Life Cycle Assessment of Crude Oil Processing by Energy Management Approach

Kioumars Naseri[1] | Alireza Noorpoor[2]✉* | Fatemeh Razavian[1] | Behnosh Khoshmaneshzadeh[1]

1. Department of Environmental Science and Engineering, West Tehran Branch, Islamic Azad University, Tehran, Iran.
2. Department of Environmental Engineering, Graduate Faculty of Environment, University of Tehran, Tehran, Iran.

Article Info	ABSTRACT
	The first future challenge facing human beings is to supply the world's energy needs. However, energy consumption and resource depletion in industrial processes are significantly increasing. Therefore, life cycle assessment can be an excellent tool to quantify resources and energy consumption in different parts of industrial processes. The combination of process simulation and assessment of process life cycle can be resources & energy consumption in different parts is quantified and can be significantly reduced by optimizing the process, energy wastage. The process stimulation is done by HYSIS software, then by collecting output data, energy and materials flow, life cycle assessment is conducted using SIMAPRO software. According to output of the release list, 1709 items are released into the environment, of which 396, 407, 340 items are released into the air, water, soil, respectively and 556 items are extracted from sources. The most appropriate procedure to assess the life cycle of crude oil processing is Cumulative Energy Demand and Cumulative Exergy Demand energy approach. Based on the first-order analysis, the highest consumption of resources and energy is in the crude oil transmission sector; (Road construction with 44.95 petajoules and transmission pipelines with 19.85 petajoules). Also, regarding the second-order analysis, the highest consumption of resources and energy is related to crude oil production processes with 1.65 petajoules per operation and desalination unit, medium voltage electricity consumption with 0.002194 petajoules and exergy of power lines with 0.00087 petajoules.

INTRODUCTION

Today, almost everything produced, consumed, or disposed definitely cause energy consumption and greenhouse gas emissions. About 30% of the annual consumption of fossil energy is consumed in the industrial sector, with oil and gas refineries having the largest share. Therefore, energy management in the refinery sector will help in optimize the consumption of fossil fuels and is the main source of energy production (Pirzadeh et al., 2014; Rikhtegar, 2014). Economic development and energy consumption are interdependent; Because with increasing energy consumption. On the other hand, increasing efficiency that leads to energy savings is the result of economic development (Tamazian, 2009). according to global energy consumption statistics, with a growth of 42% by 2025 year And suplying the world's growing energy needs

*Corresponding Author Email: *noorpoor@ut.ac.ir*

is the first future challenge facing humans in the energy sector (Rikhtegar, 2014; Yousefikhah, 2017). According to the Global Development Indicators (2009), global energy consumption in 2006 was double compared to 1971. More than 80 percent of the energy consumed in 2006 came from the non-renewable emitter fossil fuels. Therefore, the environmental and energy debate on OPEC countries is essential (Global Development Indicators, 2009).

