The JEC Well-to-Wheels Study

The JEC's Well-to-Wheels report has been updated with new results on biofuel production pathways.

In 2000, when the 'JEC' Consortium was formed (see the box on page 7), the first area identified for joint research was the 'cradle-to-grave' comparison of conventional and alternative road fuels and powertrains in Europe. In those early days, 'Well-to-Wheels' (WTW) was a comparatively new concept, requiring new data and new approaches. It was also an excellent starting point for the JEC's scientific and technical studies in areas of common interest.

Thus, the JEC WTW Study was conceived with little expectation that, ten years later, it would still be relevant and providing a scientific benchmark for evaluating future fuel, vehicle and energy options. At the start, the objectives of the JEC study were to:

- assess the WTW energy use and associated greenhouse gas (GHG) emissions for a wide range of automotive fuels and powertrains that were expected to be important to Europe; and
- assess the viability of each of these fuel pathways including best estimates for the associated macroeconomic costs.

While the WTW Study integrated results from 'cradle to grave', companion reports separated the WTW results into two discrete steps: 'Well-to-Tank' (WTT) and 'Tank-to-Wheels' (TTW). These reports, taken together, provided a more detailed understanding of how the energy and GHG differed for fuel production steps (the WTT part) and fuel consumption steps in vehicles (the TTW part).

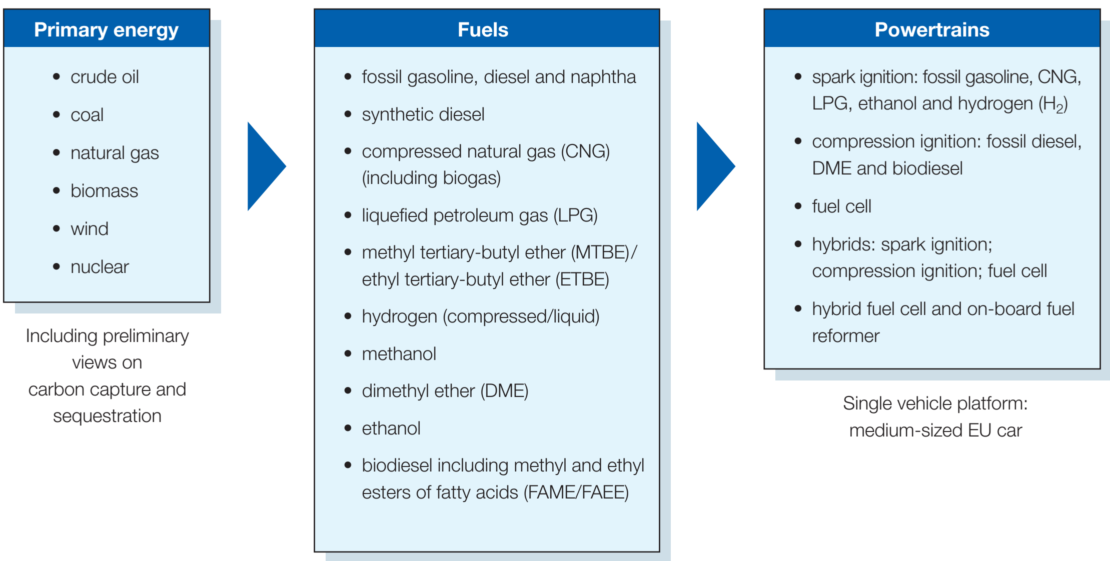
Version 1 of the JEC's WTW Study was published in December 2003 and Version 2 followed in January 2007 with updates to pathways and results. While new TTW results were released in December 2008, the complete Version 3c combining the WTT and WTW parts will be published soon.

This article provides an overview of the WTW studies and a preview of the new or modified results in Version 3c compared to previous versions.

Scope and methodological choices

Figure 1 shows the scope of the JEC WTW Study. Plausible primary energy resources and transport fuels are included as well as vehicle powertrain options such as: internal combustion engines (ICEs) fuelled by liquid fuels, natural gas and hydrogen; various hybrid configurations; and fuel cells (including on-board fuel reformers). Pure battery electric vehicles have not been included in the WTW Study so far and may be addressed in the next revision. The time horizon, which was originally 2010 in earlier versions of the study, has been extended to 2020 for which today's state-of-the-art technologies (both WTT and TTW) are considered to be representative.

Figure 1 Scope of the Well-to-Wheels Study



The JEC's WTW reports are available for free download from the website of the European Commission's Joint Research Centre: http://ies.jrc.ec.europa.eu/about-jec

In general, the fuel pathways and underlying data examined in the study are representative of the European situation. There are some exceptions, such as fuels produced from Brazilian sugar cane or from East Asian palm oil.

