ERTRAC

Carbon-neutral Road Transport 2050

a technical study from a well-to-wheels perspective

Online
April 2021

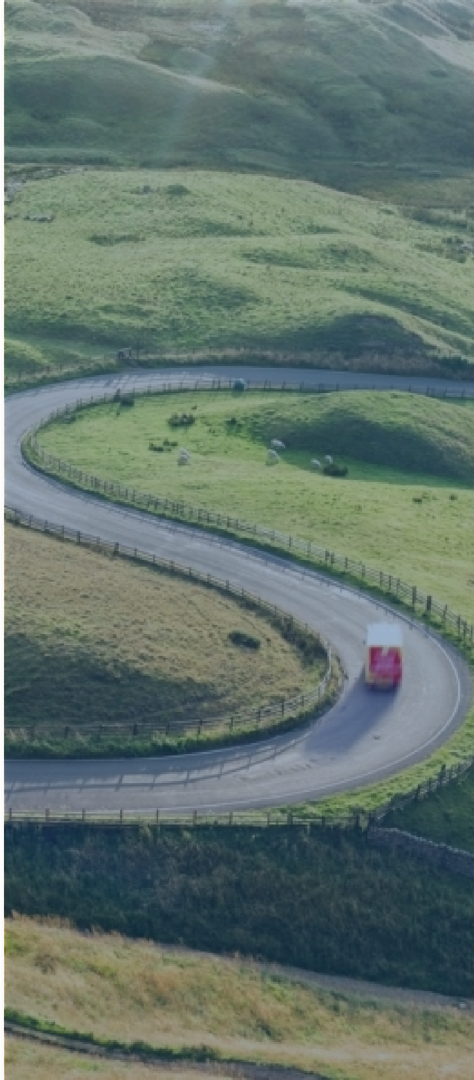
DISCLAIMER

➜ **The ERTRAC Carbon neutrality Study 2050 (WTW) analyses different "extreme" scenarios and compares effects**. It does not aim at giving a projection or at describing the way to achieve a carbon neutral road transport.

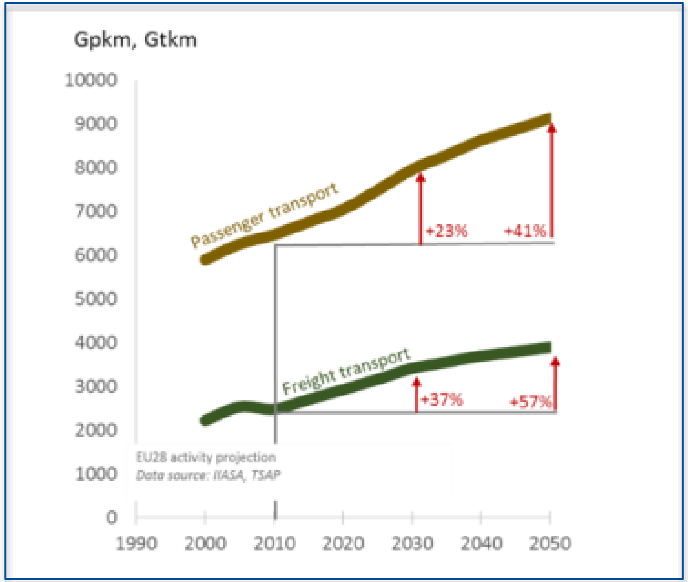
➜ The study only reflects the views of the contributing authors and is not an official European Commission position.