Due to this fact, the major economies of these countries depend on non-renewable energy sources and fossil fuels, important factors in the realeas of pollution (IRAN Electricity and Energy Macro Planning Office, 2009).Therefore, efforts to increase energy efficiency and sustainable energy consumption are important factors in controlling greenhouse gas emissions and maintaining the environment in general. This is not only about reducing renewable energy consumption, but more importantly, about reducing energy consumption per unit of production (energy intensity) (Dargahi et al., 2011). Today, the refining industry, oil and gas processing is growing in Iran. Moreover, Iran is ranked third in the world among the producers of hydrocarbon pollutants due to burning gas in Fellers or its discharge to the environment (Masoudnia et al., 2011). Crude oil processing operations are among the processes with high environmental impact and energy consumption. so quantifying energy consumption and resources of the crude oil processing process helps industries identify other parts of the process that are wasting energy to improve the situation. (www.wogpc.ir, 2021; Documents in Cheshmeh Khosh, 2021). In this research, Life Cycle Assessment (LCA) is used as an environmental tool with a "cradle to grave" approach to assess various (Heeran et al., 2012; McIntosh et al., 2016; Krishna et al., 2017). The suitability of LCA as a tool in the assessment of chemical products and processes has been shown by various authors (Graedel, 1999; Domènech et al., 2002; Lankey, 2002; Sikdar, 2003; Hellweg et al., 2004). It is important to note that cradle-to-grave analysis has a comprehensive approach that examines environmental effects at a fixed time and place (Kargari, 2009; Kargari et al., 2010). In 2016, Goodcop et al., conducted a study introducing life cycle assessment using SIMAPRO software (life cycle assessment; requirements and guidelines, ISO 2006). Wafi et al., (2014) conducted a study on the use of various models to evaluate the life cycle of oil and showed that due to the divergence of different models, the results of greenhouse gas emissions are different (SimaPro Database Manual, 2019). Lorenzi et al., (2016) evaluated the life cycle of greenhouse gas emissions and fresh water consumption associated with Bakken tight oil. The results showed that greenhouse gas emissions are highly correlated with oil development and if at the time of drilling, the an appropriate method is used, it is possible to a large extent to prevent the emission of greenhouse gases (Kokossis et al., 2004). Margarita (2005) conducted a life cycle assessment of renewable energy desalination technologies using SIMAPRO software. The main goal was to conduct an Environmental assessment, using the life cycle assessment technique for a broad perspective and in a precise and purposeful way to create lower environmental load (Goedkoop et al., 2006). Stokes (2006) cnducted a study on the Assessment of external costs showed significant environmental effects of greenhouse gases and air pollutants relative to the economic cost of water (Vafi et al., 2014). Life cycle interpretation is the final step of the LCA implementation method, in which the results of an LCI or an LCIA or both are summarized and discussed as a basis for conclusions (Raluy et al. 2005; Stokes et al. 2006; Laurenzi et al., 2016). The LCA process can help decision makers to select the product or process with the least environmental impact (Bösch et al., 2007; Frischknecht et al., 2007; Frischknecht et al., Ecoinvent report 2007; Kargari et al., 2014;Familiarity with life cycle assessment, 2018).

Most of the research conducted so far has been done either by comparing the distribution of several industries with each other or on a specific material, and no specific study has been done on crude oil from the extraction stage to production and export. According to the mentioned studies above, the most important objectives of the present research are; Assessment of the life cycle of crude oil processing with an energy management approach And Quantification of energy consumption based on the type of energy consumed in different parts of the crude oil processing

process during its life cycle using SIMAPRO software. Therefore, with respect to the current environmental crisis and energy shortage in the world, taking into account the high share of oilprocessing units in energy production and the economy, as well as the importance of strategic adjacent of Cheshmeh Khosh region to the Iraq country border and international commitments to the environmental issues, this study was designed. The present study aims to manage energy, and significantly reduce waste resources, environmental impacts and costs using simulating and assessment of the life cycle of the crude oil production process by up-to-date software.

MATERIALS AND METHODS

Cheshmeh Khosh exploitation unit located at 52 km of Dehloran, Ilam, Iran, process and transfer a nominal capacity of 55,000 barrels per day of oil production by an 18-inch pipeline stretched in 153 km to the Ahvaz and the pump house of Shahid Chamran. Also, Cheshmeh Khosh desalination unit was set up in 2006 with a nominal capacity of 75,000 barrels (Figure1).

