POTENTIAL OF COMBINED VEHICLE TECHNOLOGY, FUEL AND ICT MEASURES IN REDUCING CO2 EMISSIONS FROM ROAD TRANSPORT BY 2030

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Abstract

This study presents the evolution of CO2 emissions from road traffic to 2030 taking into account latest statistical information for historical years and agreed policy targets at an EU level up to 2030. Different scenarios are formulated by considering: i) advanced biofuel production pathways, and ii) deployment of Information and Communication Technologies/Intelligent Transport Systems (ICT/ITS). The scenarios are built on the basis of two possibilities for base vehicle technology evolution, with respect to the penetration of electrified vehicles. A key result of the study is that CO2 emission evolution in a business-as-usual (baseline) scenario does not reach the 2030 indicative target. Therefore, additional technical effort is required by combining the synergetic effects of these three pillars, namely, the vehicle technology, fuel, and ICT measures.

1 Introduction

Combating global warming and climate change is one of the most important environmental challenges in recent years. As a result of its heavy dependence on fossil fuels, the transport sector is a significant consumer of energy and a major source of GHG emissions. Road transport is the dominant mode, emitting ~72% of all transport-related GHG emissions [1]. A major concern is that, although total GHG emissions in EU28 decreased from 1990 to 2013, emissions from the transport sector (all modes) increased for the same time period (Fig. 1:). This is mainly due to the increase of transport activity, both passenger and freight. Nevertheless, by focusing on the time period 2008-2013, reductions in GHG emissions from transport are observed. The latter can mainly be attributed to the economic recession and, secondarily, to specific measures taken at local or global level aiming at reducing fuel consumption. In any case, it is more than obvious that this decrease trend must continue (or even intensify) in order to meet the reduction targets for 2030 and 2050.

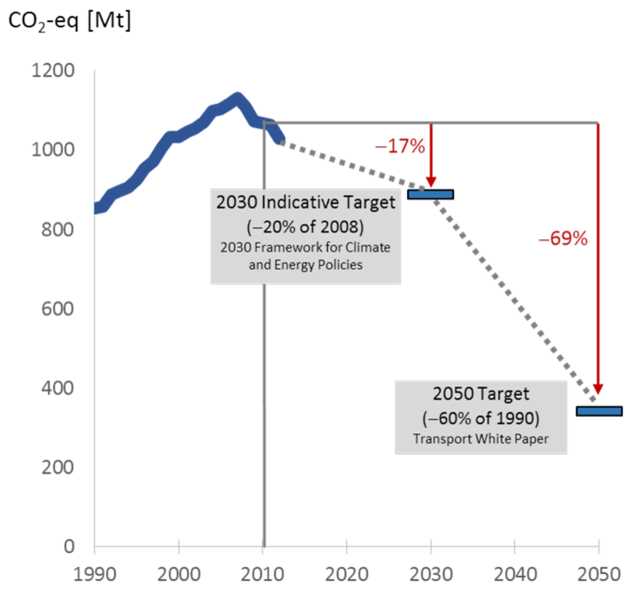

Fig. 1: EU28 all transport GHG (CO2–equivalent) (Historical data: EEA, 2015) [2]

Despite the demanding future targets that have been set on Tank-to-Wheel (TtW) emissions, a key result of the study is that the CO2 emissions evolution in a business-as-usual (baseline) scenario does not reach the -17% checkpoint in 2030. Specifically, CO2 reductions in 2030 are projected to reach -13.1% (over 2010) on a fleet level in an integrated approach including Well-to-Wheel (WtW) CO2 emissions from total road transport. Another factor that must be taken into consideration is that the EU28 passenger and freight transport activity projection presents a continuous increase from year to year (IIASA, Thematic Strategy on Air Pollution). This increase in transport activity, together with the fact that ~72% of CO2 emissions come from road transport, make the future targets even more demanding. Hence, significant additional technical effort is required and actions need to be undertaken in all fronts on behalf of the automotive/fuel industry and other involved stakeholders.

The main objective of this paper is to assess the impact of alternative fuel pathways on upstream (WtT) and of ICT measures on downstream (TtW) CO2 emissions; these measures, combined with advanced vehicle technology, can lead to significant CO2 reductions. An interesting finding is that the usage of advanced biofuels together with moderate implementation of ICT measures may suffice in order to reach total WtW CO2 reductions above the -17% indicative target. Further reductions are technically possible by combining advanced biofuels with accelerated deployment of ICT/ITS and advanced vehicle technology measures (fleet renewal with electrified vehicles – battery/plug-in hybrid electric – and high efficiency improvements).

