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ENVIRONMENTAL IMPACT CAUSED BY ELECTRIC ENERGY GENERATION DURING DIESEL OILS PRODUCTION CYCLE

WPŁYW SPOSOBÓW WYTWARZANIA ENERGII ELEKTRYCZNEJ NA OBCIĄŻENIE ŚRODOWISKA W CYKLU PRODUKCJI OLEJÓW NAPĘDOWYCH

A b s t r a c t

In this paper the LCA method was used for evaluating environmental impacts associated with the installations for the Diesel oils production in the PKN Orlen S.A. Płock. In the analysis assume that this plant was supplied with different energy sources.

Keywords: LCA analysis, Diesel oils, the PKN Orlen S.A. Płock Company, energy production

S t r e s z c z e n i e

Zastosowano metodę LCA (*Life Cycle Assessment*) do oszacowania potencjalnego oddziaływania na środowisko naturalne procesów produkcji olejów napędowych w Zakładzie PKN Orlen S.A. Płock. W analizie przyjęto, że instalacje zaopatrywane są z różnych źródeł energii.

Słowa kluczowe: analiza LCA, oleje napędowe, Zakład PKN Orlen S.A. Płock, produkcja energii

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1. Introduction

26,1% of newly registered personal cars in Poland in 2005 were vehicles with Diesel engines, but in 2006 market part of Diesel engines amounted to 32,8 %. Because of economic combustion they are more and more competitive for petrol engines. Fuels saving in Diesel engines reaches about 30% in comparison with petrol engines, and Diesel fuels – in most European countries – cost less than petrol. According to report of Polish Market of Liquid Fuels 60% of Diesel oils on Polish market comes from the PKN Orlen S.A. Płock [1]. Technological objects for Diesel oils production in this plant consist of tubular-tower distillation unit (DRW), hydrodesulfurization unit (HDS), as well as heavy product processing – i.e. hydrocracking (HC), fluid catalytic cracking (FCC) and vacuum residue hydrodesulfurization (HOG). Process units in the PKN Orlen S.A. Płock are electric and heat power supplied from in-site heat and power station with 79–80 % efficiency. The main raw materials used in electric power production in the PKN Orlen S.A. Płock are fuels obtained from oil processing, i.e. desulfurized residue from HOG unit – about 97% (m/m) and fuel gas – about 3% (m/m). Natural environmental burden because of Diesel oils production could be changed, when the PKN Orlen S.A. Płock would be connected to domestic power gird. The main fuel in Polish power industry is coal, and 92% of heat and electric power was produced in 2004 based on coal [2].

2. Assessment of ecological effect of Diesel oils production in the PKN Orlen S.A. Płock, using LCA method

Assessment of the environmental burden by the Diesel oils production system in the PKN Orlen S.A. Płock contains comparison of the real technological diagram of this refinery (Fig. 1) with another production alternative, where electric energy comes from the domestic power grid.

Process assessment was made basing on real data from 2003 about material and energy flows, shared by the PKN Orlen S.A. Płock [3]. Selection of the technological system was aimed on Diesel oils production combining such installations as: hydrogen production, hydrogen recovery and sour water stripping. The main raw material in tubular-tower distillation system (DRW) was Rebco oil (about 80%), with density 0,866 t/m^3 and sulfur content equal to 1,53 % (m/m); that was transferred by the „Przyjaźń" pipeline from Russia. The alternative material source was Brent-Blend oil, with density 0,831 t/m^3 and sulfur content equal to 0,29 % (m/m) delivered by pipeline from the Baltic Sea fuel terminal. The mass ratio of batch to HC and FCC systems in the PKN Orlen S.A. Płock was equal 3:2 in 2003. To lubricating oil system was directed about 10% of vacuum distillates fraction from DRW. In order to calculate environment burden coefficients, which were connected with 1 TJ of electric energy production in Polish environment, the data presented in Table 1 were used. The coefficients come from the GEMIS 4.42 database [4] and include the widen version of influence on environment i.e. raw material extraction and transport.

