Towards the Sustainability in Conceptual Process Design: Petroleum Refinery

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1. Summary

Chemical design approaches are economic-based while environmental and sustainability issues are considered as constraints and included at a second level of decision. This work contributes to incorporate sustainability in the early-stages of the design procedure. This objective requires a multidisciplinary approach and therefore it integrates various tools (Aspen Plus®, Matlab®, SimaPro®…) and several analysis methods (energy integration, NINLP, optimization…) to increase the sustainability of a process. In this way, the application of Life Cycle Assessment (LCA) is motivated by its holistic approach. After simulation of the flow sheet by incorporating the diagnostics, then multi-objective optimization is to be applied to the modified process. The utility requirements and environmental emissions are to be optimized for a sustainable design of the process.

Key Words: sustainability, modelling, refinery, CO2 reduction

2. Extended Abstract

A petroleum refinery (Preflash, atmospheric and vacuum columns) with a capacity of 100000 bbl/day is simulated on Aspen Plus. The system has 4 pumparounds, 3 side strippers, 2 condensers and 3 furnaces, and therefore it represents a broad casuistic of chemical processes. Hot utility represents 80% of the energy requirement, while the first two columns consume 80% of the utilities. The process is modeled using Aspen Plus®, while the environmental loads of the process inputs were retrieved from the ETH Report and the TEAM® database. Environmental calculations were done for the whole process and for each unit, mainly the boiler and the furnaces, to clarify calculations. As expected, most of the CO_2 emissions are related with the units with higher energy consumption.

Table 1: CO_2 emissions from the base process

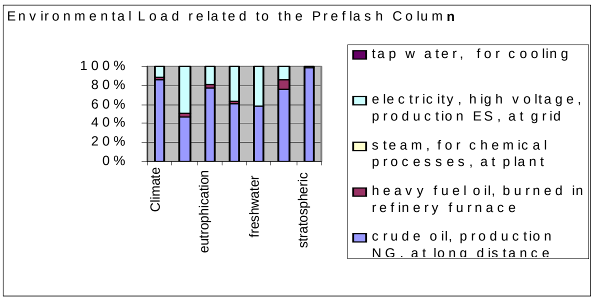
	Columns		
	Preflash	Atmospheric	Vacuum
Steam flow rate(Kg/hr)	2268	7756	9072
Condenser duty(MW)	-19	-29	0
Pump around duty(Mw)	0	-16	-32
Furnace duty(MW)	59	58	26
CO2 from stripping steam(ton/hr)	2.7	9	10
CO2 from furnace(ton/hr)	18	18	8
Total CO2(ton/hr)	21	27	18.5

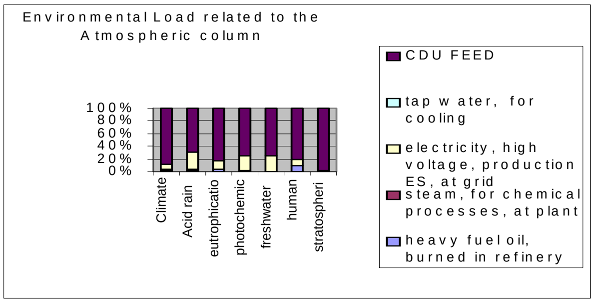
For the reduction of CO_2 from the preflash furnace, increasing the feed temperature of the crude is one option among different possibilities. To do this, we need to extract more heat with high quality from the hot streams. To do this, a sensitivity analysis was done on the atmospheric column pumparounds and it is found that it is possible to get a higher duty for the first pumparound at a temperature well above the existing feed temperature of the crude(93^{o}C) and also the duty from the second pumparound is available at a temperature well above the storage temperature of the crude (25^{o}C). With this minor improvement in the operating condition of the atmospheric column pumparounds, we can increase the feed temperature of the crude by 10^{o}C thereby resulting in a 2% energy saving and reduction of CO_2 emission by the same percentage.

Table 2: Sensitivity analysis on the atmospheric column pumparounds

Pumparounds	Existing temperature	New temperature	Existing duty	New duty
PA1	168^{o}c	141^{o}c	-12 MW	-16 MW
PA2	202^{o}c	95^{o}c	-4.4 MW	-9 MW

Emission calculations can only give us the environmental load of the process under consideration. To calculate the environmental load associated with a product throughout its life cycle, including the upstream processes, LCA is an important tool. An LCA calculation scheme has been developed on Excel Spreadsheet to calculate the environmental impacts associated with the input streams and allocate the environmental loads to the products. The environmental impact summary quantifies the emission and impact of each chemical from each piece of equipment. It is utilized to seek opportunities to reduce the environmental impacts by process modification or pollution control. As a motivation for process diagnostic, mass and energy input/output tables and environmental impact summary are developed. A mass input/output analysis is performed on the base case flowsheet to generate the process stream information.





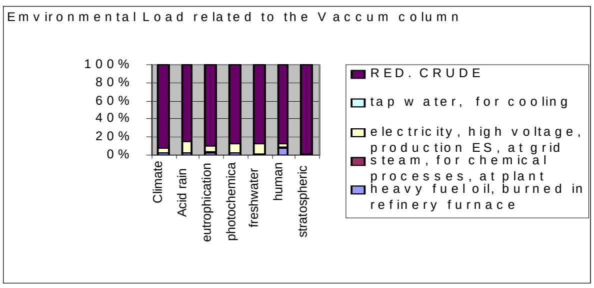


Figure1: LCA results (show the impact sources in percentage for the different impact categories for the three columns).

References

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