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# SULTAN modelling to explore the potential contribution of bioethanol to EU transport GHG reduction in 2030

Report for ePURE

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# Executive Summary

The EU's climate and energy policy framework for 2030, which has been agreed by Member States (MS), sets an economy-wide greenhouse gas (GHG) reduction objective of 40% compared to 1990 levels by 2030. This objective is split between the ETS (Emissions Trading System[1]) and non-ETS sectors and translates to a reduction of 30% for non-ETS sectors by 2030 (versus 2005).

ePURE commissioned Ricardo-Energy & Environment to build upon previous work Ricardo carried out for the European Climate Foundation (ECF) and the European Commission using the SULTAN model to give a high level assessment of the potential contribution of bioethanol to reduction in EU transport GHG emissions in the 2030 context:

In this new work for ePURE the objective was to explore the potential impacts of a possible alternative bioethanol deployment pathway, focused on the introduction of E20[2] (high octane) fuel and vehicles with engines optimised to run more efficiently on this fuel. This required the development a series of additional scenarios in SULTAN, including the following:

1. Exploration of a revised baseline scenario without any biofuel use;
2. Exploration of the contribution of advanced low-carbon biofuels up to 2030 following current trends;
3. Exploration of the contribution of E20-optimised vehicles and increased use of bioethanol.

In both of the alternative biofuels scenarios modelled, the rate of growth in biofuel use between 2020 and 2030 is significantly lower than between 2010 and 2020, so remains within the current sustainability constraints.

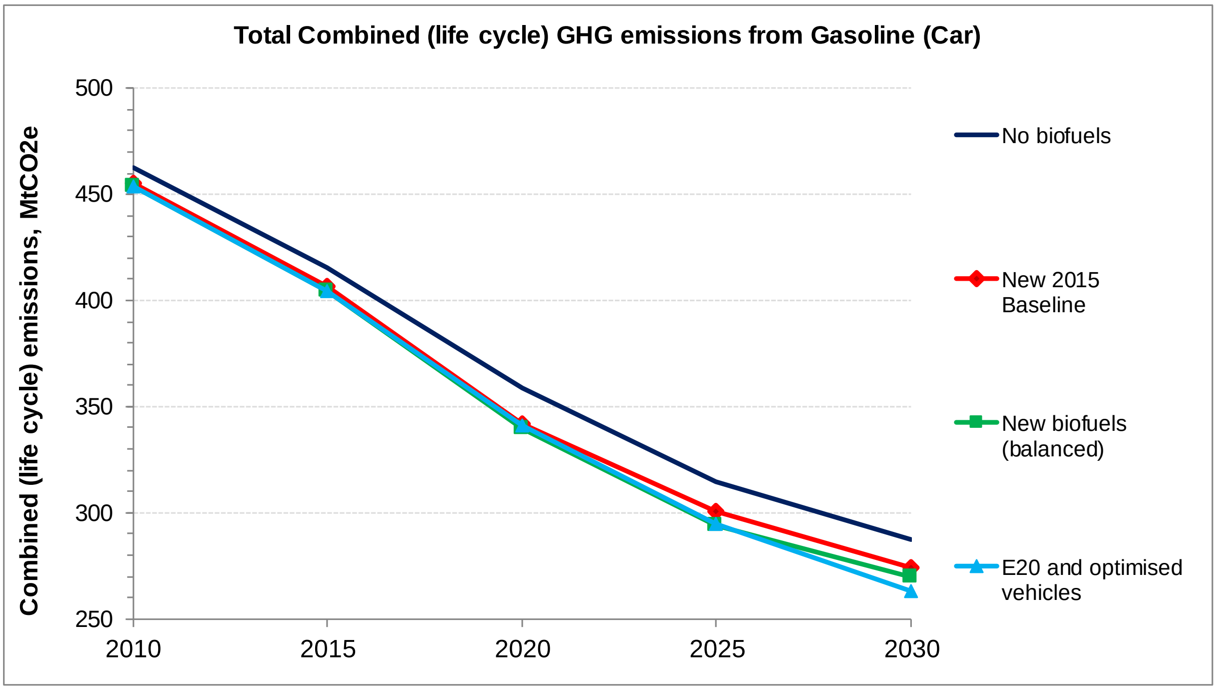
The results from the modelling analysis show that, even accounting for estimates of additional land use change GHG emissions (ILUC), the use of biofuels results in significant well-to-wheel (WTW) GHG reductions compared to the use of conventional fossil/oil based fuels. Bioethanol shows significantly higher savings in comparison to biodiesel, when including estimates for land use change (LUC), and increasing the share, beyond 2020 levels, further reduces GHG emissions. Other measures would certainly need to be implemented to reach 2030 decarbonisation objectives if bioethanol share is not increased, as was also explored in other recent SULTAN modelling work (Ricardo Energy & Environment, 2016). The use of bioethanol contributes to a 14.1% GHG savings in the transport sector by 2030 from 2005 in the E20 scenario (compared to a 9.3% saving with no biofuels at all).

Specifically, with regards to bioethanol, the results of the analysis clearly show additional benefits of an E20 optimised pathway in comparison to the previously modelled 'balanced biofuel uptake' pathway, let alone the "no biofuels" scenario. This is due to a combination of effects: the relatively low ILUC of conventional (1G) bioethanol, and the improved efficiency benefits of E20 optimised vehicles resulting in lower net fuel consumption. The ILUC impact of 1G bioethanol (based on the GLOBIOM modelling work) has relatively little impact on the results, in contrast to that for biodiesel, which results in a significant erosion in GHG savings when it is included. The following Figure ES1 also illustrates that the E20 scenario more than doubles the GHG savings (from ~1.8% to 4.0%) in 2030 from the previous 'balanced biofuel' scenario versus the baseline scenario.

In conclusion, therefore, it would seem worthwhile that the deployment of high-octane E20 fuel and vehicles with E20 optimised engines should be further explored by policymakers in considering the suite of options available for reducing transport's emissions in the context of both medium-term 2030 GHG reduction objectives, as well as longer-term objectives for 2050.

[1] http://ec.europa.eu/clima/policies/ets/index_en.htm
[2] Fuel containing 20% ethanol on a volumetric basis

**Figure ES1: Time series for WTW GHG emissions for various scenarios in comparison to the no biofuels scenario for petrol cars (including ILUC)**



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# Table of abbreviations

| Abbreviation | Description |
|---|---|
| 1G | First generation [biofuels produced mainly from crop based feedstocks] |
| 2G | Second generation/advanced [biofuels produced mainly from non-feed crop based feedstocks] |
| BAU | Business As Usual |
| BEV | Battery Electric Vehicle |
| CI engines | Compression-ignition engines |
| $CO_2$ | Carbon dioxide |
| E20 | Petrol fuel containing 20% bioethanol on a volumetric basis |
| ECF | European Climate Foundation |
| ESD | Effort Sharing Decision[3] |
| ETS | Emissions Trading System[4] |
| GDP | Gross Domestic Product |
| GHG | Greenhouse gas |
| HDV | Heavy Duty Vehicle |
| ICCT | International Council for Clean Transportation |
| ICE | Internal Combustion Engine |
| ILUC | Indirect Land Use Change |
| LCV | Light Commercial Vehicle |
| LDV | Light Duty Vehicle (i.e. cars and LCVs) |
| LUC | Land Use Change (direct or indirect) |
| MS | Member State (of the European Union) |
| OEM | Original Equipment Manufacturer |
| SI engines | Spark-ignition engines |
| WTW | Well-to-Wheel analysis on a life-cycle basis |

[3] http://ec.europa.eu/clima/policies/effort/index_en.htm
[4] http://ec.europa.eu/clima/policies/ets/index_en.htm

# 1 Introduction

ePURE commissioned Ricardo-Energy & Environment to build upon previous work Ricardo carried out for the European Climate Foundation (ECF) and the European Commission using the SULTAN model to give a high level assessment of the potential contribution of bioethanol to reduction in EU transport GHG emissions in the 2030 context.