Process simulation is performed to assess the energy consumption and extraction of inefficient components and the results are used as the input of the life cycle assessment. The use of process simulation based on environmental productivity and economics can be considered as a prerequisite for life cycle assessment as well as knowledge-based decision making to increase process sustainability. Therefore, according to the study of previous research and consultation with process chemists, in this study, HYSIS process simulator software was selected due to its user-friendliness, freeness, having a large information center and also extensive use in industry. HYSIS software is one of the most powerful simulation software in chemical engineering. Of the possibilities of this software are comprehensive library information, extensive thermodynamic equations and two-component coefficients. This software helps chemical engineers to perform lengthy calculations in seconds. With the help of HYSIS software, the operational conditions of the factory can be quickly improved and also the correct operation of the devices can be ensured. HYSIS has a variety of unit operations such as heat exchangers, rotating equipment
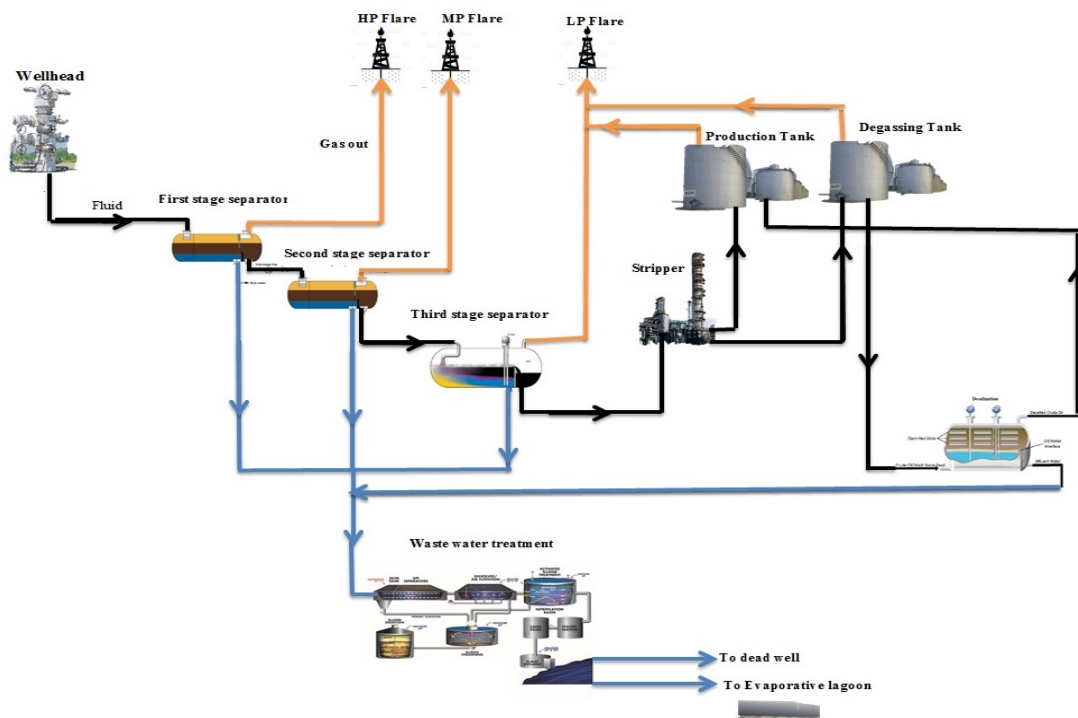

Fig. 1 crude oil production and desating plant

such as pumps and compressors, separators, distillation towers, reactors, solids separation operations and logic operations. In Cheshmeh Khosh oil processing unit, there are equipments such as pumps, compressors and turbines (in this section, the inlet and outlet flow of the pump as well as the energy were determined). Or, for example, in heaters, the inlet and outlet currents are specified and the heat load is obtained by specifying its own outlet temperature. The purpose of this study is to optimize and assess the life cycle of crude oil processing with energy management approach. Hence, first, the existing simulation process (based on process drawings and mass and heat balance of PFD, P & ID8, H & MB and drawings and diagrams of pipelines), processes and equipment using Aspen HYSYS V11-aspen one (37.0.0395) and Hysys output and flow of available materials and energy are used to assess the process life cycle using Simapro software (SimaPro 9.1.1.1). Afterward, energy indicators are reviewed and the results are presented. In this research, Ecoinvent 3 Consequential unit and Allocation at point of Ecoinvent 3 substitution-databases were used in SimaPro 9.1.1.1 Faculty V 4.15 software with FFUT008 license. Developed by the Swiss Life Cycle Registration Center in collaboration with the Federal Institute of Technology Zurich, it is one of the most comprehensive databases. The database covers more than 10,000 public processes covering the energy, transportation, construction, chemical, agricultural, cardboard, laundry and waste management industries.