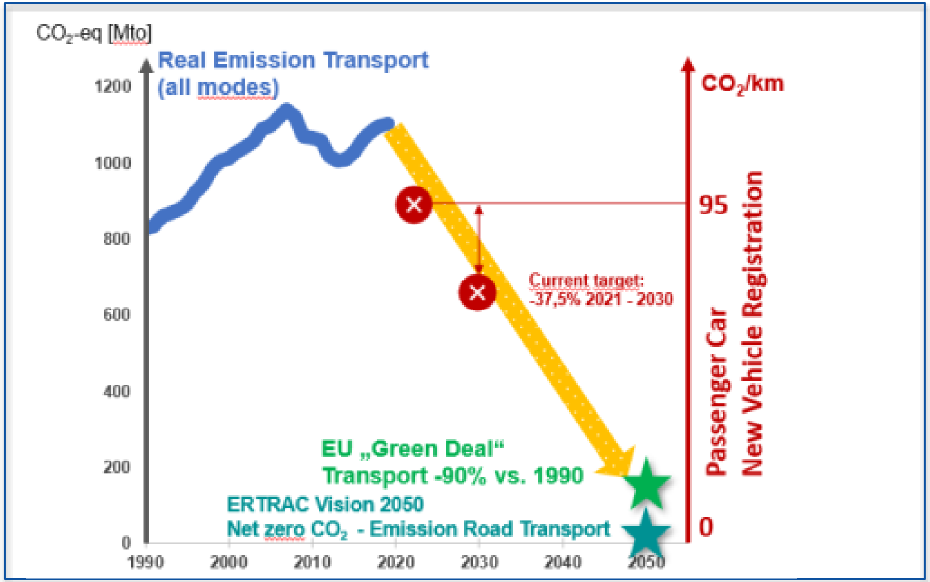
➜ **Results:**

- This study explored different corner scenarios based on a static fuel and fleet modelling exercise.
- The analysis does not include dynamic modelling or prediction; the results of the analysis should be considered as estimates for comparative purposes.
- The analysis does not draw conclusions on fuel and electricity availability, competition with other sectors demand, economics, societal acceptance ...



European CO_2 targets for transport





To reach the overall European **CO_2 targets for transport**, a **system approach** is needed addressing: Vehicle technologies, Traffic modalities, Infrastructure, Energy production

INITIAL QUESTIONS

- ? Which technologies can support net **carbon-neutrality in road transport?**[1]
- ? How large is their **specific effect**?
- ? What could be the **fleet and fuel impact?**
- ? **How much energy** and **which energy** is needed for road transport?
  (electricity? hydrogen? synthetic fuels?)
- ? Which **energy paths** do we have and **how much electricity** is needed to produce the different energy carriers?

(1) Technical process which may locally have GHG emissions (CO2, CH4 and N2O emissions), but compensated on a life cycle basis by a GHG removal / offsetting mechanism (e.g. growth of biomass, Carbon Capture Use and Storage (CCUS, including from bioenergy), Direct Air Capture (DAC), etc.)

Concept of the study

TTW

Which powertrains could be used in in 2050?

3 Powertrain Scenarios

Which efficiency improvements are possible by 2050?

Optimistic – Pessimistic ranges

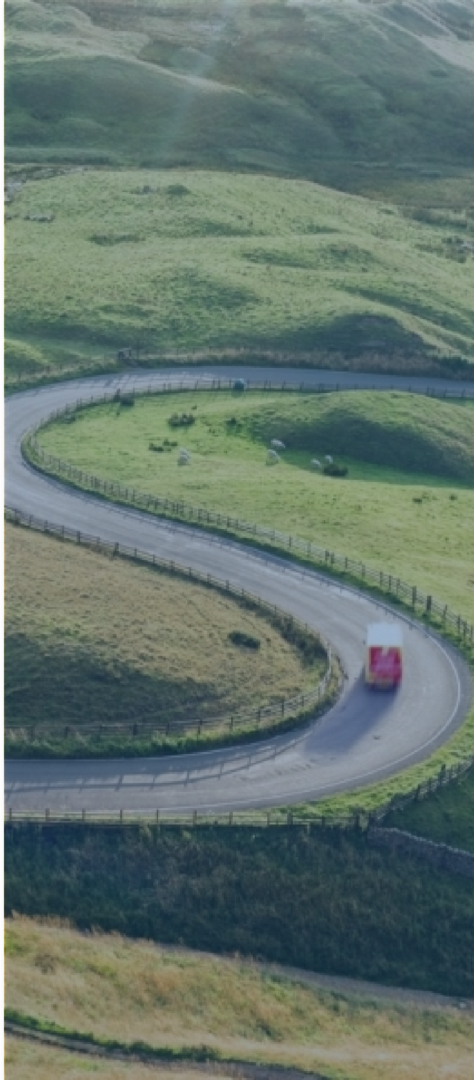
WTT

What will be the CO_2-footprint of electricity production in 2050?

2 Electricity Scenarios: 100% Renewable (RES) & 1.5 Tech

Which fuel production paths could be used in 2050?