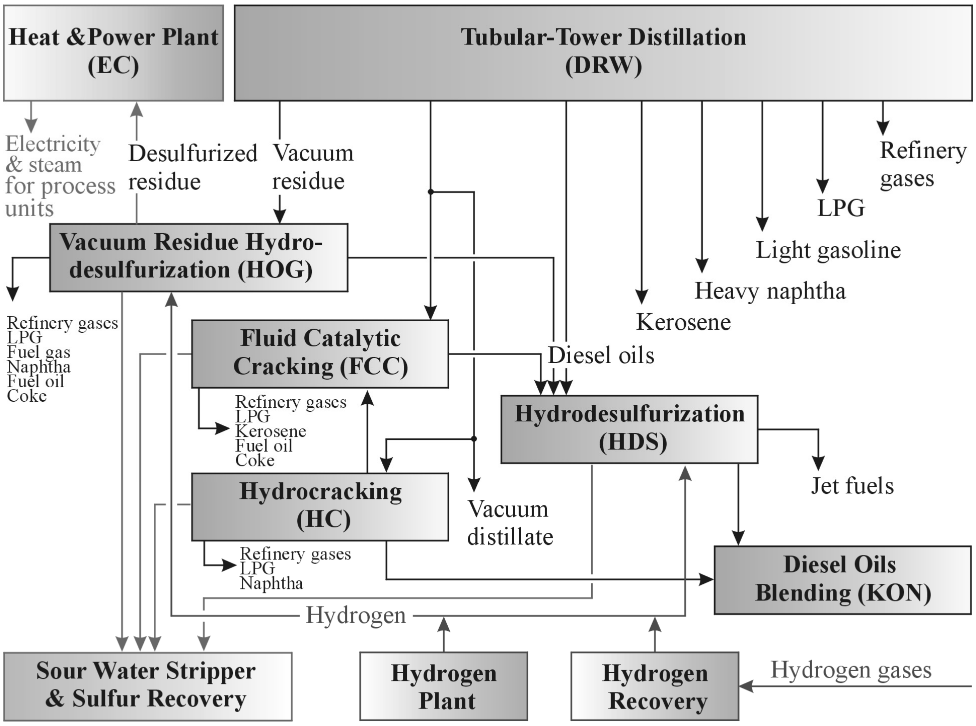

Fig. 1. Diesel refinery scheme in the PKN Orlen S.A. Płock [3]

Rys. 1. Schemat technologiczny produkcji olejów napędowych w PKN Orlen S.A. Płock [3]

The main point of reference in the research were guidelines and recommendations collected in ISO 14040 standards [5–7]. The methodology of LCA analysis includes four phases – it means goal and range definition, input and output set analysis, life cycle assessment and interpretation. Isolated coefficients were calculated according to instructions gathered in LCA manual [8], compatible to ISO standards. Net structure allowing for analysis of Diesel oils production was done using Umberto 3.6. consult computer programme (Fig. 2).

Final report gives comparative assessment of Diesel oils production system used in the PKN Orlen S.A. Płock, considering two sources of electric energy. The production of 1 kg of Basic Diesel oil was accepted as a functional unit of LCA analysis. Assessment of environmental burden quantity was estimated basing on seven environmental impacts, counted on 1 kg of Diesel oil produced (Table 2). The research did not include impact categories, that did not come out from inventory analysis, i.e. noise, smell, land use.

Table 1

Increase of environment burden as a result of 1 TJ electric energy production In Poland [4]
(1 TJ = 10^{12} J)