The way in which energy and GHG emissions relate to co-products is a critical methodological choice in any WTW study. In the JEC study, we calculate credits or debits associated with co-products based on a 'substitution' method which provides the closest representation of 'real life' practice. 'Substitution' means that co-products from fuel production are credited based on the product that they are most likely to replace, for example, pressings from oil seeds can be substituted for soy meal as animal feed. The downside to this approach is that the WTW results will depend on the specifics of the substitution scenario that is considered, and these must be clearly defined.

For biomass-based fuels, it is now well-recognised that the effect of land use change (LUC), both direct and indirect can, in many cases, significantly affect GHG emissions. Considerable work on LUC effects is in progress by many researchers and governments. However, the JEC Consortium is not yet in a position with Version 3c to provide credible estimates of LUC impacts on GHG emissions, so these are not included in the JEC's WTT results at the present time. The focus has been on specific fuel production chains, and LUC effects related to these chains are being considered as one option for future study.

What is new or changed in Version 3c?

Focusing first on the WTT results, several changes and some additions have been made in Version 3c.

Crude oil production

In earlier versions of this study, GHG emissions associated with crude oil production were reported to be 3.3 gCO_2/MJ (with a range of 2.8–3.9). This value was estimated from an average of results provided by the International Oil Companies (IOCs) dating back to the 1990s. An update to this crude oil production figure was needed because GHG emissions reporting was not as well developed a decade ago as it is today. Recent industry statistics from the International Association of Oil & Gas Producers (OGP), and flaring and venting data collected by the National Oceanic and Atmospheric Administration (NOAA), has provided a more relevant basis.

Using these data, a new estimate for the EU average crude oil supply is reported in Version 3c. This new estimate is 4.8 gCO_2/MJ (with a range of 3.6–6.1), an increase of 1.5 gCO_2/MJ compared to earlier results. This addition to the crude oil production step translates into an increase in the total WTW GHG emissions for gasoline and diesel fuel production to 87.6 and 89.2 gCO_2/MJ, respectively, including CO_2 from fuel combustion. Although these appear to be small changes, they are relevant updates, since fossil products provide the baseline against which new processes for biofuels and alternative energies are compared.

Biofuel pathways: modified data and new options

Since the release of Version 2 in 2007, legislative initiatives in the EU and in North America have provided strong incentives for introducing more bio-blending components into transport fuels. This has resulted in new production data from commercial facilities for many existing biofuel pathways as well as the development of entirely new biofuel pathways.

Figures 2 and 3 summarise the new results from the Version 3c report for selected ethanol and biodiesel pathways. These results are expressed as the percentage savings of both fossil energy and GHG emissions compared to conventional fossil gasoline or diesel fuel, as applicable.

These figures highlight the importance of the biomass source or crop that is used to produce the bio-component as well as the accounting mechanism for co-products and residues. For ethanol, plausible domestic pathways for ethanol production span the entire range from 10% to nearly 100% GHG savings compared to conventional fossil gasoline. For many biodiesel pathways, the GHG balance is particularly uncertain because of the contributions from agricultural nitrous oxide emissions, a potent GHG. Using soy as an example, the effect of nitrous oxide emissions is exacerbated by the large yield of soy meal co-product that must be used for other purposes.

