JRC Scientific and Technical Reports

Well-to-wheels Analysis of Future Automotive Fuels and Powertrains in the European Context

WTT APPENDIX 3
Energy requirement and GHG emissions for marginal gasoline and diesel fuel production

R. Edwards
European Commission Joint Research Centre, Institute for Energy

J-F. Larivé
CONCAWE

J-C. Beziat
Renault/EUCAR

EUR 24952 EN - 2011

The mission of the JRC-IE is to provide support to Community policies related to both nuclear and non-nuclear energy in order to ensure sustainable, secure and efficient energy production, distribution and use.

European Commission
Joint Research Centre
Institute for Energy and Transport

Contact information
Address: Ispra Site I – 21027 (Va)
E-mail: infojec@jrc.ec.europa.eu
Tel.: +39 0332 783902
Fax: +39 0332 785236

http://iet.jrc.ec.europa.eu/about-jec
http://www.jrc.ec.europa.eu/

JRC 65998

EUR 24952 EN
ISBN 978-9279-21395-3
ISSN 1831-9424
doi:10.2788/79018

Luxembourg: Publications Office of the European Union

Printed in Italy

WELL-TO-WHEELS ANALYSIS OF FUTURE AUTOMOTIVE FUELS AND POWERTRAINS IN THE EUROPEAN CONTEXT

concawe

EUCAR
EUROPEAN COUNCIL FOR AUTOMOTIVE R&D

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

WELL-to-TANK Report – Appendix 3

Version 3c, July 2011

http://iet.jrc.ec.europa.eu/about-jec
infojec@jrc.ec.europa.eu

This report is available as an ADOBE pdf file on the JRC/IES website at:

http://iet.jrc.ec.europa.eu/about-jec

Questions and remarks may be sent to:

infojec@jrc.ec.europa.eu

Notes on version number:

This document reports on the third release of this study replacing version 2c published in March 2007. The original version 1b was published in December 2003.

This is a partial revision of version 2c in that it does not include an update of section 8 on cost and availability.

Energy requirement and GHG emissions for marginal gasoline and diesel fuel production

This study is about alternative road fuels and their potential to replace conventional gasoline and diesel fuels. When we evaluate these alternatives we need to consider their potential to save energy and GHG. At the 2010-2020 horizon, alternative fuels can only be reasonably expected to supply say 10% to 20% of the road fuel demand. As far as the conventional fuels are concerned, the issue is therefore how much can be saved by not producing the marginal 10 or 20% of the 2010-2020 expected demand.

Oil refineries produce a number of different products simultaneously from a single feedstock. Whereas the total amount of energy (and other resources) used by refineries is well documented, there is no simple, non-controversial way to allocate energy, emissions or cost to a specific product. Distributing the resources used in refining amongst the various products invariably involves the use of arbitrary allocation keys that can have a major influence on the results.

For example energy content is a popular allocation key; there is, however, no physical reason why a product with higher energy content should systematically attract more production energy. Another example is provided by naphtha reforming, a ubiquitous refinery process that dehydrogenates virgin naphthas into a high octane gasoline component; a superficial analysis would call for allocating most of the energy requirement of this process to gasoline production; however the bulk of that energy is chemical energy related to the simultaneous production of hydrogen which, in turns, is used for the desulphurisation of diesel components.

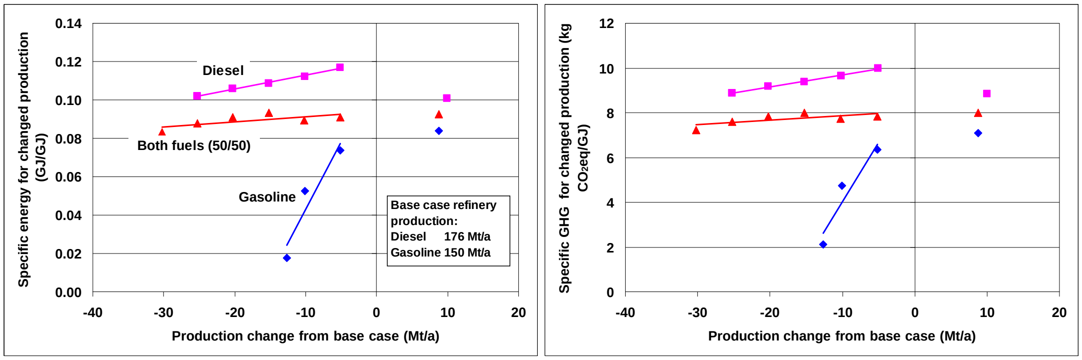
More to the point, such a simplistic allocation method ignores the complex interactions, constraints, synergies within a refinery and also between the different refineries in a certain region and is likely to lead to misleading conclusions. From an energy and GHG emissions point of view, this is also likely to give an incomplete picture as it ignores overall changes in energy/carbon content of feeds and products.

To approach the problem we performed a marginal analysis of the European refining system using the CONCAWE EU refining model. In a “business-as-usual” base case no alternative fuels are involved and the EU refineries have to substantially meet the total 2010 demand with minimum adaptation of the refining configuration. In the alternative cases conventional gasoline and/or diesel demand is reduced by a certain amount assumed to be substituted by other fuels. Demands for other oil products are fixed to the values expected to prevail in 2010. The crude oil supply is also fixed, with the exception of a balancing crude (heavy Middle Eastern considered as the marginal crude). Gasoline and diesel maximum sulphur content are assumed to be 10 ppm. All other fuel specifications are assumed to remain at the currently legislated levels i.e. maximum 35%v/v aromatics in gasoline from 2005 and other specifications remaining at current values.