Road transport accounts for more than a fifth of the EU's greenhouse gas (GHG) emissions and over two-thirds of its 'domestic' transport emissions. The EU's climate and energy policy framework for 2030, which has been agreed by Member States (MS), sets an economy-wide GHG reduction target of 40% compared to 1990 levels by 2030. This target is split between the ETS (Emissions Trading System[5]) and non-ETS sectors and translates to a reduction of 30% for non-ETS sectors by 2030 (compared to 2005).

The exploration of different scenarios for delivering GHG reductions by 2050 (as well as intermediate objectives) was the subject of the two *'Routes to 2050'* projects undertaken for DG CLIMA between 2009 and 2012. These studies were both led by AEA (now Ricardo Energy & Environment). On the basis of a review and validation of the GHG reduction potential of a range of technical and non-technical options, an illustrative scenarios tool (SULTAN) was developed during these projects, which was used to identify the potential contribution of different options to meeting the long-term GHG reduction target (i.e. 60% reduction in direct emissions from all transport by 2050) (AEA, 2010) (AEA, 2012) . The focus of the second '*Routes to 2050*' project was on identifying in more detail how the 60% GHG reduction target could be met. This was undertaken by the development of various illustrative scenarios in SULTAN that enabled different options for delivering the 60% GHG reduction target to be explored, along with their trade-offs.

Recent work by Ricardo Energy & Environment for ECF further built upon this work in an analysis of an enhanced understanding of the wider potential impacts of transport GHG reduction policies in 2030 (Ricardo Energy & Environment, 2016), in the context of the EU's climate and energy policy framework.

In this new work for ePURE the objective was to explore the potential impacts of a possible alternative bioethanol deployment pathway, focused on the introduction of E20[6] (high octane) fuel and vehicles with engines optimised to run more efficiently on this fuel. The work required the development a series of additional scenarios in SULTAN, including the following:

1. Exploration of a revised baseline scenario without any biofuel use;
2. Exploration of the contribution of advanced low-carbon biofuels up to 2030 following current trends;
3. Exploration of the contribution of E20-optimised vehicles and increased use of bioethanol.

The following sections provide a summary of the work completed under this project.

[5] http://ec.europa.eu/clima/policies/ets/index_en.htm
[6] Fuel containing 20% ethanol on a volumetric basis

# 2 Scenario background and development

## 2.1 The model baseline scenario

The SULTAN reference scenario originally developed for the European Commission (AEA, 2012) covered all transport modes. However, the scope of this work for ePURE is limited to the non-ETS transport sectors (that are also covered by the Effort Sharing Decision), i.e. transport by road, rail and inland waterways only. This baseline was further updated in other recent SULTAN modelling work (Ricardo Energy & Environment, 2016) to take into account changes in the European economy, biofuels policy, and improvements in the understanding of the difference between test-cycle and real-world fuel consumption from LDVs in the last few years. These amendments can be briefly summarised as follows, with the revised SULTAN baseline (BAU-15) shown in Figure 2.1, in comparison to the original baseline developed for the European Commission (black line marked “BAU” – business as usual). The updating of the baseline was discussed in greater detail in (Ricardo Energy & Environment, 2016) and included the following changes:

- Adjustment for revised activity growth forecasts (reflecting reduced economic growth/activity);
- Adjustment for biofuels to lower forecast uptake rates and include accounting for ILUC (indirect land use change);
- Revisions to assumptions on real-world vs test-cycle $CO_2$ emissions (reflecting larger discrepancies than originally estimated);
- Amendments to the survival rate function across all vehicle types (reflecting a lower rate of fleet turnover).

A summary of the significance of the impact on future transport GHG emissions for 2030 in the revised SULTAN baseline, compared to the previous baseline, is shown in Table 2.1 below.

**Figure 2.1: Updated SULTAN baseline scenario (BAU-15) in comparison to the original baseline (BAU)**

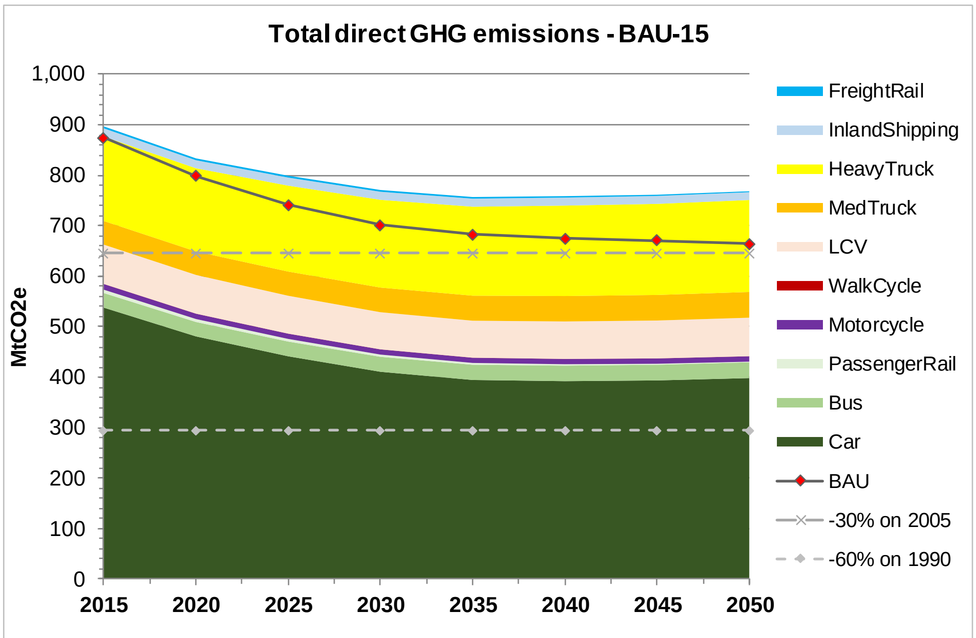



**Table 2.1: Summary of the action of different elements on the SULTAN baseline scenario**

| Baseline revision | GHG impact in baseline |
|---|---|
| Adjustment of activity based on change in GDP forecasts for EU | ↓ |
| Amendment to the assumptions for baseline biofuel use, ILUC | ↑ |
| Revision to the assumed real-world energy consumption of LDVs | ↑↑ |
| Amendments to the survival functions for all vehicle types | ↑ |

### 2.1.1 Biofuels in the baseline/business as usual (BAU) scenario

In 2015 the EU made a decision to cap crop-based biofuels at 7% of energy consumption from transport and also set a non-binding 0.5% sub-target for advanced low-ILUC biofuels (European Commission, 2015a). Currently there are no further requirement or proposals on the further deployment of biofuels post-2020.