Figure 2 New results for selected ethanol pathways

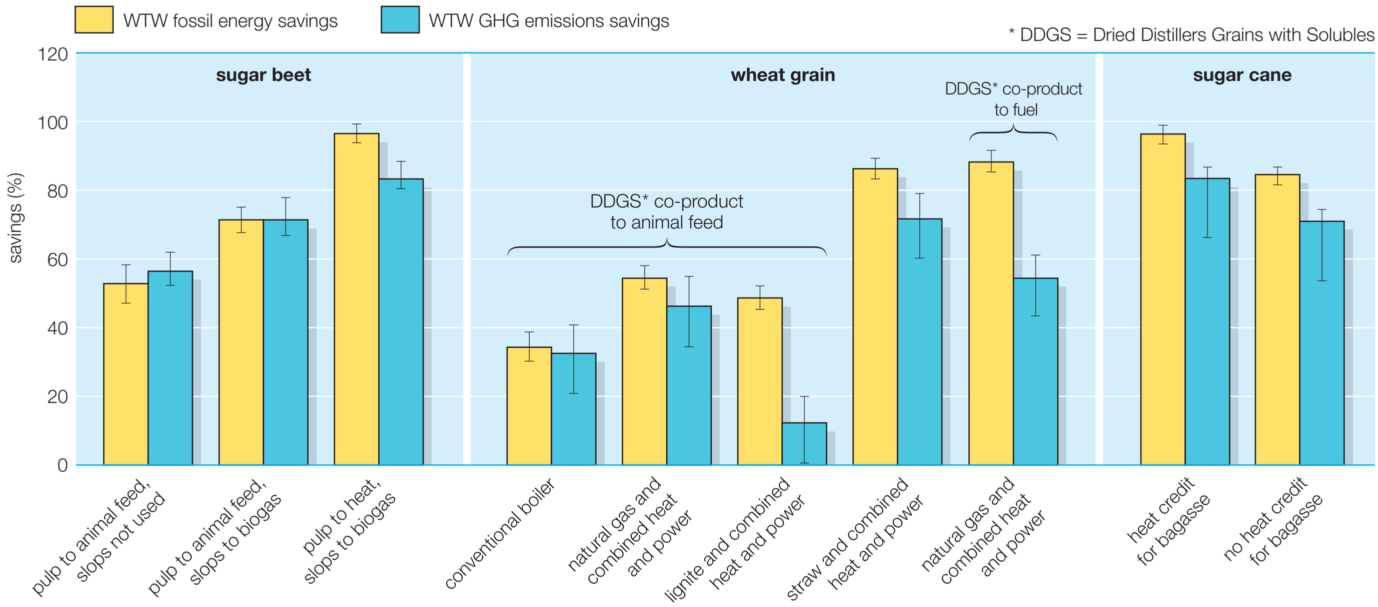
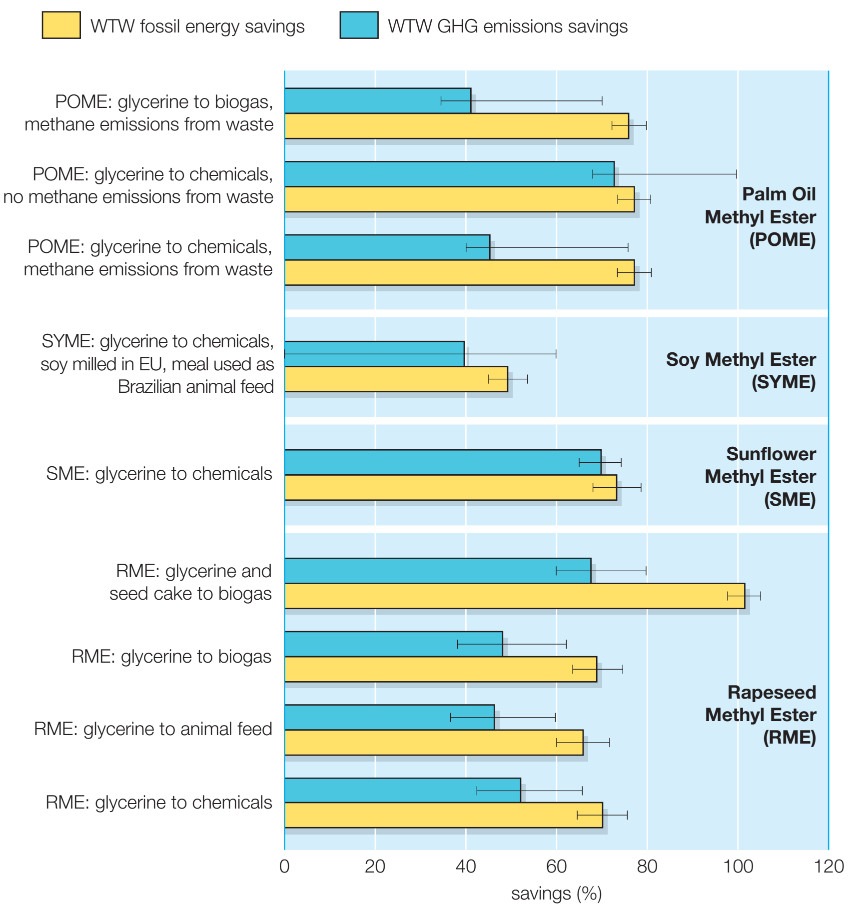


Figure 3 New results for selected biodiesel pathways



Hydrotreated vegetable oil (HVO) processes are an attractive way to produce high-quality hydrocarbons from vegetable and animal oils. For a given vegetable oil, Figure 4 shows that different pathways to produce HVO and biodiesel are very close in terms of their overall GHG savings potential. Two different HVO technologies considered in Version 3c (NExBTL from Neste Oil and a pyrolysis oil technology offered by Honeywell UOP) are essentially equivalent for GHG savings.

Version 3c also includes new data for pathways to produce biogas from dedicated crops rather than from waste material.

Heat and power

Previous versions of the study included electricity production pathways that were then used as inputs to many of the fuel pathways that require electricity in the production process. Continuing this approach, Version 3c now includes heat production pathways, both at domestic and industrial scales, as well as several combined heat and power (CHP) approaches.