2 Basic methodological components

The main methodological components are two fuel and two ICT scenarios applied on two fleet projections. These scenarios explore the possibilities to reduce CO2 and can be used to inform and guide policy. They are shortly outlined below:

- 2 fuel scenarios: These are based on the JEC study [3] and E4tech Auto-Fuel biofuel roadmap [4] on fuel impacts. The main difference between the two scenarios is that one is built according to policy targets using current feedstock pathways, while the other benefits from increased penetration of advanced biofuels, improved production pathways, and more renewable energy sources.
- 2 ICT scenarios: These are based on the FP7 ICT-Emissions project and their main difference is on the penetration to the fleet and their application level.
- 2 fleet projections: They have been implemented using the SIBYL software tool (http://emisia.com/products/sibyl) and are based on activity and energy evolution to 2030, as agreed in high level EU policy studies. Baseline fleet assumes normal fleet renewal and efficiency improvement, while advanced fleet benefits from higher penetration of electrified vehicles and higher efficiency improvements.

The above scenarios can be combined in 8 different ways (2 x 2 x 2 = 8 scenario combinations). For convenience, fuel and ICT scenarios are distinguished using the terms low/high, which represent how much effort has to be put for implementation. In general, low effort means business-as-usual with no additional policy measures than already agreed; high effort means that significant additional efforts are needed.

2.1 Fuel measures and alternative pathways

The methodology followed to create the two fuel scenarios is summarized below:

- Main fuels considered: Fossil diesel and substitutes (biodiesel, Hydrotreated Vegetable Oil - HVO, Fischer-Tropsch - FT), fossil petrol and substitutes (bioethanol, Ethyl-Tertiary-Butyl Ether - ETBE), electricity, and hydrogen.
- WtW CO2 of each pathway: Impact of each fuel production pathway on CO2 (JEC study [3]). Of particular importance is the upstream part (WtT) of fuels with renewable production pathways, since these are expected to contribute to the target of total CO2 reduction.
- Fuel consumption statistical data (2010-2013): Official statistics from Eurostat and Biofuels Barometer, showing current situation and trends in usage (blending) of biodiesel and bioethanol. Historical data are fully respected.
- Fuels and pathways for the period 2014-2030: This is the most important component, since it is about deciding the percentage of fossil diesel and petrol to be substituted, and the specific pathways to be used for the production of each fuel substitute (including electricity and hydrogen). The decision is based on the feedstock availability and biofuels supply to 2030 (EU Auto-Fuel biofuel roadmap) and on the CO2 impact of each pathway (JEC study). The objective is to select optimum pathways (to reduce total CO2), while at the same time respecting upper limits of feedstock availability and biofuels supply.

Both scenarios utilize policy studies in EU and respect policy measures already agreed. This is reflected in Fig. 2: which shows the volumetric blending (%) in diesel/petrol mix. Historical statistical data from Eurostat (2010-2013) are fully respected. For diesel, B7 (Fatty Acid Methyl Ester - FAME) is the maximum blend considered in both scenarios; for petrol, the highest blending ratio is E10 (after 2021) with an intermediate step of E7 (from 2016 to 2020). In general, the fuels considered for diesel substitutes are biodiesel (FAME blended) and drop-in fuels (HVO and FT), while the fuels considered for petrol substitutes are bioethanol (EtOH), and bio ETBE.

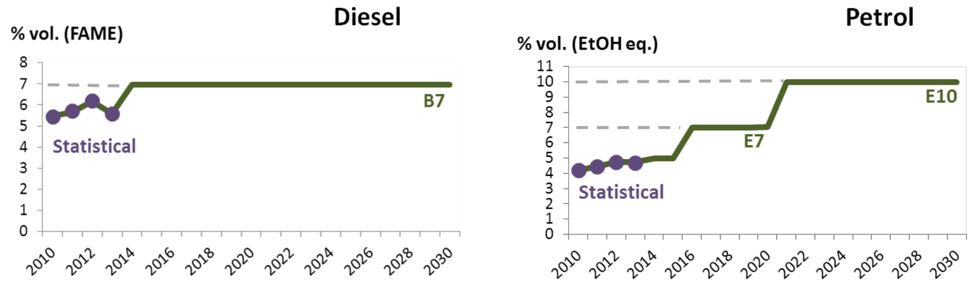

Fig. 2: Policy targets respected for diesel (left) and petrol (right)