There is currently high uncertainty over the GHG benefits of 1G (conventional or 1st generation) biofuels produced from crop based feedstocks (in particular biodiesel), especially with regard to ILUC (indirect land use change). Therefore two scenario variants for 1G biofuels were developed as part of the previous work (Ricardo Energy & Environment, 2016): one for the baseline/business as usual (BAU) scenario, and one for a 'New biofuels' scenario.

In the baseline scenario, the share of 1G crop-based biofuels <u>on an energy basis</u> was assumed to increase from the 2015 level (bioethanol at ~3.4% of petrol demand and biodiesel at ~5.3% of diesel demand) to 7% overall in 2020, with no further expansion thereafter. Advanced waste-based biofuels (with essentially zero ILUC) were assumed to reach a share of 0.5% in 2020, and held constant thereafter up to 2050.

ILUC was also included in the updated baseline at levels taken from the updated Renewable Energy Directive (RED) demonstrated by recent modeling (European Commission, 2015a), (EC JRC/IFPRI, 2014) (i.e. ~12.5 $gCO_2e/MJ$ for bioethanol from cereals and sugar feedstocks, and 55 $gCO_2e/MJ$ for biodiesel from oil crops).

It should be emphasised that ILUC inclusion only affects the assessment of emissions on a Well-to-Wheel basis (and that the EU ESD (Effort Sharing Decision) only takes account of direct emissions within Europe (European Commission, 2016)). These emissions are therefore not fully accounted for in national inventories under the EU ESD, which only measure direct emissions, and will not account for emissions outside of the EU.

In the current project for ePURE, the assumptions for (indirect and direct) land use change (LUC) have been updated based on more recent GLOBIOM modelling results (Ecofys/IIASA/E4tech, 2016) that were not publically available when other SULTAN modelling work was completed earlier this year (Ricardo Energy & Environment, 2016). These results are summarised in Figure 2.2 below, from the final report, which illustrate the range of estimates for different biofuel feedstock types. It is worth emphasising that these estimates are for land use change resulting from additional biofuel deployment versus the 2010 baseline (as did the earlier IFPRI analysis), and as such are not necessarily representative of any LUC resulting from the deployment of biofuels up to 2010 levels. In contrast, the estimates provided in the RED, which are significantly lower, are to be applied to all biofuels at all levels of deployment. (This is also discussed further in later Section 2.2.3).

In order to calculate the GHG emissions resulting from LUC on the basis of the GLOBIOM work, it was necessary to account for two elements[7]:

i. The relative share of biofuel supply from different feedstocks;
ii. The increase in the use of these feedstocks versus 2010 levels.

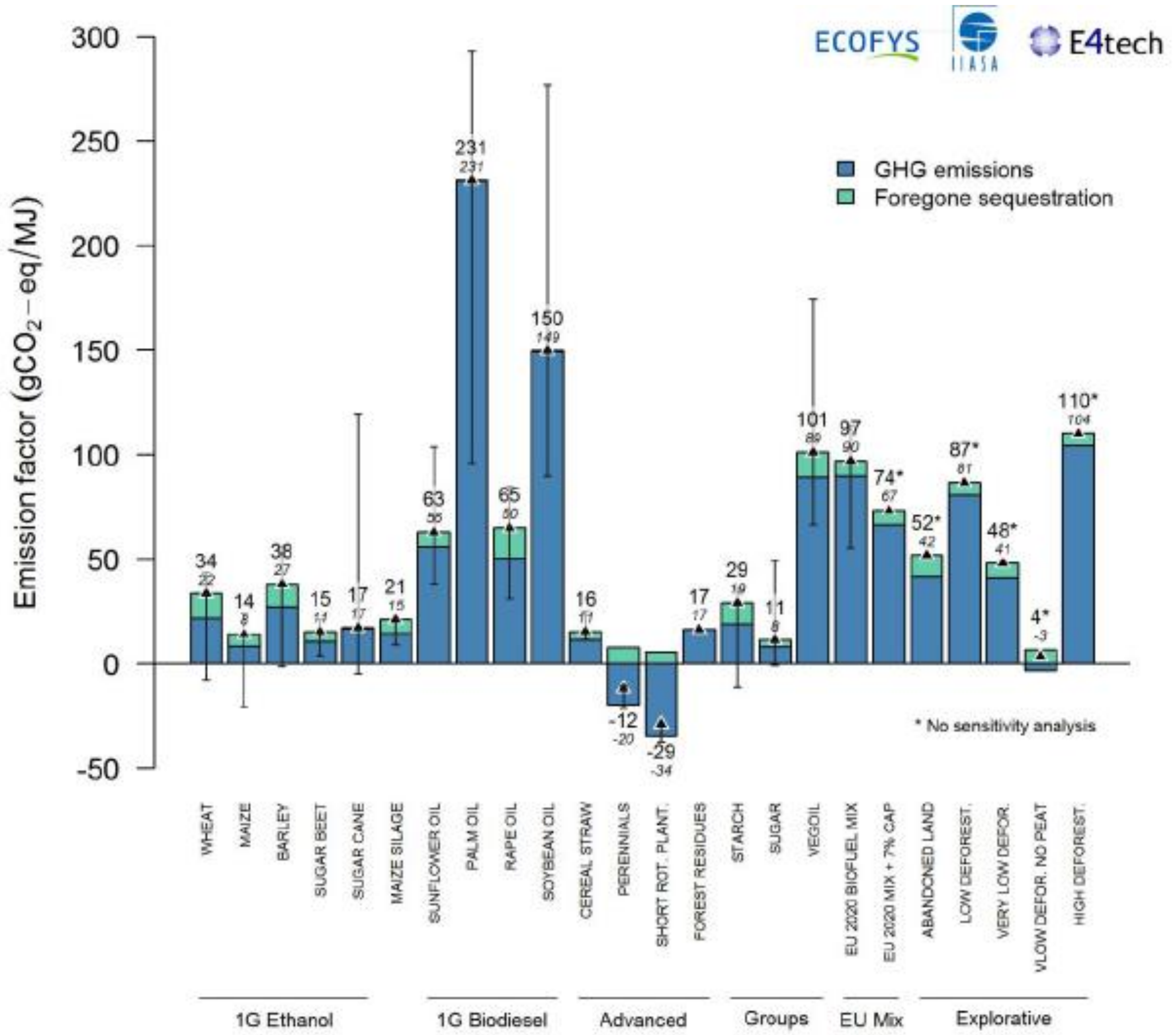
The overall level of biofuel use (in PJ) is an output from the SULTAN model for different periods (based on the assumed biofuel substitution share, and the effects of changes in the efficiency of vehicles and relative powertrain shares). The GLOBIOM modelling work (Ecofys/IIASA/E4tech, 2016) provides the assumptions on the relative shares of different feedstocks for 2010 and 2020. However, ePURE was able to provide more accurate industry data on the shares of different feedstocks for EU-supplied biofuels up to 2015, which was used to derive a revised extrapolation for 2020 onwards, as presented in Table 2.2 below.

These estimates were used to derive the feedstock-weighted average LUC emission factors for bioethanol and for biodiesel, which are presented in Table 2.3 in comparison to the equivalent values included in the RED. It is assumed that the mix of different feedstocks used for advanced biofuels

[7] Note: the GLOBIOM report (Ecofys/IIASA/E4tech, 2016) does not include advice on how the factors should be applied, so this is an interpretation on the appropriate use of these figures based on the information available.

results in a net zero emission factor (some are positive and some are negative in Figure 2.2 below), in the absence of better information.