In this study, the system boundary is oil output from exploitation wells (does not include wells and well facilities), to oil output from Cheshmeh Khosh oil exploitation unit by oil transmission lines to Ahvaz 3 and Sabzab (including all exploitation processes, Oil pipelines, as well as roads). In fact, this study does not consider the wells facilities and those facilities used in the exploitation and desalination. In addition, pipelines, road construction, the amount of water used, the amount of energy consumption, as well as all processes included (First Order Analysis).

input data to Simapro software are realistic and achieved through studying company documents, field observations and previous reports, consulting with academic experts and oil industry experts, as well as Hysis soft output including (oil flow input, oil flow output, outlet compounds into the air, water and soil, amount and composition of effluent, amount of energy and exergy consumption in exploitation and desalination units), amount of materials, amount of energy, amount of water, land area, minerals and organic substances used, amount of waste, consumption of fossil fuels and Electricity consumption (Figure 2).

By investigation and studying 42 methods available in SIMAPRO, the SINGLE ISSUE: CUMULATIVE ENERGY DEMAND (HHV) methods And (CE_xD) SINGLE ISSUE: CUMULATIVE EXERGY DEMAND were determined to assess the crude oil processing life cycle with energy approach (EPA 2006; Hunkeler et al 2008; Andrews et al 2009). After entering the data into SIMAPRO software and also based on the selected methods, life cycle assessment is calculated with the energy approach for 27681840 kg/day of crude oil produced. Based on the findings obtained from the release List, 1709 substances (Including a subset of 2602 substances) are released into the environment, of which 396, 407 and340 items are released into the air, water, and soil, respectively and 556 items are extracted from resources.

RESULTS & DISSCUSSION

In this research, first, the diagram of the exploitation and desalination unit of Cheshmeh Khosh is depicted using HYSIS simulator (Fig 3).First-Order Analysis: The output data of this method in SIMAPRO software show that out of 1709 substances released into the environment from the Release List, 1696 cases are consistent. In this method, 7 categories of effects were identified, the effects are not normalized, but weighting is done.

Table 1 shows the output of SIMAPRO software obtained from the life cycle assessment in the characterization stage, which demonstrates that the consumption of non-renewable fossil
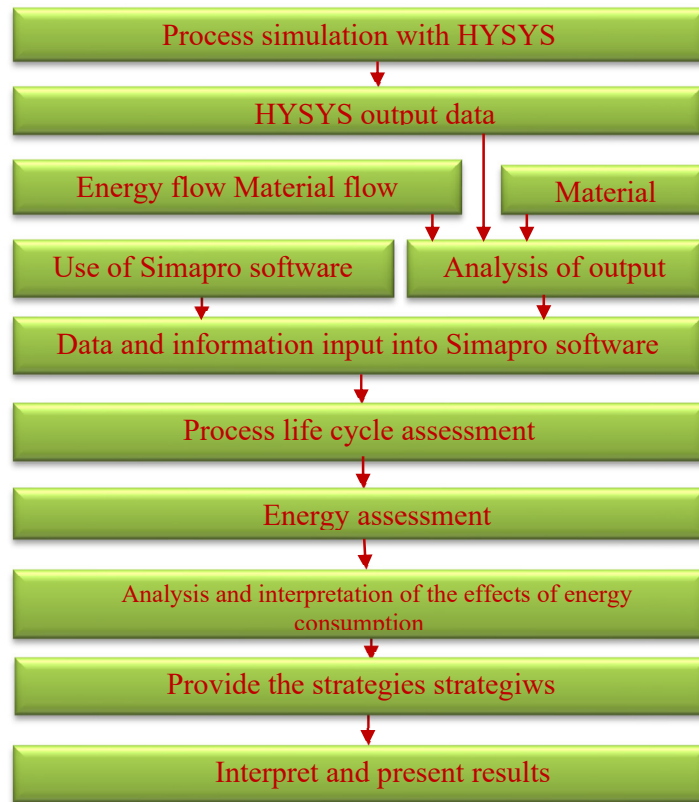
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│          Interpret and present results        │
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Fig 2. Shows the General stages of current research.