The difference in energy consumption and GHG emissions between the base case and an alternative can be credibly attributed to the single change in gasoline or diesel fuel production

The CONCAWE model is fully carbon and energy balanced so that the differentials between two cases take into account small changes in energy and carbon content of all products.

The outcome of this work is shown in the figure below where the energy and CO_2 emissions associated to a certain marginal production of either diesel or gasoline are plotted as a function of that production. The data points represent the average value per MJ for the total amount produced.



Note: data points show the average saving at a given reduction level

The first striking point is that more energy/CO_2 can be saved through substituting diesel rather than gasoline. This goes somewhat against "conventional wisdom" according to which gasoline production is more energy-intensive than diesel's. Whereas this assertion can be challenged for any modern refinery, this is particularly incorrect in Europe where the demand pattern is such that refineries struggle to produce the large middle distillate demand while having to export substantial quantities of gasoline.

The pattern is somewhat different when looking at either an increase or a decrease in production from the base case. The latter represents the point that was "planned for" i.e. for which the refineries invested.

Reducing production from the base case represents a situation where refineries would have over-invested. Diesel is in high demand in Europe and the marginal production routes are likely to be rather inefficient. At a lower production spare capacity becomes available and the system sheds first the least efficient production routes, thus the downward slope of the curve. Gasoline is in surplus and any reduction of production will increase the imbalance and therefore result in a low energy saving, the more so as the production is further decreased.

Increasing production from the base case represents a situation where refineries have correctly anticipated the level of demand for conventional fuels. The figures thus pertain to the additional "cost" that would have been incurred by having to produce more. The somewhat lower figure for diesel reflects the fact that additional new processes are likely to be efficient.

As refineries tend to adapt to the market as it develops rather than over-invest, we believe these latter figures are the most relevant. Accordingly we have proposed to use 0.08 and 0.10 MJ_{ex}/MJ_f and 7.0 and 8.6 g CO_2/MJ_f for gasoline and diesel fuel respectively.

It must be realised that the outcome of such an analysis is still dependent on a number of assumptions particularly with regard to the base case and the actual level of demand compared to the production capacity. Clearly a reduction of gasoline demand below general expectations could lead to very small energy savings.

Our base case includes a certain amount of diesel imports and it could be argued that these will be the first one to be substituted. Reality is likely to be more complex and some imports will undoubtedly still take place with or without alternative diesel sources. In any case, imported diesel will be made in non-European refineries, the level of complexity and conversion of which will have to be similar to the

European ones inasmuch as the demand for residual products relative to lighter ones is globally decreasing. The energy and GHG emissions figures associated to this production would be at most similar to European figures or more likely lower as such refineries would produce a more balanced product basket. By using the European figures we therefore err on the conservative side.

There are further sources of uncertainty that may materially affect our results:

- Although our model includes a number of safeguards to avoid over-optimisation, there is a real possibility that actual refinery operations will be sub-optimum. As this would affect both the base case and the alternative cases in a similar way it does not materially affect the differential numbers.
- Historically, European refineries have improved their energy efficiency by about 1% per year. We have assumed this trend will continue a/o under pressure of site CO_2 emissions limitations. The effect of a change to this assumption would be small compared to the variability of the figures shown in the figures above.
- Refineries traditionally use part of their crude intake as fuel, in the form of gases produced in various process units, coke produced internally in the FCC supplemented by liquid (mainly residual) fuel. Some refineries have replaced part or all their liquid fuel by imported natural gas usually to meet local SO_2 emissions regulations. This trend has the potential to increase somewhat in the future either because of increased pressure on SO_2 emissions or actions to reduce site CO_2 emissions. Such a change would not impact energy efficiency figures, but would slightly reduce CO_2 emissions. Again the effect is small compared to other sources of variability.

European Commission

EUR 24952 EN – Joint Research Centre – Institute for Energy
Title: Well-to-Wheels Analysis of Future Automotive and Powertrains in the European Context
Author(s): R. Edwards, J-F. Larivé, J-C. Beziat
Luxembourg: Publications Office of the European Union
2011 – 10 pp. – 21 x 29.7 cm
EUR – Scientific and Technical Research series – ISSN 1831-9424
ISBN 978-92-79-21395-3
doi:10.2788/79018

Abstract
WELL-TO-WHEELS ANALYSIS OF FUTURE AUTOMOTIVE FUELS AND POWERTRAINS IN THE EUROPEAN CONTEXT

The JEC research partners [Joint Research Centre of the European Commission, EUCAR and CONCAWE] have updated their joint evaluation of the well-to-wheels energy use and greenhouse gas emissions for a wide range of potential future fuel and powertrain options.

This document reports on the third release of this study replacing Version 2c published in March 2007.

The original version was published in December 2003.

How to obtain EU publications

Our priced publications are available from EU Bookshop (http://bookshop.europa.eu), where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents. You can obtain their contact details by sending a fax to (352) 29 29-42758.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

EUROPEAN COMMISSION

LB-NA-24952-EN-N

Publications Office