**Figure 2.2: Overview of modelling results: LUC emissions per scenario with and without foregone sequestration and with uncertainty ranges (bars indicate the range within the first and the last decile).**




*Source*: GLOBIOM, (Ecofys/IIASA/E4tech, 2016)

**Table 2.2: Estimated EU bioethanol consumption by feedstock**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Extrapolation 2020+ |
|---|---|---|---|---|---|---|---|
| Corn based | 28.1% | 44.8% | 44.0% | 36.5% | 37.8% | 37.8% | 45.1% |
| Wheat based | 31.4% | 28.3% | 24.1% | 24.9% | 29.8% | 29.2% | 27.1% |
| Sugar beet based | 17.7% | 12.6% | 18.0% | 18.1% | 16.4% | 18.1% | 18.5% |
| Sugarcane based | 11.7% | 6.3% | 6.5% | 12.2% | 7.2% | 5.2% | 1.0% |
| Others | 11.1% | 8.1% | 7.5% | 8.2% | 8.9% | 9.7% | 8.2% |

*Source*: for the period 2010-2015: feedstock mix processed in Europe supplied by ePURE, with imports estimated based on Eurostat; extrapolation for 2020 onwards is by Ricardo for the study analysis.

**Table 2.3: Estimated land use change emission factors, $gCO_2e/MJ$**

| | GLOBIOM basis | | | | | RED basis |
|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2025 | 2030 | All periods |
| **Bioethanol** | | | | | | |
| Corn based | | | 14 | | | 12 |
| Wheat based | | | 34 | | | 12 |
| Sugar beet based | | | 15 | | | 13 |
| Sugarcane based | | | 17 | | | 13 |
| Others based (assume barley) | | | 38 | | | 12 |
| **Weighted Average for 1G (1),*** | **0.0** | **1.7** | **10.4** | **11.5** | **12.5** | **12.2** |
| Advanced feedstocks for 2G/waste | | | 0 | | | 0 |
| **Biodiesel** | | | | | | |
| *Sunflower oil* | | | 63 | | | 55 |
| *Palm oil* | | | 231 | | | 55 |
| *Rape oil* | | | 65 | | | 55 |
| *Soybean oil* | | | 150 | | | 55 |
| **Weighted Average for 1G (2),*** | **0.0** | **38.7** | **65.3** | **65.9** | **66.1** | **55** |
| Advanced feedstocks for 2G/waste | | | 0 | | | 0 |

*Source*: GLOBIOM basis land use change emission factors (including foregone sequestration) are from (Ecofys/IIASA/E4tech, 2016). RED indirect land use change factors are from the RED. Other factors are calculated based on other study data and assumptions.

*Notes*: * In terms of the GLOBIOM modelling LUC emissions are calculated relative to pre-existing biofuel deployment in 2010, hence emission factors for 2010 biofuels are zero; (1) based on feedstock mix provided in Table 2.2; (2) based on feedstock mix information provided in (Ecofys/IIASA/E4tech, 2016).

## 2.2 Definition of individual biofuel use scenarios

A range of individual scenarios were developed previously as part of the *'Routes to 2050'* projects for DG Climate Action (AEA, 2010) (AEA, 2012), which were further updated to an extent in other recent SULTAN modelling work for ECF (Ricardo Energy & Environment, 2016). This latest work included only a single scenario on the potential for GHG savings due to biofuels, as mentioned earlier.

As part of this new work for ePURE, three alternative scenarios were developed reflecting different degrees of biofuel deployment. The assumptions for these scenarios were defined and agreed in discussion with ePURE and validated by Ricardo experts in biofuels and in engine technologies. The objective of this new work was to explore what different scenarios might contribute to reducing transport emissions, as well as to what extent they might contribute to achieving the overall 30% reduction target for all non-ETS sectors.

These scenarios were built based on a range of assumptions, which are further discussed in the following report subsections, and summarised the following Table 2.4.

The assumptions for biofuels in the updated baseline have already been summarised in the previous Section 2.1.1, and the 'no biofuels' scenario simply assumes zero biofuel deployment in an otherwise unchanged baseline scenario. The following subsections provide a summary of the definition of the remaining alternative scenarios, and the evidence upon which the modelling input assumptions are based. In addition, alternative variants of the baseline scenario, and other scenarios were also run assuming zero ILUC as a sensitivity on this aspect.

The assumptions on the impacts of LUC have set to be consistent between these scenarios and the updated baseline scenario. In addition, the rate of growth in biofuel use between 2020 and 2030 for scenario 2 and 3 is significantly lower than between 2010 and 2020, so remains within the current sustainability constraints.

**Table 2.4: Overview of the modelled scenarios**

| Scenario # and name | | Summary of scenario definition |
|---|---|---|
| **1** | **No biofuel use** | This scenario provides an alternative baseline, without any biofuel deployment, to enable an illustration of the overall GHG impacts of biofuel deployment for the other scenarios. |
| **2** | **Balanced biofuel uptake** | This scenario is based on that previously developed in (Ricardo Energy & Environment, 2016), with biofuel substation increasing to 9% by 2030, relative substitution rates of bioethanol and biodiesel similar to current trends and increased use of low-ILUC fuels. |
| **3** | **E20 fuel and optimised vehicles** | This scenario assumes a similar overall level of biofuel substitution (i.e. 9%) and a similar increase in low-ILUC 2G/waste-derived fuels as for the 'balanced biofuel uptake' scenario, but instead sees a greater level of bioethanol use via the deployment of E20 optimised passenger cars and wide availability of high-octane E20 by 2030. |

### 2.2.1 Balanced biofuel uptake ('New biofuels' scenario)

As referenced in Section 2.1.1, the first new biofuels scenario is based on a balanced uptake of different types of biofuel extrapolating from the baseline/historic trends, and was slightly adapted from that produced in other recent SULTAN modelling work (Ricardo Energy & Environment, 2016). This scenario was defined on the following basis:

(a) 1G crop-based biofuels were held constant at their 2015 levels, with no further increase assumed;

(b) In total, the "Balanced biofuel uptake" scenario assumes a combined 9% share (by energy, i.e. as a percentage of total petrol and diesel use) of biofuels and low-carbon liquids in 2030, and that the share is balanced between biodiesel and bioethanol.

(c) It is assumed that the growth in biofuel use from the current use/substitution levels (~4.5% in 2015, as shown in Table 2.5) will avoid ILUC through the introduction and implementation of EU policies to promote sustainable low-carbon liquid fuels (e.g. waste-based fuels, 2G biofuel or low-carbon synthetic fuels). This is consistent with the findings of the "Wasted" study produced for ECF, which considered the potential sustainable availability of wastes and residues in 2030 (ECF, 2014);

(d) ILUC values have been updated (from the RED based values used previously) to be based on those from the more recent GLOBIOM study (Ecofys/IIASA/E4tech, 2016), as they have also for the baseline scenario and the E20 fuel and optimised vehicles scenario.

The following Table 2.5 provides a summary of the key definition parameters for this scenario, plus an indication on the resulting volumes of biofuel output.