Name	Inlet Exergy (kJ/h)
128,129,130,131,132,133,134,135, 136,137,138,139,140,141,142,147,158,159,173,179	34147969.72
H1	14790239.19
H2	11907772.98
H3	10067014.95
P1	30757942.32
P1-2	412386.4538
H2-2	25249846.88
P2	36289.04578
P3	2471.26837
Total Exergy Inlet	**127371932.80795**

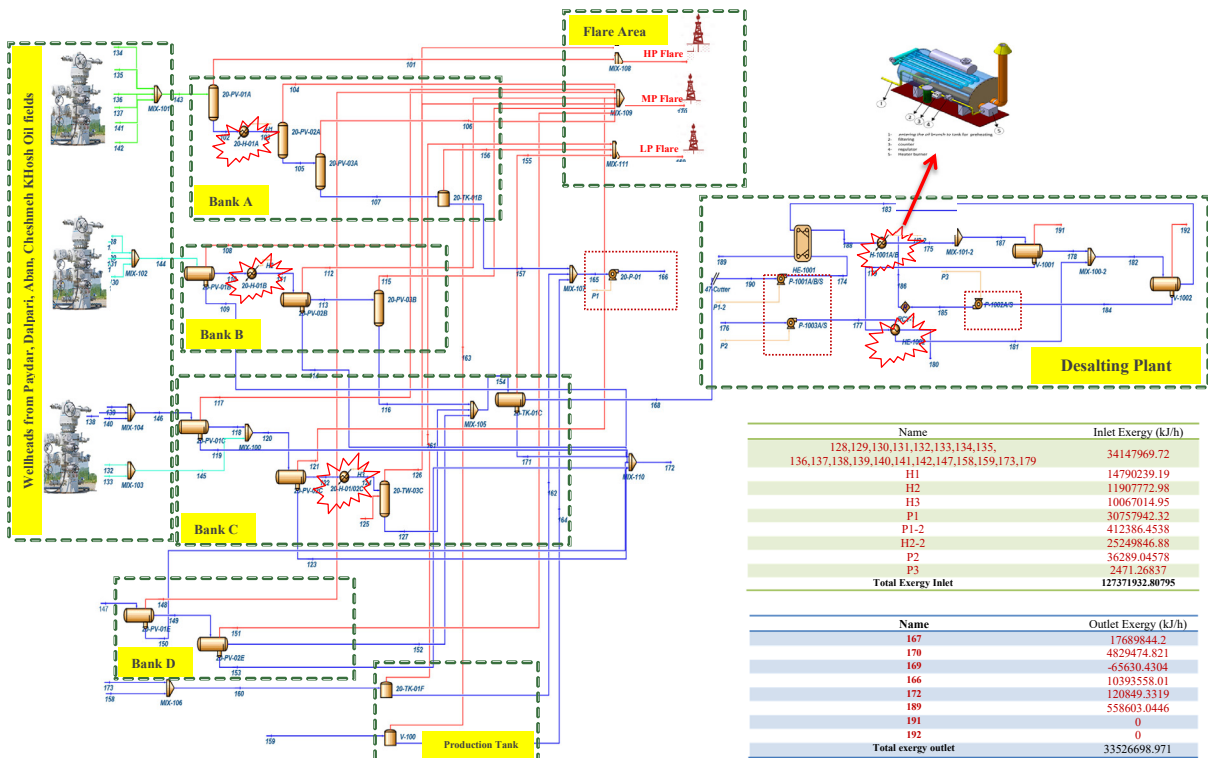| Name	Outlet Exergy (kJ/h)
167	17689844.2
170	4829474.821
169	-65630.4304
166	10393558.01
172	120849.3319
189	558603.0446
191	0
192	0
Total exergy outlet	**33526698.971**

Fig3. Simulation of Cheshmeh Khosh exploitation and desalination unit

Table 1. Impact assessment Characterization Indicator, CED V1.11 / HHV (First Order)

Impact category	Unit	Total
Non renewable, fossil	MJ	63175346222
Non-renewable, nuclear	MJ	1791291865
Non-renewable, biomass	MJ	6028444.868
Renewable, biomass	MJ	422254129.7
Renewable, wind, solar, geothe	MJ	187497083.8
Renewable, water	MJ	865805862.1