2.1.1 Diesel fuel substitute pathways

Fig. 3: provides more insight on the differences of the two scenarios concerning the usage of diesel substitutes (indicative years 2010, 2020, 2030). Specifically, the high effort scenario assumes increased penetration of drop-in fuels (HVO and FT); FAME alone remains constant (equal to 7%), while the sum of FAME + HVO + FT continues to increase (9.8% in 2020 and 14.2% in 2030). In the low effort scenario, usage of HVO and FT is moderate (compared to high effort); FAME alone decreases from 2020 to 2030, but the sum of FAME + HVO + FT remains unchanged (equal to 7%). Both scenarios fully respect supply limits.

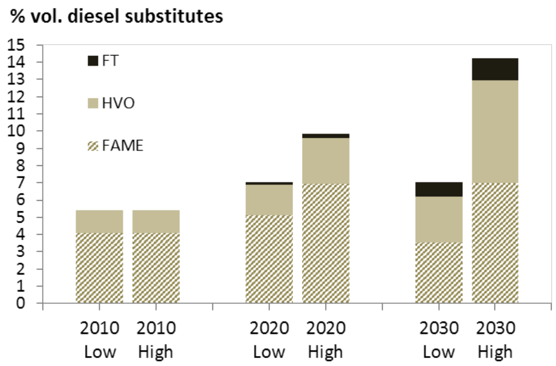

Fig. 3: Comparison of low/high effort fuel scenarios in diesel substitutes

Concerning the production pathways of diesel substitutes, low effort scenario assumes FAME, HVO, and FT mostly from food crops (similar to current situation); high-effort scenario assumes some increase of non-food feedstock from 2020 to 2030 (e.g. tallow oil, farm/waste wood) to meet Indirect Land Use Change (ILUC) recommendations. Both scenarios fully respect feedstock availability (supply chains) from the EU Auto-Fuel biofuel roadmap. The introduction of tallow oil in biodiesel and

HVO, and the increase of wood in FT, in the high effort scenario, decreases WtW CO2 (weighted average of pathways used). This WtW improvement is due to the upstream part (less CO2 for the production of biodiesel, HVO, and FT).

2.1.2 Petrol fuel substitute pathways

Petrol substitutes today do not offer as significant CO2 savings as diesel. Noticeable benefits can be achieved only in the high effort scenario (due to improved production pathways). In the low effort scenario, bioethanol and ETBE together add up to 7% in 2020 and 10% in 2030. High effort scenario utilizes only bioethanol (7% in 2020 and 10% in 2030). The reason for not considering further ETBE in the high effort scenario is that because, according to the JEC study, overall, using ethanol as ETBE would not result in substantial GHG savings (only marginal differences compared to using ethanol as such). Concerning the production pathways of petrol substitutes, low effort scenario assumes bioethanol from food crops (similar to current situation); high-effort scenario assumes increase in sugar cane imports (a pathway with less CO2 according to JEC study) and in non-food feedstock (farm/waste wood).

2.1.3 Electricity and hydrogen carbon intensity

For electricity production, low effort fuel scenario assumes 100% usage of the pathway named as ‘EU electricity mix low voltage’ in JEC study (current situation). This pathway already utilizes some renewable sources (hydro, wind, waste, other) with 11.7% sharing among all primary energy sources. The policy targets set for electricity (to be met with the high effort scenario) are:

- ~20% share of renewable energy sources (RES) in 2020,
- ~27% share of RES in 2030,
- no change in relative contribution of other pathways.

In order to meet the above targets, the sharing of EU electricity mix pathway has been decreased from 100% to 90% in 2020 and to 82% in 2030, and the remaining percentages have been allocated to other renewable pathways (biogas, wood, wind). Hence, the share of RES in 2020 is 90%*11.7% + 10% = 20.5%, and in 2030 is 82%*11.7% + 18% = 27.6%, in accordance with policy targets. The changes applied in the high effort scenario decrease WtW CO2. This WtW improvement is due to the upstream part (less CO2 for the production of electricity from biogas, wood, wind).