TYPE AND QUANTITY OF THE ENVIRONMENTAL BURDEN			
Emissions into air [kg/TJ]		**Green house gases [kg/TJ]**	
eq. TOPP	1051,65	eq. CO_2	$283{,}39 \cdot 10^{3}$
eq. SO_2	3108,93	CO_2	$268{,}70 \cdot 10^{3}$
SO_2	2454,13	CH_4	375,50
NO_X	838,64	N_2O	20,44
HCl	66,79	Perfluoromethane	$6{,}12 \cdot 10^{-6}$
HF	7,63	Perfluoroethane	$769{,}30 \cdot 10^{-9}$
CO	168,01	**Cumulative energy use [TJ/TJ]**	
NMVOC	4,76	non renewable	2,68
Particulates	471,11	renewable	$15{,}35 \cdot 10^{-3}$
H_2S	$8{,}40 \cdot 10^{-9}$	other	$892{,}57 \cdot 10^{-6}$
NH_3	$181{,}90 \cdot 10^{-6}$	**Cumulated material requirement [kg/TJ]**	
Cd	$13{,}74 \cdot 10^{-6}$	non renewable (natural gas, oil, ores, minerals)	$1{,}66 \cdot 10^{3}$
Cr	$104{,}01 \cdot 10^{-6}$		
Ni	$101{,}63 \cdot 10^{-6}$	renewable (air, water)	$621{,}00 \cdot 10^{3}$
Pb	$676{,}11 \cdot 10^{-6}$	other (iron-scrap, NF-scrap, secondary raw materials)	94,51
PAH	$1{,}39 \cdot 10^{-9}$		

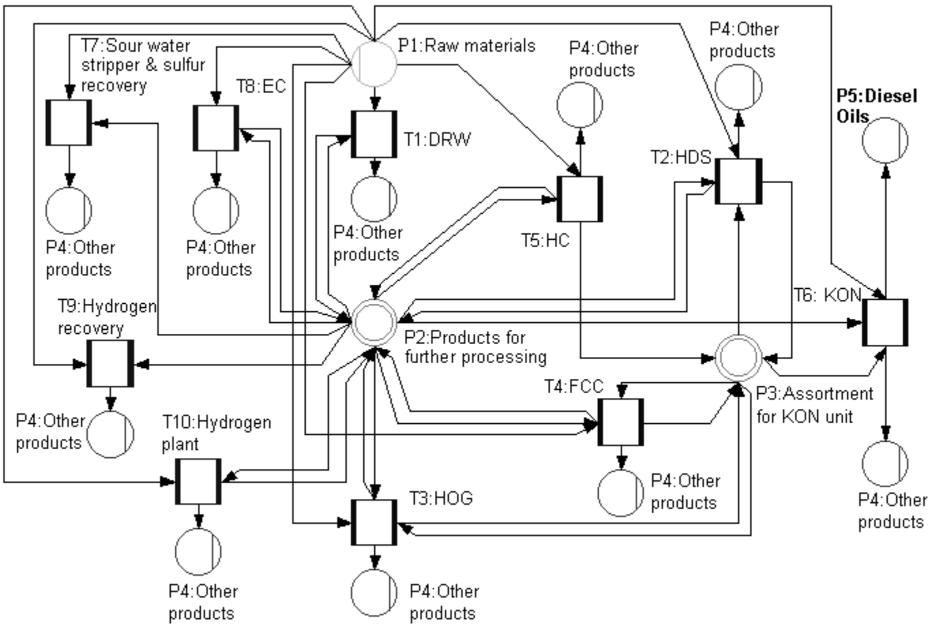

Fig. 2. The material flow network of the installations for the Diesel oils production in the PKN Orlen S.A. Płock

Rys. 2. Sieć przepływów materiałowych dla instalacji produkcji olejów napędowych w Zakładzie PKN Orlen S.A. Płock.

Table 2

Environmental impact categories [8, 9]

No.	Category	Description
1	Human toxicity (kg eq. 1,4-DCB)	Human health risk to toxic substances, potential risk of carcinogenity
2	Eutrophication (kg eq. PO_4)	Reduction of oxygen amount in water because of emission of substances causing enlargement of biomass production
3	Fotochemical oxidation (kg eq. C_2H_4)	Formation of atmospheric particles causing photochemical smog
4	Summer smog (kg eq. TOPP)	Dense fog carrying particles of NO_x, volatile organic compounds, methane and CO
5	Global warming (kg eq. CO_2)	Temperature growth caused by increasing of concentration of gases absorbing radiation
6	Acidification (kg eq. SO_2)	Increase of water and soil acidity
7	Energy depletion (kg eq. Sb)	Extraction of non-renewable energy resources