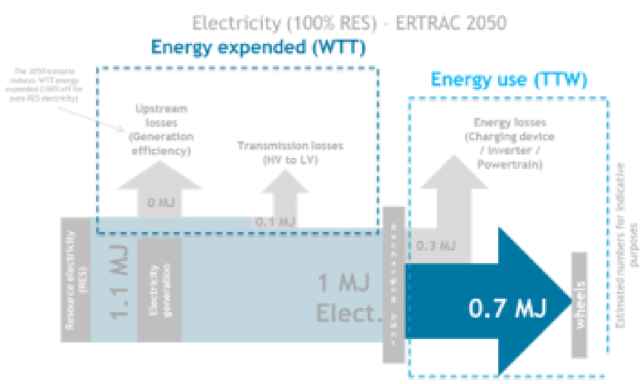
4 Fuel Scenarios: Biofuels, e-fuels, Mixed fuels and Limited fossil

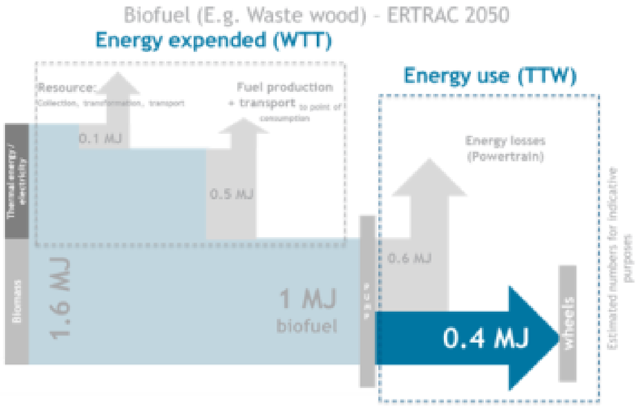


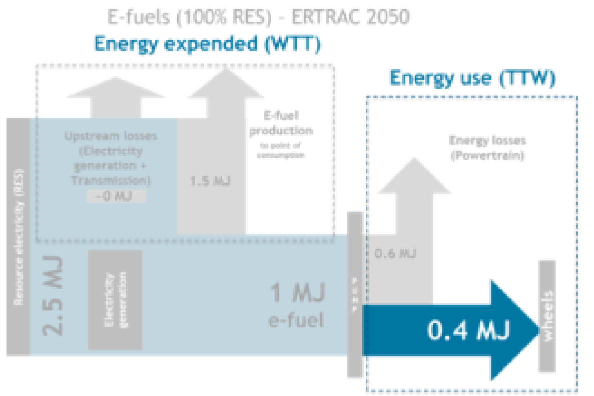
Energy flows (Well-To-Wheels)

The concept of total Primary Energy consumption

Electricity	Biofuels	E-fuel







Well-to-Tank (WTT) reflects the energy expended to produce 1 MJ final "fuel" (biofuel, e-fuel, electricity or H_2) at the point of consumption (pump at the filling station or charging point).

Tank-To-Wheels (TTW) reflects the energy use (only part of the energy in the fuel is used to move the wheels, depending on the efficiency of the powertrain).

Projected Road Transport 2050

The methodology: Well-To-Wheels (Flow chart)

TTW

1. Vehicle type definition & activity (TTW):

- **Fleet calculation** is done by JRC using the tool “**DIONE**”
- Rising activity with increasing vehicle size

2. Powertrain share per Vehicle

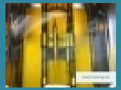
- 3 type of efficiency measures (with ranges (optimistic and pessimistic)
- 3 fleet composition scenarios