**Table 2.5: Key assumptions for Scenario BioF_2030: Balanced biofuels deployment**

| Biofuel | Conventional | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| % conventional fuel substituted | | | | | | |
| Bioethanol | Petrol | 3.0% | 3.4% | 7.5% | 8.3% | 9.0% |
| Biodiesel | Diesel | 4.4% | 5.3% | 7.5% | 8.3% | 9.0% |
| **Total** | **All** | **3.8%** | **4.5%** | **7.5%** | **8.3%** | **9.0%** |
| 2G/biowaste sources as a % total biofuel use | | | | | | |
| Bioethanol | Petrol | 0.0% | 0.0% | 54.7% | 64.6% | 62.2% |
| Biodiesel | Diesel | 0.0% | 0.0% | 29.9% | 31.3% | 41.6% |
| **Total** | **All** | **0.0%** | **0.0%** | **38.8%** | **42.2%** | **48.0%** |

| Biofuel | Conventional | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Total amount of biofuel used, PJ | | | | | | |
| Bioethanol | Petrol | 165 | 168 | 323 | 363 | 311 |
| Biodiesel | Diesel | 325 | 400 | 579 | 595 | 694 |
| **All biofuels** | **All** | **490** | **567** | **902** | **958** | **1,005** |

### 2.2.2 E20 fuel and optimised vehicles

One of the key objectives of this work was to explore the potential impacts of an alternative biofuel uptake scenario, focused on the potential benefits of rapid deployment of E20 (high-octane) fuel and engines optimised to run more efficiently using it.

Recent research funded by the European Commission has also found that there are significant additional fuel-efficiency benefits that might be unlocked by petrol-fuelled vehicles optimised to run on higher ethanol blend fuels (DCL, 2013) (TU Wien IFA, 2014) (CE Delft/TNO, 2013). It has been suggested that E20 optimised vehicles offer the right balance of benefits versus relatively low additional costs to make such vehicles, and a number of manufacturers have indicated their intention to produce such vehicles should the fuel be made available. Already many vehicles (such as from Volkswagen) are compatible with E20 fuels, but are not yet optimised to achieve the additional efficiency improvements.

To achieve the full efficiency benefits such fuels should be blended to achieve the naturally higher octane levels versus unblended fuels. *However*, current fuel blends up to E10 from fuel suppliers are generally blended to meet the same minimum RON (research octane number) requirements of unblended fuels, so most of the benefits would not be seen. Should special E20 (or higher) grades be made available in the future, it may therefore require suitable specific fuel quality standards (requiring higher minimum octane levels) to ensure/guarantee the full benefits could be attained. It should be noted that there would also be infrastructure and supply challenges to overcome in making such a fuel grade widely available.

It is to be anticipated that some of the additional efficiency benefits of running E20 optimised vehicles versus diesel vehicles running similarly high HVO- or BtL-type biodiesel fuels would be eroded by the higher efficiency of diesel vehicles. However, the gap in efficiency between petrol and diesel vehicles is anticipated to further narrow in the coming years, and diesel vehicles are also facing their own challenges concerning air quality pollutant emissions currently in the widening ‘dieselgate’ scandal. Therefore, it was deemed worthwhile to investigate the potential impacts of an alternative biofuel deployment scenario focused on the deployment of E20 and optimised vehicles, especially given the much greater GHG emissions impacts estimated due to land use change emissions for conventional biodiesel feedstocks in comparison to those for bioethanol.

In the developed scenario it is assumed that E20-optimised petrol engines could be made widely available in new passenger cars from 2023, with wide availability of E20 fuel for use in these vehicles by 2030. These assumptions have been checked/validated as technically feasible in discussion with Ricardo’s engineering and biofuels experts.

The other specific assumptions used to define the scenario are summarised in the Table 2.6 and Table 2.7 below. The developed scenario assumes a relatively conservative 2.8% improvement in the technical efficiency of E20 optimised engines (see Table 2.7), based on an assumption that only some of the increased octane benefits from ethanol blending would be seen in the fuel specification. This is due to the logic above concerning existing practice for E10 fuels which are generally only blended to meet the minimum RON requirements currently. Based on the available research evidence, should the full octane benefits be realised (versus unblended fossil fuel), then even greater efficiency improvements might be achieved.

**Table 2.6: Key assumptions for Scenario E20-opt: E20 optimised vehicles and biofuel deployment, part 1**

| Biofuel | Conventional | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Impact on new vehicle efficiency (+ve = improvement): | | | | | | |
| Cars | Petrol | 0.0% | 0.0% | 0.0% | 2.8% | 2.8% |
| % of optimised vehicles using E20: | | | | | | |
| Cars | Petrol | 0.0% | 0.0% | 0.0% | 100.0% | 100.0% |
| % new vehicles equipped: | | | | | | |
| Cars | Petrol | 0.0% | 0.0% | 0.0% | 100.0% | 100.0% |
| % total vehicle fleet equipped for E20 (result from SULTAN stock model): | | | | | | |
| Cars | Petrol | 0.0% | 0.0% | 0.0% | 17.4% | 44.9% |

*Notes*: PHEVs are assumed to only obtain 70% of the benefits of conventional ICEVs and HEVs, due to the share of their operation running on grid electricity.

The ethanol substitution rate for the scenario has been designed to follow the share of E20 optimised cars that are available in the total vehicle fleet to use it, based on the SULTAN stock model and the assumed year of introduction. This provides a limit to the total percentage substitution rate of ethanol used (although there will also be a share of non-optimised vehicles also able to use the fuel). These substitution rates are also consistent with other research carried out for ePURE (E4tech, 2016).

It is worth noting that to reach the level of ethanol indicated and the shares indicated for 2G/waste-based feedstocks, the question becomes: could bioethanol be produced at this level from wastes/residues/sustainable crop feedstocks? Certainly this would appear to pose some challenges, but it may be feasible given an appropriate level of support and a new approach to facilitate more rapid development and commercial deployment of 2G cellulosic biofuel production.

The recent land use change modelling carried out to date has indicated that the GHG impacts from crop-based feedstocks for bioethanol are significantly lower than those for biodiesel. Therefore, the scenario has also been designed on the basis that waste streams and 2G production will be first focused on replacing higher ILUC biodiesel sources, in order to minimise overall WTW GHG emissions. Since diesel use is roughly double that of petrol in Europe, a 1% increase in the percentage substitution for bioethanol can be roughly balanced by a 0.5% reduction in that of biodiesel (i.e. for no net change in total biofuel energy used). Therefore, in comparison to the 'balanced biofuel uptake' scenario, significantly higher shares of ethanol substitution are achieved through roughly maintaining the substitution rate for biodiesel between 2020 and 2030, as illustrated in Table 2.7 below. The *share* of bioethanol in petrol is assumed to reach 11.7% by 2030 from 7.5% in 2020, however in terms of total *energy consumption* the increase is much less (rising to 400 PJ by 2030, from 323 PJ in 2020) due to an overall decline in the consumption of petrol mainly due to improvements in vehicle efficiency.