*Product: 27681840 kg petroleum Cheshmeh khosh

Table 2. Impact assessment Weighting Indicator, CED V1.11 / HHV (First Order)

Impact category	Unit	Total
Total	PJ	66.44682
Non renewable, fossil	PJ	63.17395
Non-renewable, nuclear	PJ	1.791288
Non-renewable, biomass	PJ	0.006028
Renewable, biomass	PJ	0.422253
Renewable, wind, solar, geothe	PJ	0.187497
Renewable, water	PJ	0.865803

*Product: 27681840 kg petroleum Cheshmeh khosh

Table 3. Impact assessment Characterization Indicator **,** CED V1.11 / HHV (Second Order)

Impact category	Unit	Total
Non renewable, fossil	MJ	1659431681
Non-renewable, nuclear	MJ	98445.24
Non-renewable, biomass	MJ	8.770543
Renewable, biomass	MJ	4278.624
Renewable, wind, solar, geothe	MJ	4425.39
Renewable, water	MJ	72608.18

*Product: 27681840 kg petroleum Cheshmeh khosh

resources with the amount of 63175346222 MJ has the highest amount, and afterward Non-renewable nuclear resources, renewable water resources, renewable biomass resources, solar-wind-heat-renewable resources and non-renewable biomass resources has shown the highest amount, respectively. Also, the highest consumption is related to road construction sectors, oil transmission lines and crude oil production processes.

Table 2 shows the life cycle assessment results obtained in the weighting stage. Total loss is equal to 66.44822 PJ and the consumption of non-renewable fossil resources with the amount of PJ 63.17534 has the highest risks. Afterwards, non-renewable nuclear resources, renewable water resources, renewable biomass resources, renewable solar-wind-heat resources and non-renewable biomass resources are included, respectively.

In this study, in addition to First Order Analysis, Second Order Analysis (all processes except transportation, transmission lines, and capital goods) has been performed. So, after Second Order Analysis, Tables 2 and 3 are obtained.

The output of Simapro software by Second Order Analysis obtained from the life cycle assessment in the characterization stage shows (Table 3) that the consumption of non-renewable fossil resources with the amount of 1659431681 MJ has the highest amount, and afterwards are non-renewable nuclear resources, renewable water resources, renewable biomass resources, renewable solar-wind-heat resources, and non-renewable biomass resources, respectively. In addition, the highest consumption is related to crude oil production processes, medium pressure electricity consumption, and exergy of flow lines.

The output of SIMAPRO software with Second Order Analysis shows the life cycle assessment results in the weighting stage (Table 4) that the total loss is equal to 1.659611448 PJ and the consumption of non-renewable fossil resources with a value of 1.659431 PJ has the highest risks. Afterwards, there are non-renewable nuclear resources, renewable water resources, renewable biomass resources, renewable solar-wind-heat resources and non-renewable biomass resources, respectively.

The output data of this method in SIMAPRO software show that out of 1709 substances released into the environment from Release List, there are 1252 consistent items. In this method, 10 categories of effects were identified, normalization of the effects is not done, but the weighting is done.

The results of Table 5 of SIMAPRO software output obtained from the life cycle assessment in the characterization stage shows that the consumption of non-renewable fossil resources with

Table 4. Impact assessment Weighting Indicator, CED V1.11 / HHV (Second Order)

Impact category	Unit	Total
Total	PJ	1.659611448
Non renewable, fossil	PJ	1.659431681
Non-renewable, nuclear	PJ	9.84452E-05
Non-renewable, biomass	PJ	8.77054E-09
Renewable, biomass	PJ	4.27862E-06
Renewable, wind, solar, geothe	PJ	4.42539E-06
Renewable, water	PJ	7.26082E-05

'Product: 27681840 kg petroleum Cheshmeh khosh

Table 5. Impact assessment Characterization Indicator, CED V1.05 (First Order)