Regarding hydrogen, it is currently produced mainly from natural gas reforming (thermal process); this pathway is used 100% in the low effort scenario. Renewable pathways are introduced in high effort scenario (via electrolysis and thermal processes) with a sharing percentage 20% (thus, decreasing natural gas reforming to 80%). This change is applied in the high effort scenario gradually from 2015 to 2030.

2.1.4 Renewable energy sources in view of policy requirements

Both scenarios respect the following policy targets for renewable energy sources:

- ILUC caps first generation biofuels to 7% of transport energy consumption, earliest in 2020.
- ILUC calls for indicative 0.5% advanced biofuels by 2020.
- Renewable directive requires 10% of transport energy in renewables by 2020.

2.2 ICT/ITS measures

The ICT/ITS measures that have been utilized are shortly presented below.

Green navigation (GN): A satellite navigation system assigns position to a vehicle on the road and by using the road database it gives directions to other locations along roads in its database. Fuel consumption can be decreased since green navigation avoids extra mileage due to mistakes in the route followed to the destination. Also, the route calculation includes some parameters (shortest distance, fastest road) that can result in fuel savings compared to the route followed without the navigation system. There is a positive impact on traffic distribution, since vehicles with this system on board are guided in less congested routes or better green/eco routes.

Adaptive cruise control (ACC): Systems supporting the driver in the longitudinal control of the vehicle have a positive impact on fuel consumption. The simplest system, cruise control, keeps a constant vehicle speed and reduces CO2 emissions by avoiding unnecessary speed changes that produce extra fuel consumption. The system can also take into consideration the road geometry and speed limits. Furthermore, if the vehicle is equipped with speed radars, the system can detect the speed of the vehicle in front. The impact of ACC depends on the share of the on-road vehicles equipped with ACC, since such vehicles affect their surrounding traffic.

Urban traffic control (UTC): This measure includes all infrastructure based systems that are able to measure the level of traffic on a road network, thus, enabling the management or control of traffic in order to optimise the use of the available road capacity. It works by regularizing the movement of vehicles in order to save energy, reduce emissions, and increase safety. For example, traffic light management using traffic sensors can avoid traffic stopped at one way while there is no traffic in the other way. By taking into account speed limits, traffic lights can assist cars in always finding green at the intersections. As a result, the available road capacity is optimized. This measure is applicable on urban road network.

Variable speed limits (VSL): Variable (also called dynamic) speed limits use real traffic-flow and weather information to dynamically change the posted speed limit. This measure consists of dynamic message signs deployed along a roadway and connected via a communication system to a traffic management centre. The driver remains responsible for maintaining a safe and proper speed as the system gives only information and warnings, but does not intervene with his behaviour. Variable speed limits can be voluntary or mandatory. The main parameters affected are the average speed, traffic flow, and driving dynamics. Changes in vehicle speeds can have a direct impact on the level of emissions.

For each measure, the optimum CO2 emissions reduction potential (from the ICT-Emissions project) is adopted and an application level is assigned. The methodology takes into account the road type (urban/highway – measures are not applied on rural roads), traffic conditions (peak/off-peak), activity, and different vehicle categories and technologies; it results in the creation of two scenarios (low/high effort).

2.2.1 ICT low/high effort scenarios

Fig. 4: summarizes the description of the two ICT scenarios, low and high effort. The measures considered in the low effort scenario are GN and VSL, while in the high effort scenario, all four ICT measures are considered (combined where applicable).

Type	Condition	GN	ACC	VSL	UTC
Vehicle	PC	✓	×	✓	×
	LCV	✓	×	✓	×
	Urban Bus		×		×
Road	Urban	✓	×		×
	Motorway/ Urban Highway	✓	×	✓	

Type	Condition	GN	ACC	VSL	UTC
Vehicle	PC	✓	✓	✓	✓
	LCV	✓	✓	✓	✓
	Urban Bus		×		✓
Road	Urban	✓	✓		✓
	Motorway/ Urban Highway	✓	✓	✓	

Fig. 4: ICT measures considered per vehicle category and road type in the low effort (left) and high effort (right) scenarios

2.3 Vehicle technology measures

The two fuel and the two ICT scenarios are applied on two fleet projections which have been implemented in SIBYL and are based on activity and energy evolution to 2030, as agreed in high level EU policy related studies. In general, baseline fleet assumes normal fleet renewal and efficiency improvement, while advanced fleet benefits from higher penetration of electrified vehicles and higher efficiency improvements. The main characteristics of each fleet are summarized below.

