact categories are assessed which are the global warming potential, acidification potential, nutrient enrichment potential, ozone formation potential, and ozone depletion potential [18]. Furuholt also used CML to compare the impact categories of gasoline and diesel which are Global Warming Potential, Photo-oxidant formation, Eutrophication, acidification, consumption of fossil energy and waste generation

ReCiPe 2008: The ReCiPe method is used to transform the long list of life cycle inventory results, into a limited number of indicator scores. These indicator scores express the relative severity on an environmental impact category (Pre sustainability).

Morales et al. used the ReCiPe 2008 method where the hierarchic perspective was considered for the environmental impact assessment [19,20]. The impact categories considered were climate change, ozone depletion, human toxicity, photochemical oxidation formation, terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial eco toxicity, freshwater eco-toxicity, marine eco toxicity, water depletion, mineral depletion, and fossil depletion.

LCA in the oil and gas sector

GHGs and other toxic gases are emitted in all the stages of fuel production from extraction of raw materials to the combustion of fuels in an engine in the usage phase. Every fuel and production process exhibits different properties, different extraction methods, and GHG emissions, therefore, the source of crude oil should also be considered while performing LCA [10]. Eriksson discusses that fuel used in the refinery; its efficiency and heat usage have an effect on the LCA results. For instance, high-quality insulation of pipes and equipment reduces the need for heating [21]. The fuel used for the heating purpose also plays an important role in the emissions and primary energy use from the refinery. It is also important to perform a complete life cycle assessment of conventional crude oils from a variety of sources to help in policy-making towards sustainability and fulfilling environmental regulations [22].

The main challenges in performing LCA of transportation fuels are (i) Appropriate cost accounting and benefits of alternative fuels (ii) Lack of consistency in including economics-based marginal effects in fuel LCAs. (iii) Inconsistent application of time trends i.e., the energy intensity of crude oil production tends to increase with depletion as a result of increased work of lifting of fluids as an oil field depletes [23]. Hawkins compared the environmental life cycle assessment of conventional vehicles and electric vehicles and discussed the various problems in shifting from conventional vehicles to electric vehicles [24]. Author suggests that electric vehicles would aggregate emissions at a few point sources (power plants, mines, etc.) instead of millions of

mobile sources, making it conceptually easier to control and optimize societies' transportation systems [25] (Table 2).

Discussion and Findings Based on The Review

The dependency of humans on the oil and gas sector is increasing very rapidly. The LCA of this sector has helped us to study the supply chain which will identify the various emissions, energy usage, fuel usage, raw material requirement, resource consumption, material and energy balances related to each life cycle stages and the environmental impacts from these stages. It has also identified the major impact categories like according to the study done by [22,19]. Transportation phase and combustion phase are responsible for nearly half of the impact which is followed by the refinery. SOx and NOx are the major pollutants (Table 3).

Authors (Year)	Assessment Boundaries	LCA Software/Model	Variables Identified	Impact Categories	Findings	Scope
Garg et al. (2013)	Well-to-Storage	Sima Pro	Emissions from different transportat ion fuel, energy efficiency	Human health, acidification, eutrophication	1. The crude oil source should be considered 2. Total transportation emissions are higher, but not high enough as compared to other stages in the complete LCA of transportation fuels.	To implement the differential environmental taxes, the research should first focus on impact assessment.
Bicer and Dincer (2018)	Cradle-to-grave	Sima Pro	Human toxicity values	Ozone layer depletion, Global warming, Abiotic depletion, acidification, eutrophication, human toxicity, and terrestrial ecotoxicity	To achieve sustainable and clean transportation, the attention should be on the eco-friendly and cost-effective production of vehicles, batteries and alternative fuels.	This study is limited only to the environmental impacts, for the further research life cycle costing of these alternative-fueled vehicles can be performed.
Rahman & Kumar (2015)	Well-to-Wheel	FUNNEL-GHG-CCO	Energy use, emission factors	Global Warming Potential	GHG emissions are calculated using FUNNEL-GHG-CCO model. This model considers all the life cycle stages of production of crude oil from extraction to the combustion in the engines. Amongst all the crudes considered in the paper, gasoline has higher GHG emissions than both diesel and jet fuel. This is due to high energy consumption in gasoline production.	As a future scope of this study, The results can be used in the comparative assessment of different crudes and by the government and the industry for decision making.
Iribarren, Peters & Dufour (2012)	Case study	Not Specified	Electricity generation, natural gas production, and direct emissions	Global warming, photochemical oxidant formation, cumulative energy demand, acidification, land competition, ozone layer depletion, and eutrophication	The research paper focuses on the LCA study of the production of biofuels from the fast pyrolysis of biomass system. This shows that the pretreatment of the lignocellulosic biomass feedstock (drying and grinding), the pyrolysis process and the steam reforming of natural gas to provide the hydrogen used in the hydroprocessing stages were the sources with the highest environmental impact.	Not specified
Vineyard & Ingwersen (2017)	Well-to-pump	Review and comparison of various LCA models	Not specified	Well-to-pump emissions	This paper has demonstrated the differences and evaluated the data quality of five LCA models.	This comparison can be used by the various stakeholders and researchers who are conducting LCA and making models for systems that make use of petroleum products.
Matos & Hall (2007)	Cradle-to-grave	Not specified	Risk Management, Stakeholder theory	Global warming potential, ozone depletion, eco-toxicity, energy consumption, nitrification and acidification	The author argues that shift towards the sustainable development has increased the complexities and given indefinite challenges that many environmental management techniques cannot address. It has also provided a framework that addresses these issues and discusses implications for practitioners and management theory.	The proposed framework will help managers to determine if LCA is appropriate or not.
Hsu (2012)	Production to end use	Simapro	Emissions	Not specified	In this work, LCA of the production of gasoline and diesel from forest residues *via* fast pyrolysis and hydroprocessing is performed. Grid electricity and natural gas used account for 81% of the net GHG emissions in the base case.	Pyrolysis of biomass for fuels has been less well studied than gasification, and the greater uncertainty range around fuel yield contributes to the more skewed uncertainty distribution than for gasification in the previous work