**Table 2.7: Key assumptions for Scenario E20-opt: E20 optimised vehicles and biofuel deployment, part 2**

| Biofuel | Conventional | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| % conventional fuel substituted | | | | | | |
| Bioethanol | Petrol | 3.0% | 3.4% | 7.5% | 9.6% | 11.7% |
| Biodiesel | Diesel | 4.4% | 5.3% | 7.5% | 7.7% | 7.8% |
| **Total** | **All** | **3.8%** | **4.5%** | **7.5%** | **8.3%** | **9.0%** |
| 2G/biowaste sources as a % total biofuel use | | | | | | |
| Bioethanol | Petrol | 0.0% | 0.0% | 6.7% | 10.4% | 21.4% |
| Biodiesel | Diesel | 0.0% | 0.0% | 13.3% | 26.1% | 64.1% |
| **Total** | **All** | **0.0%** | **0.0%** | **10.9%** | **21.0%** | **50.9%** |
| Total amount of biofuel used, PJ | | | | | | |
| Bioethanol | Petrol | 165 | 168 | 323 | 362 | 400 |

| Biofuel | Conventional | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Biodiesel | Diesel | 325 | 400 | 579 | 595 | 602 |
| **All biofuels** | **All** | **490** | **567** | **902** | **956** | **1,001** |

### 2.2.3 Summary of key considerations and limitations for the modelling analysis

It is important to note a number of important considerations/limitations for the analysis:

- ***In terms of advanced biofuels:***
  - Although advanced biofuels technologies are close to being commercially available, they are currently progressing slowly and most of the large scale demonstrations in Europe have encountered delays due to technology, policy and financial issues. Advanced bioethanol technologies have been demonstrated in the USA, but it is still difficult to make a commercial plant feasible financially. Some new approach is therefore needed to give the market confidence to invest in these technologies.
  - Advanced technologies rely on the availability of residues or energy crops. There is competition from other bioenergy sectors for the (usually fixed) amount of residues available. More ambitious production levels for advanced biofuels rely on the development of energy crops. Energy crops have also developed very slowly, particularly in Europe.

  Such challenges would need to be overcome in order to enable the scenarios as modelled.
- ***In terms of ILUC:***
  - The ILUC factors are very dependent on which feedstocks are used for biofuel production and how they are sourced, as well as on assumptions about future (growth in the) volumes of biofuels used. In particular, the mix of feedstocks will be heavily dependent on both price and sustainability legislation;
  - LUC GHG factors for biofuels already deployed in 2010 are assumed to be zero for this study, as this is the basis of the GLOBIOM modelling analysis(IFPRI, 2011). In reality there is likely to have been some LUC effect resulting from biofuel deployment. Although it is not possible to provide a robust estimate as to how significant this might be, under the 20 year amortisation period assumed for the analysis the emissions would be zero by 2030, however.
  - ILUC factors also only account for GHG emissions, and may not account for the other environmental impacts of land use change (positive or negative);

  There is still considerable debate on / uncertainty in ILUC values, and significantly different modelling assumptions will therefore have an impact on the overall results in this regard.
- ***In terms of achieving benefits from improved efficiency of E20-optimised vehicles:***
  - In the developed scenario it is assumed that E20-optimised petrol engines are made widely available in new passenger cars from 2023, so that effectively all new vehicles by 2025 are optimised to run on E20. This is technically feasible, but in order for it to be achievable, a strong and early signal (and appropriate policy) would need to be given that E20 fuel would be made widely available in sufficient quantities to make this worthwhile. This could pose something of a challenge, particularly if there was not also support in other regions.
  - In prioritising measures for improving the $CO_2$ performance / efficiency of their vehicles, manufacturers are constantly evaluating the trade-offs in relative cost, performance and utility impacts (positive or negative) for different technical options. It is unclear exactly where this option would fit alongside other options. However, it is understood that the modifications necessary to enable optimised use of E20 are likely to be relatively inexpensive in comparison to other measures. Recent consultation with manufacturers on the potential for this option for EC-funded projects indicates the view is generally supportive of this measure (DCL, 2013).

  In order to achieve the full benefits of the E20-optimised scenario as defined, rapid, positive, EU-wide action would need to be taken. It is unclear to what extent this could be achieved, and whether the cost or practical difficulties in achieving this end would be sufficiently beneficial in comparison to other options.

# 3 Results and conclusions from the scenario modelling analysis

In this section, the results from the SULTAN scenario modelling exercise are presented for the different biofuel deployment scenarios, and a short summary of the key conclusions that might be drawn from the results are also presented for consideration.

## 3.1 Summary of key results

The following Figure 3.1/Table 3.1, Figure 3.2/Table 3.2 and Figure 3.3 provide a summary of the output results from the modelling of the three biofuel scenarios, plus sensitivities for the exclusion of ILUC:

- Figure 3.1 and Figure 3.2 show the trajectories of the WTW GHG emissions for the different scenarios for total non-ETS transport and for petrol passenger cars, respectively.
- Figure 3.3 shows (a) the level of potential reduction in 2005 WTW emissions from the non-ETS transport sector (light blue bars), (b) the level of potential contribution to the overall target of 30% reduction in 2005 emissions from all non-ETS sectors (dark blue bars), and (c) the level of WTW GHG reduction versus no biofuels deployment (orange stripped bars).

These tables and charts show that already in the baseline scenario there are significant reductions in GHG emissions achieved versus the equivalent case where no biofuels were deployed. Figure 3.3 also shows that in all modelled cases that it is anticipated that there will be significant reductions to emissions from transport by 2030, compared to 2005: as much as a 9.3% reduction in WTW transport emissions versus 2005 levels even with no additional biofuels deployed post 2020. The use of bioethanol contributes to a 14.1% GHG saving in the transport sector by 2030 from 2005 in the E20 scenario (compared to a 9.3% saving with no biofuels at all).

The results from these tables and charts also show significant WTW GHG reductions are achieved from scenarios with or without ILUC included: The different biofuel deployment scenarios including ILUC might reduce emissions by between, 2.1% (balanced biofuels) and 3.2% (E20 optimised) of emissions from non-ETS transport relative to the baseline scenario for 2030 (see Figure 3.3, light blue bars), and contribute between 0.8% and 1.2% to GHG emissions reductions from all non-ETS sectors versus 2005 levels (see Figure 3.3, dark blue bars). These results show that additional savings (vs the baseline scenario) for the E20 scenario are around 50% higher than for the balanced biofuels scenario.

As illustrated in earlier Table 2.5 and Table 2.7, both of these biofuels scenarios show rates of growth between 2020 and 2030 that are lower than between 2010 and 2020, so they remain within the current sustainability constraints. For the petrol segment (Figure 3.2/Table 3.2), the E20 scenario more than doubles the GHG savings (from ~1.8% to 4.0%) in 2030 from the previous 'balanced biofuel' scenario versus the baseline scenario. Excluding ILUC, the two biofuel deployment scenarios are closer in terms of GHG reduction levels, however the E20 scenario still results in greater overall GHG emissions reductions in 2030.

Overall, Figure 3.3 also shows that the potential for significant GHG emissions reductions versus the no biofuels scenario is significant for all scenarios including biofuels. This reduction potential has been estimated to rise from 1.7% in the baseline scenario, to 4.0% for the balanced biofuels scenario, and up to 5.2% for the E20 scenario, when including estimates for GHG due to land use change. (Savings are greater when excluding GHG emissions due to land use change).

The E20 scenario also reduces direct GHG emissions and overall energy consumption in comparison to the balanced biofuel scenario with the same amount of overall biofuel energy used, due to the efficiency improvement effect in E20 optimised vehicles. Overall this is represented by a just over 1.1% reduction in petrol consumption by passenger cars in 2030 in this scenario.