- Baseline fleet: Business-as-usual fleet, consistent with current legislation (2021 target of 95 gCO2/km in type approval for cars and 147 gCO2/km for light commercial vehicles). Normal fleet renewal with moderate sales of electrified vehicles (plug-in hybrid, battery, and fuel cell electric vehicles).
- Advanced fleet: For passenger cars and light commercial vehicles, same as baseline fleet until 2020, but then very high penetration of electrified vehicles (especially plug-in hybrid) and higher efficiency improvements. For heavy duty vehicles, higher efficiency improvements already from the present time based on Ricardo-AEA study scenarios [5].

3 Results

The impact of measures on CO2 emissions is compared against a baseline scenario, which is considered a ‘business-as-usual’ case with low technical effort requirements;

nevertheless, it does meet policy targets (e.g. for biofuels use, renewable energy sources, type approval CO2). It consists of the following methodological components:

Baseline scenario = Baseline fleet + Low effort in fuels + No ICT measures

The main technological developments expected from 2010 to 2030 include:

- Gradual increase of diesel cars and significant decrease of petrol ones.
- More than doubling the number of alternative fuelled vehicles.
- Limited changes to the number of LCVs and HDVs.

However, despite the expected increase in total fleet, a significant decrease in total energy consumption is projected (Fig. 5:).

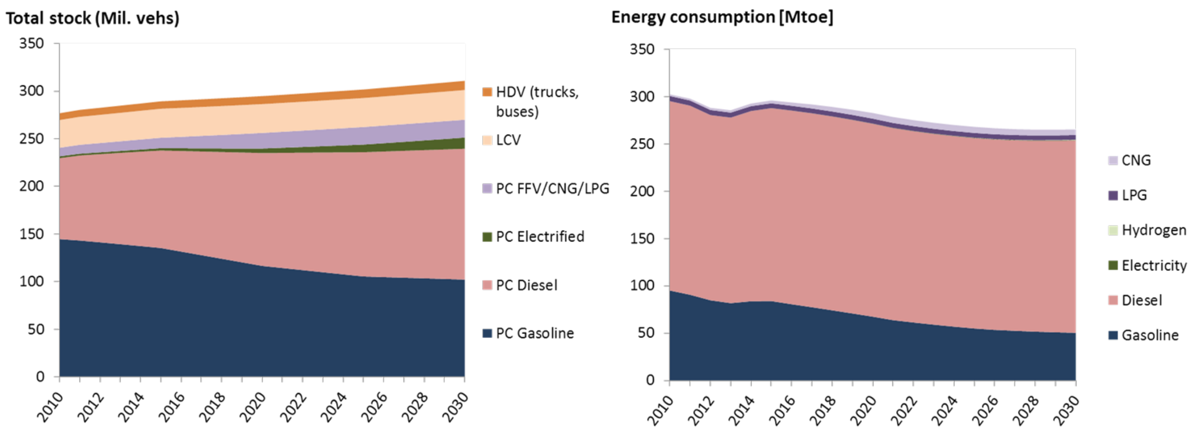

Fig. 5: Baseline scenario (total vehicle stock and energy consumption)

3.1 Total WtW CO2 reduction and relative contribution of measures

In Fig. 6: the total WtW CO2 reduction that can be achieved with the baseline scenario (-13.1% from 2010 to 2030) is presented. It is obvious from this figure that significant reduction in CO2 is already achieved in the business-as-usual case, that is, with low effort technological measures (e.g. normal fleet renewal and efficiency improvement) and usage of biofuels according to policy requirements (B7 for diesel and E10 for petrol). However, the -17% indicative target for 2030 (Framework for Climate and Energy Policies) cannot be reached with baseline developments only.

