POTENTIAL AND COSTS FOR CO_2 MITIGATION OPTIONS FOR MINERAL OIL REFINERIES IN EU-28 FOR 2050

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Overview

In February 2011,the European Council reconfirmed the EU objective of mitigating greenhouse gas emissions by 80 – 95 % until 2050 compared to 1990 to prevent drastic climate change. To reach that target, all sectors of the society are to put an effort into reducing their emission level. The European petroleum refining industry accounts for 3.4 % of GHG emissions in all industry activities and 7.2 % in the energy production and use sector. In the verified emissions table (VET) of the EU emissions trading system (EU ETS), we find 130 installations with total emissions of about 130 Mt in 2015. This makes up for about one quarter of emissions accounted for by industrial activities in the EU ETS. At present, comprehensive analysis on energy demand, CO_2 emissions, CO_2 mitigation potential and costs using energy saving options have not been conducted at plant- and energy carrier-level for this important sector. Here we present an approach to model the energy demand and CO_2 emissions for the European refinery sector based on a plant level investigation. In a scenario analysis, we investigate capacity development and saving potential.

This paper has the following contents: The profile of the refineries in EU-28 in terms of process capacities, utilization rate, and the applicable energy saving options are described. Based upon these information, we develop a bottom-up approach to calculate energy demand and CO_2 emissions for each refinery by energy carriers. Furthermore, a categorization is applied according to the technical design of the plants, taking into account the different processes applied and products produced. Correlating main drivers to production figues, we develop a reference scenario of the energy consumption and the CO_2 emissions up to 2050. Addtionally, a policy scenario is developed using inputs based on an EU roadmap (European Commission 2011). Moreover, we show technical and economic potential of energy saving and CO_2 mitigation in consideration of the energy saving options.

Methods

In regards to potential for CO_2 mitigation, Johansson et al. (2012) investigated refineries with respect to adjacent infrastructures such as district heating networks, natural gas grids and, neighboring industries. However, the application of energy efficiency measures, which are considered to be the main method to reduce CO_2 emissions, were not the focus of the study. Chan and Kantamaneni (2015) conducted a research to show the technologies and potential to reduce energy consumption at an European aggregated level. We want to add to these approaches by investigating the potential of energy efficiency options based on a plant-level analysis of refineries in the EU-28.

First, site specific data are collected in terms of process capacities and utilization rates, which are used to calculate throughputs of the refineries. Energy intensity values of the main processes (e.g. crude distillate unit (CDU), reformer unit (RF), fluid catalytic cracking unit (FCCU), hydrocracking unit (HCU), desulfurization unit (DSU)) by energy carriers are employed to assess the energy demand of the plants individually. Using fuel composition of the refineries and CO_2 intensities of the consumed fuels, the CO_2 emissions for each site are estimated.

For the subsequent scenario analysis, four categories (Complex 1-4) are assigned to the plants determined by their process configuration. With the categorization, the ratio of different products produced by the refineries as well as different energy and emission intensities are defined. Each of the refinery products is correlated to main drivers of their production such as gasoline and diesel demand in the transportation sector. Based upon these relations, the production change of the refineries up to 2050 is calculated. These drivers are, for both a reference and a more ambitious policy scenario, taken from widely acknowledged existing studies (European Commission 2011).

Finally, to quantify the energy saving and CO_2 mitigation potential, energy saving options are considered. The technologies are characterized by their packback time and, potential savings and GHG mitigation by energy carrier. Investigating the diffusion of the technologies under different assumptions, their technical and economic potential is estimated

Results

First, the analysis of the capacities of the refineries based on Oil and Gas Journal (2016), by their categorization shows that the whole European refinery, which has the capacity around 700 million ton per annum in 2015, consists of 13% of Complex 1, 46% of Complex 2, 14% of Complex 3 and 27% of Complex 4. These categories are differentiated as follows: Complex 1 does not have a conversion unit. Therefore, product compositions and their qualities are confined by crude oil sources. Complex 2 and Complex 3 use a FCCU and a HCU as a conversion unit respectively, which are geared toward maximizing the production of gasoline for Complex 2 and diesel for Complex 3. Complex 4 has both FCCU and HCU and it is characterized by its flexibility of the production.

Second, the bottom-up calculation of energy demand and CO_2 emissions by energy carrier in each site shows that there are roughly 49.0 million of tonnes of oil equivalent consumed and about 130 million of tonnes of CO_2 released in the year of 2015, which are contributed by each complex similar to the capacity ratio. These findings are coherent with both energy balaces from Eurostat and emission balances from the EU ETS.

Third, the reference projection of CO_2 emissions suggests about 16 % GHG mitigation potential by 2050 in comparison to the level in 2015 with further potential of about 53% by 2050 in the policy scenario. These effects are mainly governed by activity changes due to dwindling demand of mineral oil products in the investigated scenarios.

Fourth, the reviewed energy saving options indicate approximately 7% and 9% of fuel saving potential in the economic and technical diffusion, respectively.

Figure 1 summarizes these main results along with the research process: refinery process profile generation, site-level calculation of energy consumption and CO_2 emission, scenario development and CO_2 mitigation potential using energy saving options.

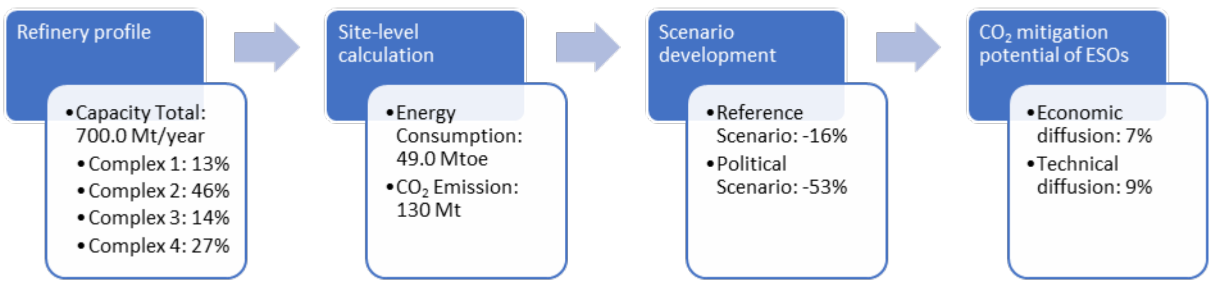

Figure 1. Summary of the research process and the main results of the study. ESOs, energy saving options.

Conclusions

The petroleum refineries in Europe releases 3.4% of GHG emissions in European industry sectors. The reference scenario suggests that the transportation and the chemical industry could have the biggest impact on the activity of the refinery sector up to 2050. The applied energy saving technologies indicate potential for CO_2 mitigations under economic and technical assumptions implying a relevant contribution to GHG reduction in the future years. However, estimations of activity change seems to outweigh efficiency gains by a factor of 4 to 5. Assuming that the demand changes are deemed reasonable, this indicates that the business model of refineries is threatened.

The methodology of site-specific estimation and projection of energy demand and emissions by refinery category seem plausible enough, given the good match of top-down and bottom-up values on an overall level. Furthermore, the methodology shows primise for applicability to further mitigation options and to other industry sectors.

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