**Figure 3.1: Timeseries trajectory for WTW GHG emissions for various scenarios in comparison to the no biofuels scenario**

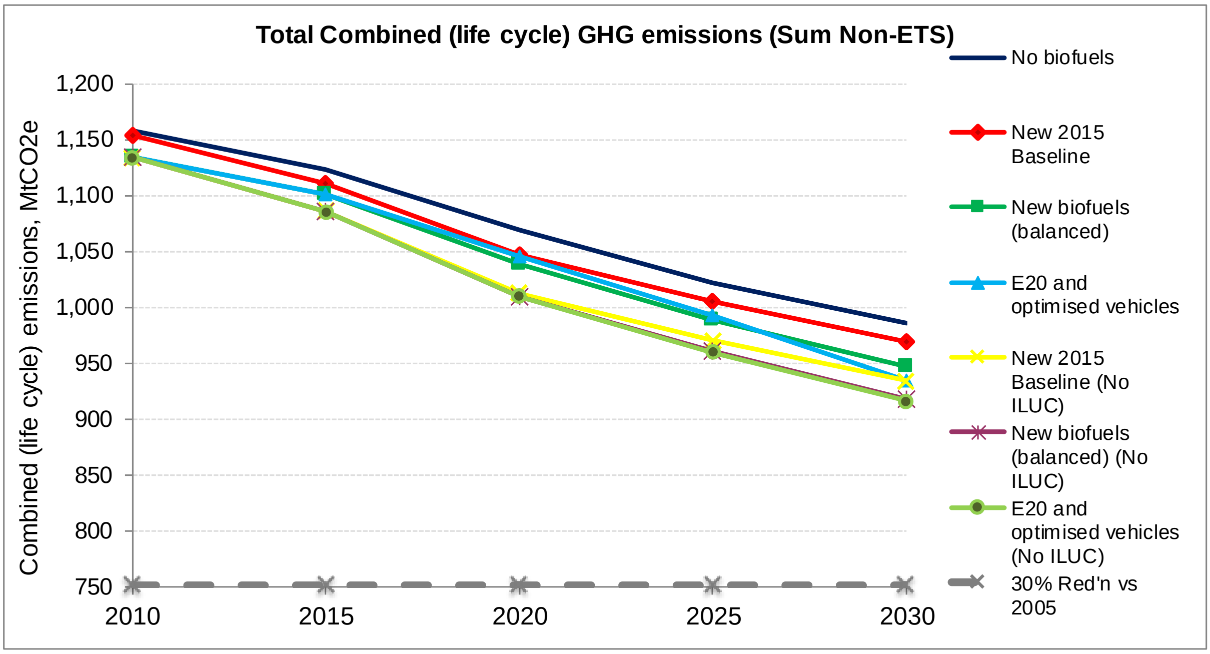
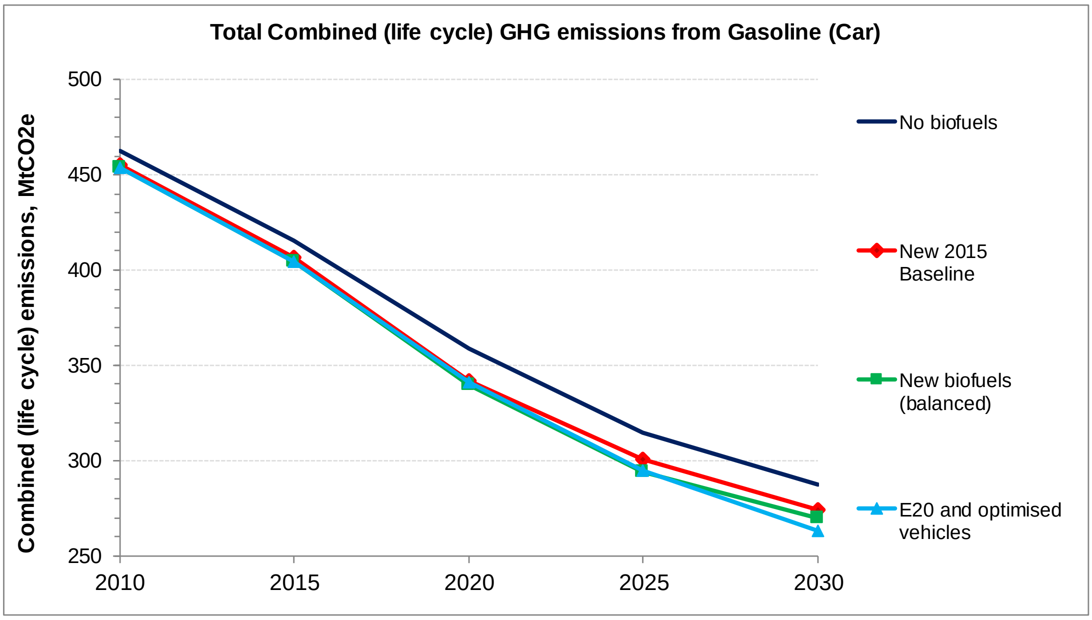



**Table 3.1: Time series trajectory for WTW GHG emissions for various scenarios in comparison to the no biofuels scenario**

| Total Combined (life cycle) GHG emissions (Sum Non-ETS), $MtCO_2$ | | | | | |
|---|---|---|---|---|---|
| | **2010** | **2015** | **2020** | **2025** | **2030** |
| **No biofuels** | 1,157.3 | 1,123.7 | 1,068.5 | 1,021.7 | **985.8** |
| **Baseline** | 1,153.6 | 1,110.3 | 1,047.1 | 1,005.0 | **969.1** |
| **Balanced biofuel** | 1,133.9 | 1,101.2 | 1,037.8 | 989.2 | **946.3** |
| **E20 optimised** | 1,133.9 | 1,101.2 | 1,045.7 | 992.3 | **934.1** |
| **Baseline (No ILUC)** | 1,133.9 | 1,085.9 | 1,012.2 | 969.8 | **933.9** |
| **Balanced biofuel (No ILUC)** | 1,133.9 | 1,085.4 | 1,009.8 | 960.8 | **918.0** |
| **E20 optimised (No ILUC)** | 1,133.9 | 1,085.4 | 1,009.8 | 959.7 | **915.9** |

**Figure 3.2: Time series trajectory for WTW GHG emissions for various scenarios in comparison to the no biofuels scenario for *petrol cars***