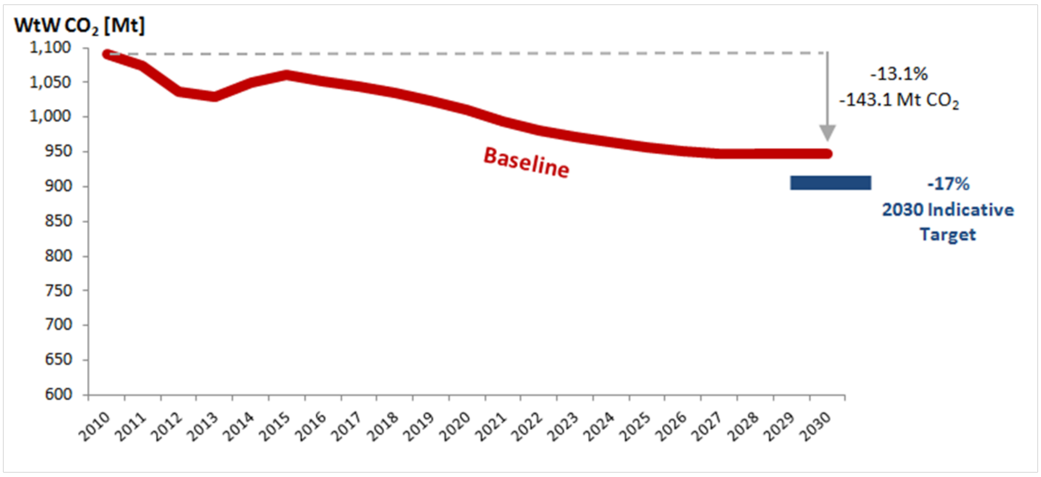

Fig. 6: Total WtW CO2 reduction achieved with baseline scenario

Fig. 7: presents total WtW CO2 reduction potential (%) from 2010 to 2030 for all possible scenario combinations (2 fleet x 2 fuel x 2 ICT = 8 combinations). It is obvious that the 2030 indicative target can only be met with additional efforts in fuels and ICT measures (Sc. 4: Fleet Baseline, Fuel High, ICT High → -18.6% CO2 reduction over 2010). Maximum benefit in 2030 can be achieved with the combination of advanced vehicle technology measures and high efforts in fuels and ICT (Sc. 8: Fleet Advanced, Fuel High, ICT High → -25.2% CO2 reduction).

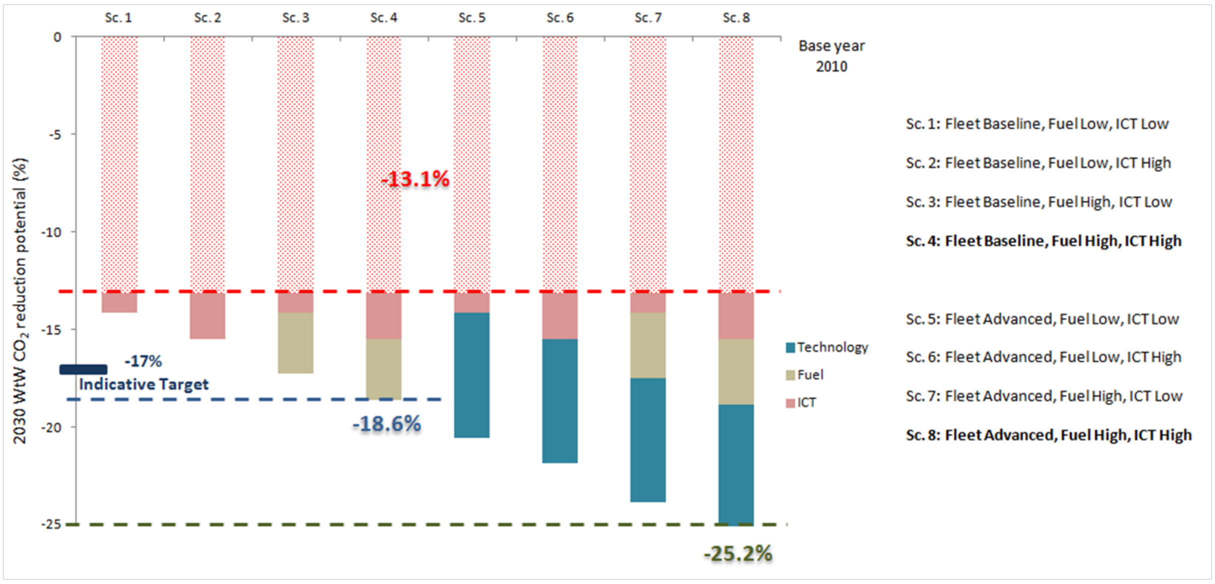

Fig. 7: Total CO2 benefits from all scenario combinations

Fig. 8: shows the contribution of different measures in meeting maximum CO2 reductions in 2030. In general, reductions are split almost equally between vehicle technology (53%) and other (fuel and ICT) measures (47%). Among vehicle technology measures, passenger car (PC) electrification is the single most important contributor with 41%, while the remaining 59% is split to efficiency improvement of cars, light commercial vehicles (LCVs), and heavy duty vehicles (HDVs). Regarding fuel measures, diesel substitutes (biodiesel, HVO, and FT) constitute the most

important contributor with 82.3%, followed by electricity (9.4%) and bioethanol (7.6%). The relatively high percentage of electricity is due to the increased number of electrified vehicles in the new car sales of advanced fleet.