Impact category	Unit	Total
Non renewable, fossil	MJ	63917779653
Non renewable, nuclear	MJ	1791291865
Renewable, kinetic	MJ	163973678.5
Renewable, solar	MJ	2031353.81
Renewable, potential	MJ	865805862.1
Non renewable, primary	MJ	6329867.111
Renewable , biomass	MJ	443366836.2
Renewable, water	MJ	-131253018.7
Non renewable, metals	MJ	2325652534
Non renewable, minerals	MJ	1563215120

*Product: 27681840 kg petroleum Cheshmeh khosh

the amount of 63917779653 MJ has the highest amount. Afterwards, Non-biodegradable metals, non-renewable nuclear resources, non-biodegradable minerals, biodegradable potentials, biodegradable biomass resources, biodegradable kinetics, primary-biodegradable metals, and non-biodegradable metals are in lower position, respectively. It should be mentioned that renewable water resources by -131253018.7 MJ has the lowest consumption. In addition, the highest consumption is related to road construction, oil transmission lines and crude oil production processes.

Table 6; The results obtained from the life cycle assessment in the weighting stage show the total amount of loss 70.94819375 PJ and the consumption of non-renewable fossil resources with 6391777 PJ as the highest risk.

Table 7 of Simapro software output with Second Order Analysis obtained from life cycle assessment in the characterization stage shows (Table 7) that the consumption of non-renewable fossil resources with 1684430814 MJ has the highest amount. It is worth mentioning that the biodegradable water resources of the mass with the amount of 263116-MJ have the lowest consumption. Also, the highest consumption is related to crude oil production processes, medium pressure electricity consumption, and exergy of flow lines.

Simapro software output with Second Order Analysis of life cycle assessment results in the

Table 6. Impact assessment Weighting Indicator, CED V1.05 (First Order)

Impact category	Unit	Total
Total	PJ	70.94679
Non renewable, fossil	PJ	63.91639
Non renewable, nuclear	PJ	1.791288
Renewable, kinetic	PJ	0.163973
Renewable, solar	PJ	0.002031
Renewable, potential	PJ	0.865803
Non renewable, primary	PJ	0.00633
Renewable , biomass	PJ	0.443366
Renewable, water	PJ	-0.13125
Non renewable, metals	PJ	2.325651
Non renewable, minerals	PJ	1.563213

*Product: 27681840 kg petroleum Cheshmeh khosh

Table 7. Impact assessment Characterization Indicator, CED V1.05 (Second Order)

Impact category	Unit	Total
Non renewable, fossil	MJ	1684430814
Non renewable, nuclear	MJ	98445.23776
Renewable, kinetic	MJ	3563.658787
Renewable, solar	MJ	90.44052409
Renewable, potential	MJ	72608.17892
Non renewable, primary	MJ	9.209069832
Renewable , biomass	MJ	4492.554817
Renewable, water	MJ	-263116.3909
Non renewable, metals	MJ	2344.735177
Non renewable, minerals	MJ	4761.425928

*Product: 27681840 kg petroleum Cheshmeh khosh

Table 8. Impact assessment Weighting Indicator, CED V1.05 (Second Order)

Impact category	Unit	Total
Total	PJ	1.684354013
Non renewable, fossil	PJ	1.684430814
Non renewable, nuclear	PJ	9.84452E-05
Renewable, kinetic	PJ	3.56366E-06
Renewable, solar	PJ	9.04405E-08
Renewable, potential	PJ	7.26082E-05
Non renewable, primary	PJ	9.20907E-09
Renewable , biomass	PJ	4.49255E-06
Renewable, water	PJ	-0.00026312
Non renewable, metals	PJ	2.34474E-06
Non renewable, minerals	PJ	4.76143E-06

*Product: 27681840 kg petroleum Cheshmeh khosh

weighting phase shows that the total loss is equal to PJ 1.684354013 and the consumption of non-renewable fossil resources with PJ 1.684430 has the highest risks (Table 8).

Evaluation of the life cycle of the crude oil production and energy optimization, reduces the amount of energy consumed (gas, water, electricity, etc.), reduces emissions, increases the amount of exported oil and also reduces costs economically.