**With ILUC**




**Without ILUC**

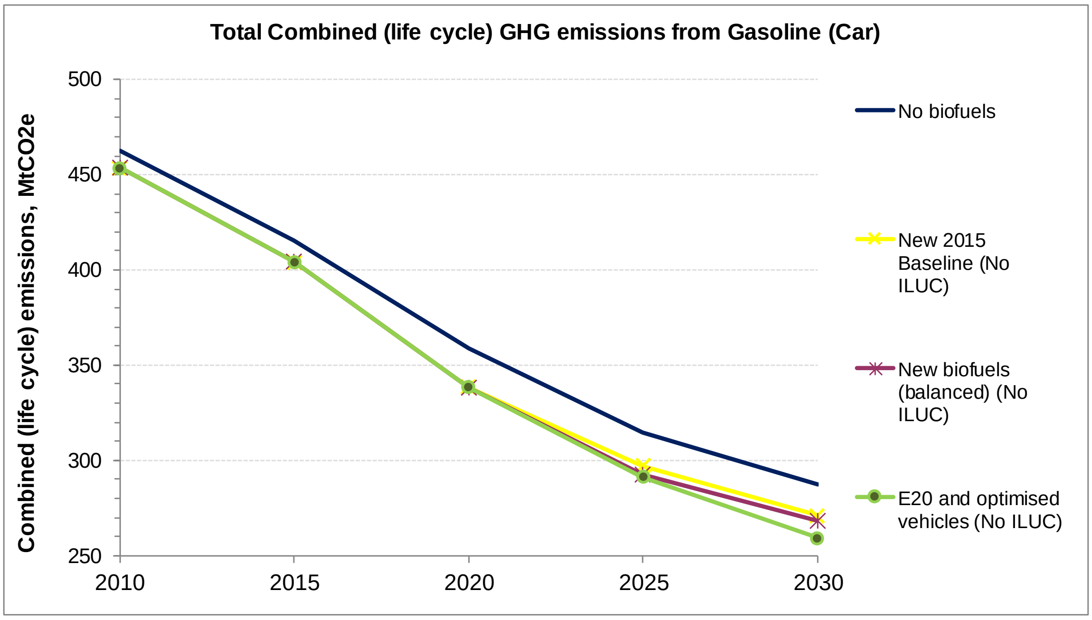
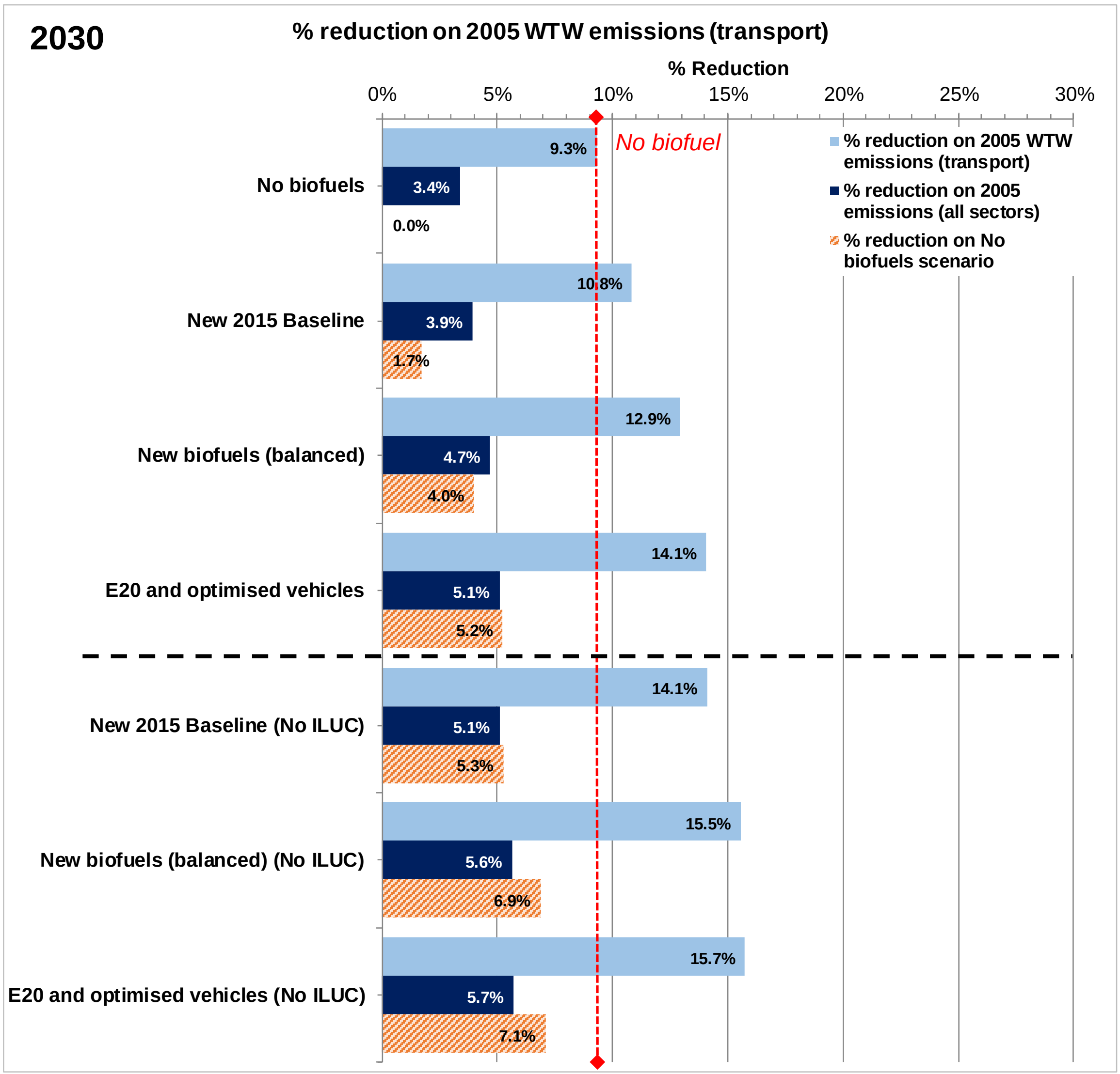



**Table 3.2: Time series trajectory for WTW GHG emissions for various scenarios in comparison to the no biofuels scenario for *petrol cars***

| Total Combined (life cycle) GHG emissions (Sum Non-ETS), $MtCO_2$ | | | | | |
|---|---|---|---|---|---|
| | **2010** | **2015** | **2020** | **2025** | **2030** |
| **No biofuels** | 462 | 416 | 359 | 314 | **287** |
| **Baseline** | 456 | 406 | 342 | 301 | **274** |
| **Balanced biofuel** | 454 | 405 | 340 | 294 | **269** |
| **E20 optimised** | 454 | 405 | 341 | 295 | **263** |
| **Baseline (No ILUC)** | 454 | 404 | 338 | 297 | **271** |
| **Balanced biofuel (No ILUC)** | 454 | 404 | 338 | 292 | **268** |
| **E20 optimised (No ILUC)** | 454 | 404 | 338 | 291 | **259** |

**Figure 3.3: Contribution of transport biofuels deployment to the reductions in (a) transport sector GHG emissions for 2030, (b) all sector GHG emissions, (c) reductions vs the no biofuels scenario**




## 3.2 Summary of key conclusions

The results from the modelling analysis show that, even accounting for estimates of additional land use change GHG emissions, the use of biofuels results in significant WTW GHG reductions compared to the use of conventional fossil/oil based fuels. Bioethanol shows significantly higher savings in comparison to biodiesel, when including estimates for ILUC, and increasing the share, beyond 2020 levels, further reduces GHG emissions. Other measures would certainly need to be implemented to reach 2030 decarbonisation objectives if these shares are not increased, as was also explored in other recent SULTAN modelling work (Ricardo Energy & Environment, 2016).

Specifically, with regards to bioethanol, the results of the analysis clearly show additional benefits of an E20 optimised pathway in comparison to the previously modelled 'balanced biofuel uptake' pathway. This is due to a combination of effects: the relatively low ILUC of 1G bioethanol, and the improved efficiency benefits of E20 optimised vehicles resulting in lower net fuel consumption. The ILUC impact of 1G bioethanol (based on the GLOBIOM modelling work) has relatively little impact on the results, in contrast to that for biodiesel, which results in a significant erosion in GHG savings when it is included.

Therefore, it would seem worthwhile that the deployment of high-octane E20 fuel and vehicles with E20 optimised engines should be further explored by policymakers in considering the suite of options available for reducing transport's emissions in the context of both medium-term 2030 GHG reduction objectives, as well as longer-term objectives for 2050.

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