3.2 Individual impact of vehicle technology, fuel, and ICT measures on CO2

- Advanced vehicle technology measures reduce TtW (downstream) CO2 emissions by ~69Mt in 2030 compared to the baseline case. That is, passenger car electrification and efficiency improvement in all vehicle categories lead to significant TtW CO2 benefits.
- Advanced fuel measures (high effort scenario) reduce WtT (upstream) CO2 emissions by ~34Mt in 2030. That is, advanced biofuels and improved production pathways lead to substantial CO2 reductions.
- Increased penetration of ICT measures (high effort scenario) has a very positive impact on TtW (downstream) CO2 emissions, offering a reduction of ~26Mt in 2030. Most of this comes from passenger cars, followed by light commercial vehicles and buses.

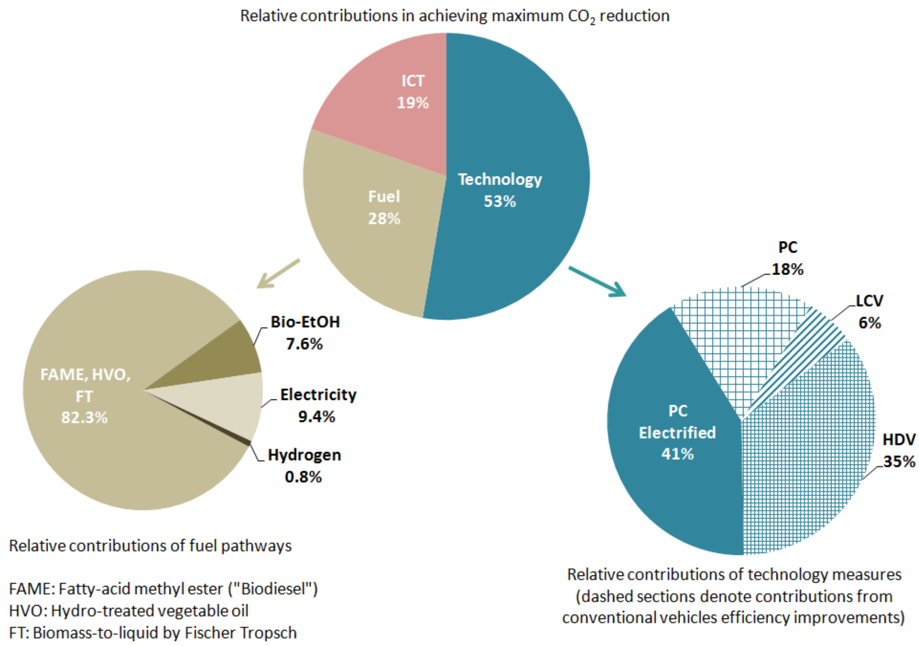

Fig. 8: Relative contributions in achieving max CO2 reduction from 2010 to 2030

4 Conclusion

Reaching future CO2 targets does not necessarily mean more advanced vehicle technology; use of more sustainable fuels and moderate ICT implementation may suffice. Additional reductions are technically possible by combinations of concentrated efforts in the introduction of advanced biofuels (e.g. drop-in fuels based on waste and tallow), accelerated deployment of ICT systems, fleet renewal with electrified vehicles and efficiency improvements in all vehicle categories.

5 References

[1] EU transport in figures – EU energy in figures, Statistical Pocketbook.
European Commission, 2015.

[2] Annual European Union greenhouse gas inventory 1990-2013 and report 2015.
European Environment Agency Technical Report No 19/2015.

[3] Well-to-Wheels analysis of future automotive fuels and powertrains in the European context.
JRC Technical Report, EUR 26236 EN, 2014.

[4] A harmonised Auto-Fuel biofuel roadmap for the EU to 2030.
E4tech Final Report, November 2013.

[5] Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy.
Ricardo-AEA Final Report to the EC - DG Climate Action, February 2011.