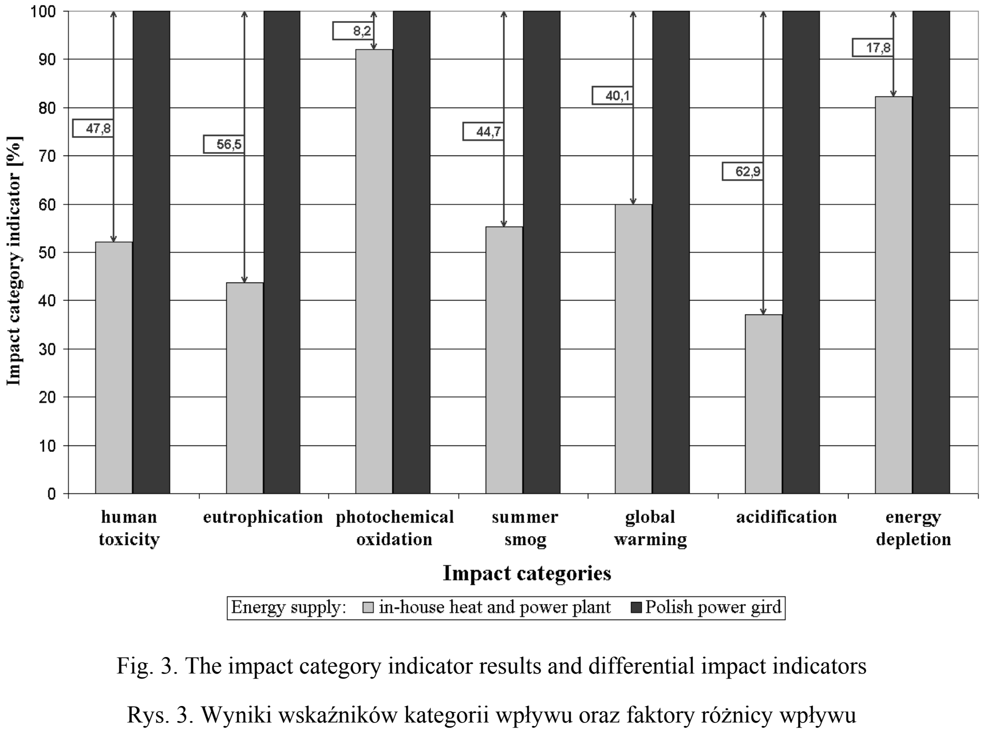

Fig. 3. The impact category indicator results and differential impact indicators

Rys. 3. Wyniki wskaźników kategorii wpływu oraz faktory różnicy wpływu

The results of comparative analysis on non-modified coefficient level, scaled up to 100% of the major influence within the given category, are presented in Fig. 3. Within each category there is differential impact indicator, it means relative factor of environment threat. Positive value of this indicator should be explained in such way, that within the influence category the real technological object of Diesel oils production in the PKN Orlen S.A. Płock containing in-house heat and power plant is more advantageous than model system connected with the domestic power grid. Negative value of the indicator as a better solution could point out the Diesel oils production system, when energy source comes out from the domestic power grid. The LCA method widened to level of normalized indicator is presented in Fig. 4. The results of impact category indicators related to reference indicators of normalization [9] were calculated within each technological version, and finally summed up as one indicator value. Reference indicators of normalization illustrate the average environment impact for one inhabitant of 25 UE countries in 2000. The results of normalized indicators are expressed by general unit [person × year × 10^{-3} / kg $_{ON}$] and they determine the size of environment impact. The bigger the impact value, the higher potential negative influence on environment.

