Alireza Tehrani Nejad M. and Valérie Saint-Antonin

A MULTI OBJECTIVE OPTIMIZATION APPROACH TO EVALUATE THE IMPACT OF ULTRA-LOW SULFUR SPECIFICATION POLICUIES ON THE CO2 CONTENT OF AUTOMOTIVE FUELS

Alireza Tehrani Nejad M.: Corresponding author Institut Français du Pétrole (I.F.P.),
Tel.: +33 1 47 52 60 00 (post 8969), alireza.tehrani@ifp.fr, artehrani2000@yahoo.fr
Valérie Saint-Antonin: Institut Français du Pétrole (I.F.P.), valerie.saint-antonin@ifp.fr

Overview

Due to the transport and fiscal policies in Europe, the demand for automotive diesel, at the expense of gasoline, has been drastically increased from the past 10 years. These trends are anticipated to continue in the near future. Despite the "gasoline structure" of most of the European refineries, their primary focus at this time is to boost the production of diesel while reducing gasoline output or keeping it stable. This imbalanced supply-and-demand market is worsen with the tightening of oil product specifications required by the European Union legislation. For instance, the gasoline and "on-road" diesel sulfur content is reduced to 50 ppm in 2005 and will be reduced to 10 ppm in 2009. All these evolutions would significantly increase the refineries energy consumption and their CO_2 emissions.

Since in Well-to-Tank (WTT) studies the main difference among the CO_2 and energy content of automotive fuels are exclusively due to the refining process (EUCAR et al., 2004), especial care should be taken on this component. Oil refining is a joint production system with a very complex technical structure and a vast number of outputs that are strongly correlated. Therefore a key methodological problem which inevitable arises is how to correctly identify and quantify the real cause-effect chains that should be considered in estimating the marginal energy and the resultant CO_2 content of automotive fuels at the gate of the refinery. Neither the traditional WTT approaches, nor the existing databases can be useful because they fail to capture the complex interdependencies and synergies which exist among the refinery oil products and process units.

This paper illustrates that a practical way to perform such an analysis is to use Linear Programming (LP) models. In contrast to the traditional WTT methods, the information created through the duality in LP incorporates the complete interdependency and economic effects associated with any marginal variation in the refinery; these information can be directly used for prospective WTT studies. The proposed methodology is then applied to a real-type refinery LP model in order to evaluate the European ultra-low sulfur specification policies within a "cost-efficient" and an "emissions-efficient" objective criteria. The optimal solution of these two private v.s. public equilibrium are compared and discussed from an economical and technical point of view. This question is of importance because the reduction of the environmental impacts of automotive fuels constitutes one of the prime objectives of the European environmental policies.

Methods

A typical European refinery model based on linear programming2 is used to evaluate the impact of tightening the oil product sulfur specifications based on two different economical and environmental objective criteria. The economic criterion corresponds to the well-known cost minimization framework in which operate the private European refineries (Babusiaux, 2003; Tehrani Nejad M., 2006; Pierru, 2007). In this framework, the dual variables associated with the product demand constraints are interpreted as their marginal costs; and, the marginal contribution of oil products to the refinery's CO2 emissions can be extracted from the final simplex matrix calculated at the optimal solution of the LP. On the other hand, the environmental criterion corresponds to a public regulation framework in which refineries are subject to minimize the CO2 emissions generated from their production activity (Azapagic and Clift, 1998, 1999). In this case, the dual variables associated with the product demand constraints represent directly the marginal CO2 content of automotive fuels.

As opposed to the traditional WTT methods, these LP-based emission coefficients (within both economical and environmental objective criteria) include all consequences of the desired change on the operation of the refinery as well as compositional changes of the oil products. Using these models, three simulations for years 2005, 2008 and 2010 are performed to evaluate the impact of the sulfur tightening policy on the CO2 content of automotive fuels at the gate of the refinery.

Results

Some of the general and technical results can be summarized as follows:

- Since the equilibrium extent of gasoline-to-diesel conversion has been reached, adjusting the European refineries output to meet the new oil product quantities, would be more energy-and CO_2-intensive for diesel as compared to gasoline; this conclusion holds in both cost-efficient and environmental-efficient equilibriums.
- Unlike the predictable behavior of the marginal CO_2 contribution of automotive fuels in the environmental-effective approach (where the total carbon dioxide emissions of the refinery are minimized), the ones emerging from the cost-efficient equilibrium have an erratic behavior.
- In the European refinery context, where the production of middle distillates are boosted, we observed that the optimal components of diesel remain almost the same in both cost-effective and environmental-effective optimal solutions. This result is of importance because, the environmental-effective-based coefficient for automotive fuels which follow a more predictable trend (piecewise linear and nondecreasing) could replace their respective cost-effective emissions in WTT studies.

Conclusions

In order to evaluate the marginal CO_2 content of automotive fuels at the gate of refineries, a practical method based on linear programming was developed. These marginal CO_2 contents were separately computed following two different economical and environmental objective criteria. In both cases, we illustrated that these LP-based emission coefficients embody all the interdependency and synergy effects among the unit processes in the refining system; and, they provide a more realistic estimates of the environmental impacts of automotive fuels. Our estimates follow the general conclusions driven by Kavalov and Peteves (2004) who claimed that the gap between diesel and gasoline marginal CO_2 contribution would be widen further, because of the more expensive adjustment of diesel properties to the new European standard requirements.

References

Azapagic, A., Clift, R., 1999. Allocation of environmental Burdens in Multiple-Function Systems, *Journal of cleaner Production*, 7, 101-119.

Babusiaux, D., 2003. Allocation of the CO2 and Pollutant Emissions of a Refinery to Petroleum Finished Products, *Oil & Gas Science and Technology – Rev. IFP*, 6(58), 685-692.

EUCAR, CONCAWE and JRC, 2004. Well-to-Wheels Analysis of Future Automotive Fuels and Associated Powertrains in the European Context. Well-to-TANK Report, Version 2b.

Kavalov, B., Petevs, S.D., 2004. Impacts of increasing automotive diesel consumption in the EU. European Commission, Directorate General Joint Research Center, Petten, The Netherlands.

Pierru, A., 2007. Allocating the CO_2 emissions of an oil refinery with Aumann-Shapley prices. Energy Economics, In press.

Tehrani Nejad M., A., 2006. Allocation of CO_2 Emissions in Petroleum Refineries to Petroleum Joint products: a Linear Programming Model for Practical Application. Energy Economics, In press.

2 The LP model is developed by the French Petroleum Institute (IFP) and contains 650 constraints and more than 1800 variables. 1 Corresponding autor, Tel.: +33 1 47 52 60 00 (post 8969).