Hsu (2012)	Production to end use Gate-to-grave	Simapro CMLCA	Emissions Impact assessment	Not specified Abiotic depletion, GHG emissions, Ozone layer depletion, Photochemical oxidation, Human and eco-toxicity, Acidification, Eutrophication	In this work, LCA of the production of gasoline and diesel from forest residues via fast pyrolysis and hydro-processing is performed. Grid electricity and natural gas used account for 81% of the net GHG emissions in the base case. The research has focused on the LCA of gasoline and ethanol as fuels and results showed that ethanol fuels are better than gasoline, while gasoline is a better fuel where human toxicity, eco-toxicity, acidification, and eutrophication are concerned.	In the future case scenario ethanol industry can be made more economically attractive by studying its cost model and technological development can be studied which helps in lowering the environmental impacts.
Luo et al. (2009)	Gate-to-grave	(Chain Management by LCA)	Fuel usage	Abiotic depletion, GHG emissions, Ozone layer depletion, Photochemical oxidation, Human and eco-toxicity, Acidification, Eutrophication	The research has focused on the LCA of gasoline and ethanol as fuels and results showed that ethanol fuels are better than gasoline, while gasoline is a better fuel where human toxicity, ecotoxicity, acidification, and eutrophication are concerned.	In the future case scenario ethanol industry can be made more economically attractive by studying its cost model and technological development can be studied which helps in lowering the environmental impacts.
Garraín et al. (2014)	Well-to-tank	Not specified	Temperature	Fossil energy	The research shows that HBD (Hydrobiodiesel) systems have good environmental & technical performance when its compared to FAME (Fatty Acid Methyl Ester) and diesel. Regarding the impact categories analyzed, the reductions in terms of fossil energy use and GHG emissions	Future research must focus on the matter of indirect Land Use Change (iLUC), which is leading to higher GHG emissions related to biofuel or renewable diesel production
Nanaki & Koroneos (2012)	Well-to-wheel	Simapro 5.0		Ecotoxicity, Acidification, inorganic respiratory effects, fossil fuels, eutrophication, Organic respiratory effects, greenhouse effect and carcinogenic effects.	The author has compared the environmental impacts of the use of gasoline, diesel, and biodiesel in Greece. From the environmental point of view, biodiesel seems to be eco-friendly because the GHG emissions are very low as compared to gasoline and diesel. Methane emission is also low. But, the use of biodiesel as the transportation fuel increases emissions of PM10, nitrous oxide, nitrogen oxides (NOx) as well as nutrients such as nitrogen and phosphorous; which is the main reason for eutrophication.	This study can be considered as an opportunity for further research and evaluate the available options for a sustainable
Morales et al. (2015)	Well-to-wheel	Simapro v8		Acidification,human toxicity, Climate change, Ozone depletion, terrestrial eco-toxicity, water depletion, marine eutrophication, mineral depletion photochemical oxidation formation, marine ecotoxicity, terrestrial freshwater eutrophication, freshwater eco-toxicity, and fossil depletion	The outcomes of refining activities and use of gasoline in cars are extremely sensitive to the allocation approach considered. The maximum impacts were found in the economic allocation, then by the volume allocation and lastly energetic allocation. The high impacts resulting from the economic allocation were due to the high price assigned to the gasoline in the Chilean market	Future improvements of technologies in gasoline production and transport sector can be done. It can be identified as the key subsystems within the life cycle of gasoline.

Table 2: Various LCA study focusing on the oil and gas sector.