Based on the results of the First Order Analysis of crude oil production LCA using the CED method in the characterization stage, the consumption of non-renewable fossil resources has the highest amount, followed by renewable nuclear resources, non-renewable, renewable water resources, renewable biomass resources, renewable solar-wind-heat resources, respectively. It should be mentioned that non-renewable biomass resources has the lowest consumption amount. And the highest consumption of energy resources is in the road construction sector for facilities and transmission lines, oil transmission pipelines and crude oil production processes, respectively. and the weighting stage, the total amount of loss and destruction is equal to 66.44822 PJ, consumption of non-renewable fossil resources with the had the highest loss.

Based on the results of Second Order Analysis of crude oil processing LCA using the CED method in the characterization stage, the consumption of non-renewable fossil resources has the highest amount, followed by renewable nuclear resources, non-renewable water resources, renewable biomass resources, renewable solar-wind-heat sources and non-renewable biomass resources, respectively. It should be mentioned that Non-renewable biomass resources has the lowest consumption. And the highest consumption of energy resources is related to crude oil production processes, medium pressure electricity consumption, and exergy of flow lines. And method in the weighting stage, the total amount of damage and degradation is equal to PJ 1.659611448 and the consumption of non-renewable fossil resources with PJ 1.659431 has the highest loss .

Based on the results of the First Order Analysis of crude oil processing life cycle assessment using the cumulative exergy demand method in the characterization stage, the consumption of non-renewable fossil resources has the highest amount, followed by energy related to non-renewable metals, non-renewable nuclear resources, non-biodegradable minerals, biodegradable potential, biomass resources, biodegradable kinetic, primary-biodegradable and non-biodegradable metals. It is worth mentioning that the energy consumption of renewable water resources has the lowest consumption. The highest energy consumption is in road construction for facilities and transmission lines, oil transmission pipelines and crude oil production processes, respectively.

in the weighting stage, the total amount of loss is equal to 70.94819375 PJ.

Based on the results of Second Order Analysis of crude oil processing life cycle assessment using the cumulative exergy demand method in the characterization stage, the consumption of non-renewable fossil resources has the highest amount. It is worth mentioning that the biodegradable water resources of the mass has the lowest consumption. Also, the highest energy consumption is in the sectors of crude oil production processes, medium pressure electricity consumption, and exergy of flow lines. And in the weighting stage, the total amount of loss is equal to 1.6843540013 PJ .

CONCLUSIONS

In the life cycle assessment among three types of analysis, first-order, second- order, and third- order can, The most complete type of analysis is third- order, which includes capital goods in addition to all processes, this requires having complete data of the process and equipment, materials, etc. Considering that the Cheshme Khosh process was establishment in 1984, there was no available data for third-order analysis, so in this research, first and second-order analysis were used. based on the system boundary and the purpose of this article, the best methods among the 42 available methods for analysis is CED (HHV) and CEXD. Life cycle assessment with First-Order Analysis shows that the highest energy consumption is in the crude oil transmission sector with a length of more than 1000 Km including transmission from wealheads to Cheshmehkhosh pre-refining and transmission from cheshmehkhosh unit to Ahwas (transmission lines with 28.9 %, road construction with 68.4 %) and Energy consumtion in prosess sector in ranked nexd with 26.2 %.

Life cycle assessment by quadratic analysis shows that the highest energy consumption is related to crude oil pre-refining processes with 99.5%. In this section most of energy consumption is due to the use of **five** pumps, **five** heaters and **three** gas turbines, and all exhaust gases from the seperators of second and third stages and production tanks are sent to the flare for burning, Also a lot of fresh water is used to sweeten the oil. medium pressure electricity consumption with 0.00152% and flow line exergy with 0.001121% are in the next ranks.

According to the results obtained from this article, process simulation with exergy analysis and process optimization (increasing the efficiency of pumps, reducing the number of heaters using fluid exergy to heat crude oil, using gas sent to flares), It can be a useful contribution to the life cycle assessment of crude oil that pre-refining process. and significantly reduce waste of energy, environmental effects (reduction of the ozone layer, global warming, resource consumption and carcinogenesis) and thus economic costs.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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