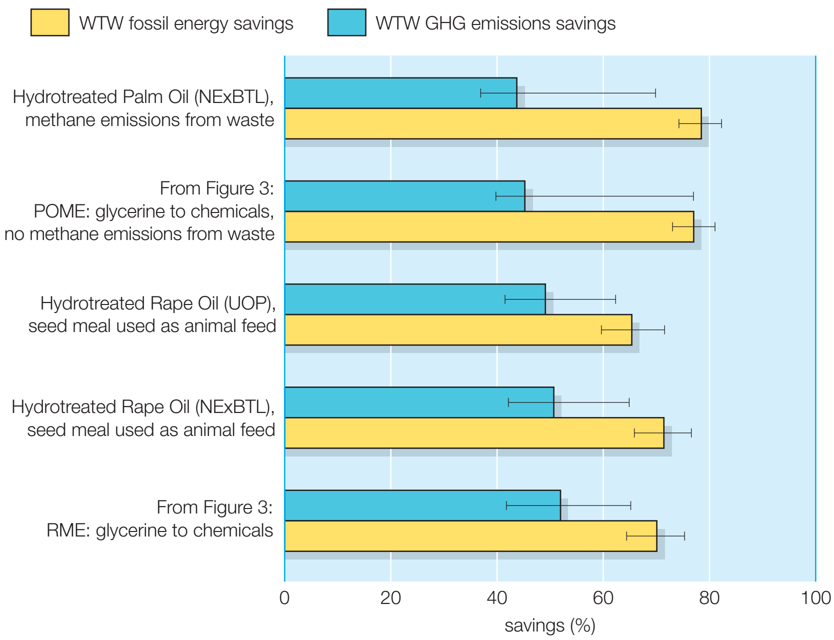
Tank-to-Wheels

For the TTW results, the assumed vehicle performance characteristics have been updated. The primary change is that the gap in engine efficiency between gasoline and diesel ICEs has been extended in time. This reflects a slower than expected narrowing of the efficiency difference between these engine types over the past ten years.

Where next?

Clearly, the WTW approach has proven to be a valuable scientifically-based tool for comparing and contrasting the energy, GHG, and cost performance of different fuel and vehicle options. The speed with which the WTW approach has matured has been dramatic. Both within the JEC Consortium and among the international research community, substantial work is in progress so that important energy and GHG-related decisions can be made more quickly and reliably on a 'well-to-wheels' basis.

Figure 4 Oil seed pathways to FAME and Hydrotreated Vegetable Oil



What is the JEC Consortium?

If you have heard of the 'JEC Consortium' before, it is most likely through work related to the development of the Well-to-Wheels (WTW) methodology and results. Although this is still a central part of the JEC Consortium's work, the scope of its activities has grown considerably over the years.

In 2000, CONCAWE recognised the importance of joining forces with the European Council for Automotive R&D (EUCAR) and the Joint Research Centre (JRC) of the European Commission on topics of common interest. The 'JEC Consortium' formed by these three partners was designed to pursue scientific and technical studies in evolving areas of road transport. A Scientific Advisory Board consisting of senior managers and researchers from all three organisations is responsible for agreeing on the scope of new projects and stewarding the completion of results.

One of the first technical areas identified by the Consortium was the development of scientifically robust tools for comparing different combinations of vehicles and fuels from 'Well-to-Wheels' (WTW), that is, from fuel production to its consumption in vehicles. It was quickly recognised that experimental measurements could not provide all of the answers on the energy requirements and GHG emissions for new vehicle and fuel technologies, and that new approaches would be needed.

The JEC's WTW work has stood the test of time with Version 3c of the WTW Report to be published in 2011, and work already in progress on Version 4. The JEC approach has also been recognised by the European Commission as a 'sound science' way to value different biofuel manufacturing pathways and products, and served in 2009 as an important input into European legislation on renewable and alternative fuel products for energy use.

Although WTW has been its most visible work product, the JEC Consortium has pursued research in other areas as well. Vehicle studies have focused on evaporative emissions, fuel consumption, and regulated emissions from ethanol/gasoline mixtures. The Consortium also recently published results of the 'JEC Biofuels Study Programme', a project to assess the challenges associated with possible biofuel implementation scenarios to achieve the 2020 targets and objectives of the EU's Renewable Energy and Fuels Quality Directives.

Most importantly, all of the JEC's work is published on the Joint Research Centre's website and is freely available for download, review, and critique by interested researchers and organisations. The Consortium members monitor an email address (infoJEC@jrc.ec.europa.eu) for those who have questions or find technical errors in the published work that should be corrected in future revisions.