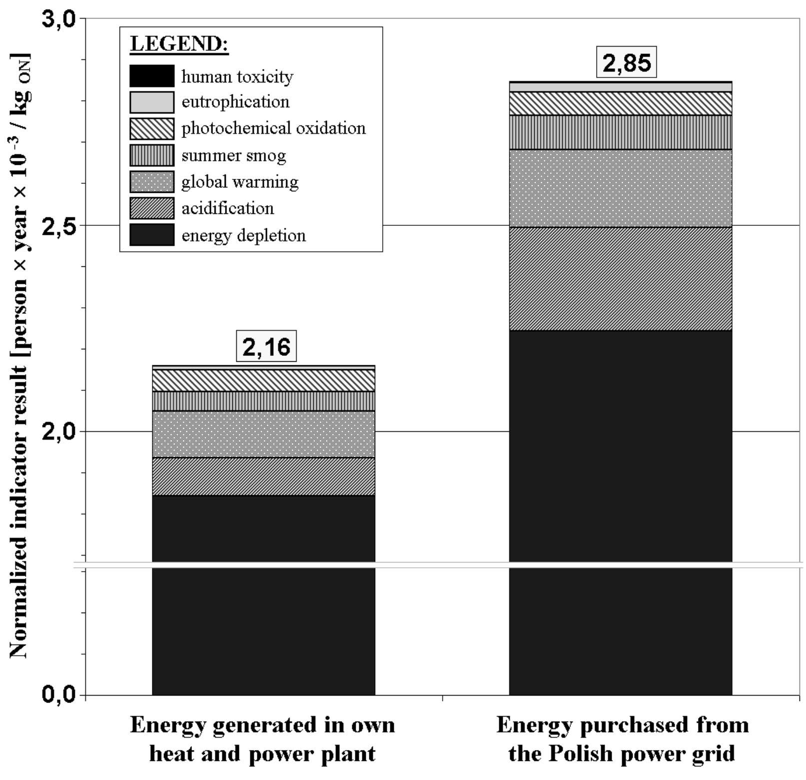

Fig. 4. Normalization histogram

Rys. 4. Histogram normalizacji

3. Conclusions

The results of comparative ecological assessment of two equivalent technological systems of Diesel oils production, it is the real plant in the PKN Orlen S.A Płock and the model system prepared on the basis data from domestic power grid show, that technological system in the PKN Orlen S.A Płock has got less potential influence on environment (about 32%). The result interpretation on the level of normalized indicator also allows for conclusion, that refinery with in-house heat and power plant is more advantageous in a category environment impact.

The operation strategy of the PKN Orlen S.A Płock Refinery assumed, that all heavy half-finished products, such as desulfurized residue from HOG process, were converted at the in-house heat and power plant to electric energy (1,84 TWh/year) and heat – steam with 6 different pressure for process (13,63 mln ton/year) and circulating hot water. The heat and power plant system with annual consumption of electric energy for internal load about 0,22 TWh, makes this plant competitive in comparison with closest coal power stations. Emission of the substances acidifying environment in [kg eq. SO_2/kJ of electric energy] is 7 times less for electric energy production in Płock heat and power plant, in comparison with average emission produced in Poland counted for electric energy unit (Table 1). The essential source of environment impact in Diesel oils production are the processes generated during energy production

Symbols

1,4-DCB – 1,4 - dichlorobenzen
DRW – Tubular-tower distillation – *destylacja rurowo-wieżowa*
EC – Heat and power plant – *elektrociepłownia*
FCC – Fluid Catalytic Cracking – *fluidalny kraking katalityczny*
HC – Hydrocracking – *hydrokraking*
HDS – Hydrodesulfurization – *hydroodsiarczanie*
HOG – Vacuum Residue Hydrodesulfurization – *hydroodsiarczanie gudronu*
KON – Diesel oils blending – *komponowanie olejów napędowych*
LCA – Life Cycle Assessment – *ocena cyklu życia*
NMVOC – Non-Methane Volatile Organic Compound – *niemetanowe lotne związki organiczne*
ON – Diesel Oils – *oleje napędowe*
PAH – Polyaromatic Hydrocarbons – *wielopierścieniowe węglowodory aromatyczne*
TOPP – Tropospheric Ozone Precursor Potential – *wskaźnik służący do przeliczenia gazów*: NOx, NMVOC, CH_4 i CO *odpowiedzialnych za smog letni; zalecany przez* EEA

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