In the review of various papers, it is found that while selecting a boundary for doing LCA it is important to consider the source and all the stages where the emissions and environmental impacts are higher. According to one report on Global Climate Disclosure Framework in the year 2012 for oil and gas companies, the bulk of GHG emissions generated through the oil and gas lifecycle are in the consumption and combustion of the final product, So while doing the LCA study this stage has to be considered. Literature also argues that the shift towards sustainable development have increased complexities and presented indefinite challenges that many current environmental management techniques cannot adequately address the issue [26].

The main impact categories studied are the Global Warming Potential (GWP), Climate Change (CC), Ozone Depletion Potential (ODP), Acidification Potential (AP), Eutrophication Potential (EP) and Human Toxicity Potential (HTP). Authors have identified these as impact categories [15,19,27-35].

We have compared five LCA studies done in different countries and found that there is difference in LCA result due to factors such as geographical locations, refining technology, fuel price supply, and demand, source of crude oil and other methodological factors such as data quality, system boundary and databases [31-36].

Inspite of so many technological innovations, we are still in the

Author (Year)	Country Studied	Functional Unit	Boundary selected	Software/LCIA methods	Impact category Analyzed	Findings
Cavalett et al. (2012)	Brazil	1 MJ of fuel	Cradle to grave	Comparison of the seven midpoint LCIA methods CML 2001, Eco-indicator 99, TRACI 2, ReCiPe, EDIP 2003, Impact 2002+ and Ecological Scarcity 2006	Global Warming Potential (GWP), fossil depletion and Ozone layer Depletion Potential (ODP).	Authors have compared different LCIA methods of ethanol and gasoline and found that ethanol has less impact than gasoline in main impact categories such as global warming, fossil depletion, and ozone layer depletion. But ethanol has much higher impacts in acidification, eutrophication, photochemical oxidation, and agricultural land use categories.
Morales et al. (2014)	Chile	Distance of 1 km driven by a middle size passenger car	Well to Wheel	Simapro software v8 CML 2000 method	Climate Change (CC), Ozone Depletion (OD), Human Toxicity (HT), Photochemical Oxidation Formation (POF), Terrestrial Acidification (TA), Freshwater Eutrophication (FE), Marine Eutrophication (ME), Terrestrial Ecotoxicity (TET), freshwater ecotoxicity (FET), marine ecotoxicity (MET), Water Depletion (WD), Mineral Depletion (MRD) and Fossil Depletion (FD).	The majority of emission is from refining process and combustion phase. Climate change is the main impact category identified which is due to these emissions from the refinery and combustion phase. The climate change impact category is 3.9. 10^{-1} kg CO_2 eq which is highest among all impact categories studied.
Restianti and Gheewala (2012)	Indonesia	1 kL of gasoline	Cradle to gate	CML 2000 method	Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP), Abiotic Resource Depletion Potential (ADP), Human Toxicity Potential (HTP), and Eco toxicity Potential (ETP).	The results showed that the combustion phase contribute 93%, 84%, 95% for the Global Warming potential, Acidification potential and eutrophication potential respectively followed by oil refining and then by crude extraction phase. GWP for the combustion phase is 3.35W+04 g CO_2 eq. and for full process chain is 3.61E+04
Rahman et al. (2014)	North America	1 MJ of fuel	Well to Wheel	LCA Model FUNNEL-GHG-CCO	GHG emissions	The result showed that gasoline has high GHG emissions than both diesel and jet fuel which is due to higher energy consumption The well-to-wheel GHG emissions for the three transportation fuels range from 97.55 g-CO_2eq/MJ-gasoline to 127.74g-CO_2eq/MJ-gasoline, 95.0 g-CO_2eq/MJ-diesel to 126.02 g-CO_2eq/MJ diesel, and 88.17 g-CO_2eq/MJ-jet fuel to 118.17g-CO_2eq/MJ-jet fuel (HTP), and Eco toxicity potential (ETP).
Nguyen and Gheewala (2008)	Thailand	1 1gasoline equivalent consumed by a new passenger car to travel a specific distance	Cradle to grave	Not specified	Net energy use, fossil energy use, GWP, AP, and NP	The results show that using MoE in the form of E10 as a gasoline substitute leads to fossil energy and petroleum savings

Table 3: Comparison of LCA study of various countries.

phase of conventional refineries which needs to be upgraded. Various clean technologies are identified and used such as flare gas recovery system, vapor recovery system, tail gas treatment which has helped in minimizing the emissions but, Since the world has moved towards the concept of bio refinery and using the green methods such as Bio Desulphurization (BDS), We also need to be more advanced in making oil and gas supply chain a sustainable Green supply chain [37-44].

Conclusion

This paper gives a brief idea of the present various LCA models used in different context by authors and various LCA methods and their impact categories. Different technologies used in this sector are also [45-51]. The Life cycle assessment of the oil and gas sector performed by various authors in different countries has been reviewed but there is very limited study in the Indian context. The LCA studies have given the complete insight of supply chain of oil and gas sector and helped to identify the Life cycle stages which are more environmentally intensive [52-55]. It is concluded that the LCA studies help us in estimating the available options for more sustainable transportation.

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