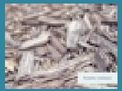
WTT

3. Energy demand & GHG emissions per fuel type (for each fleet scenario)

3.1. Two Scenarios for electricity production: 100 % Renewable (RES) & 1.5 TECH scenario (EC, ACP4A)

3.2. Individual feedstock/conversion route / fuel

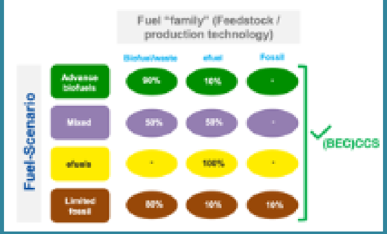




- JEC WTT v5 as basis
- Projection for process improvements 2050

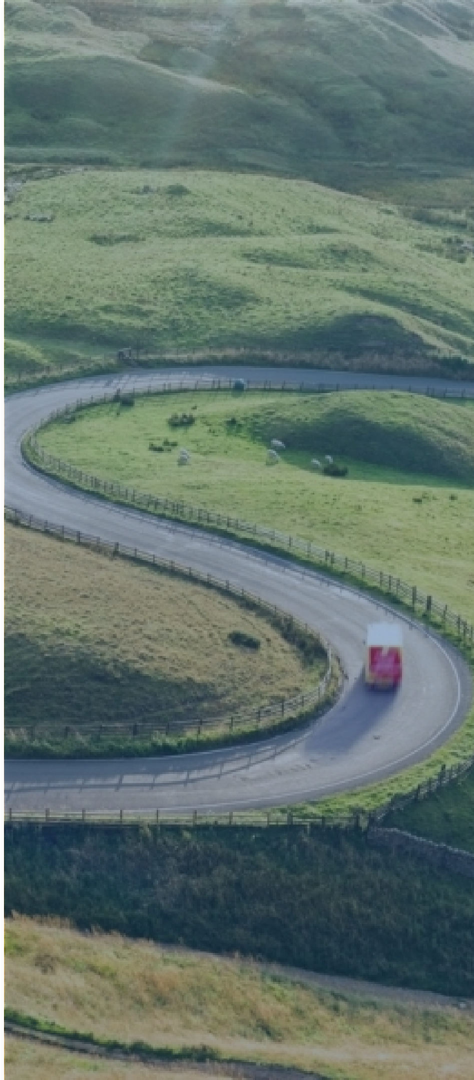
3.2. Fuel scenarios

4 “extreme” fuel mix scenarios explored

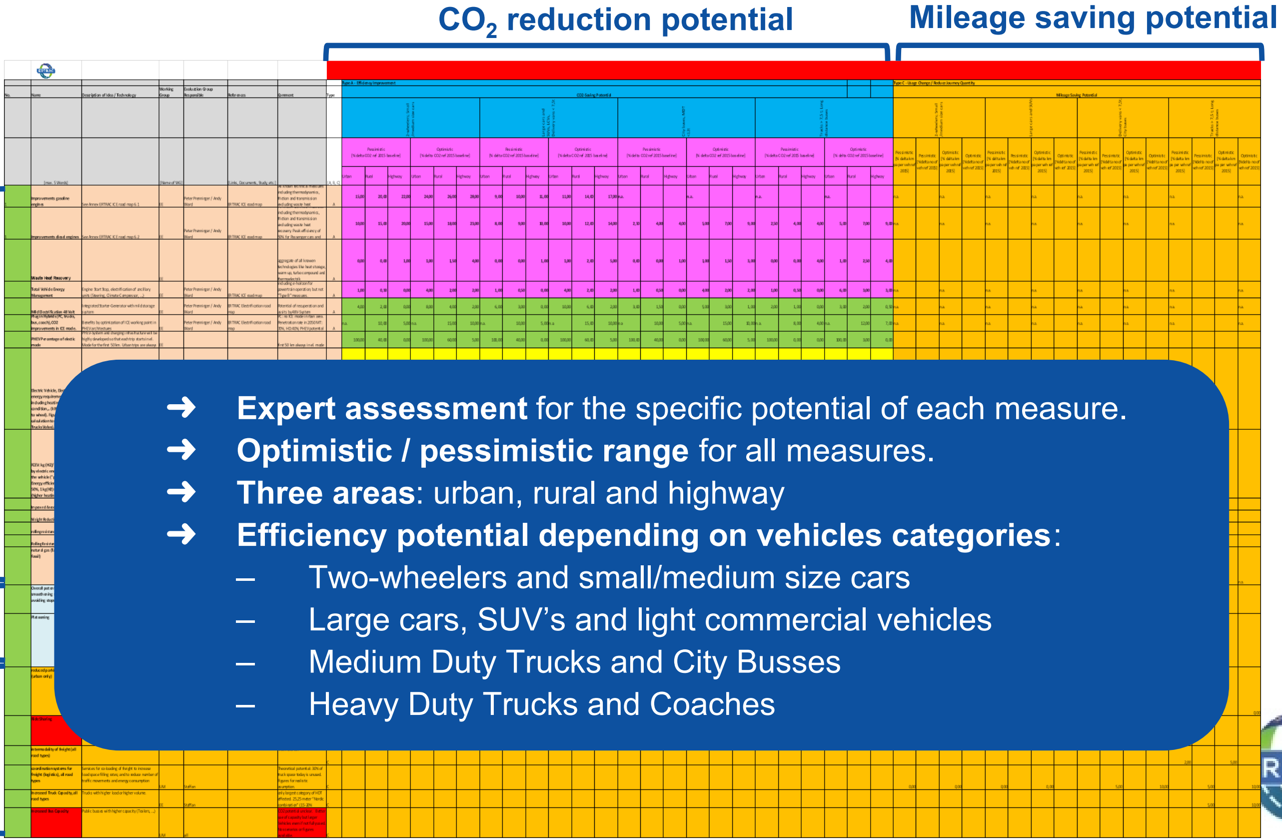


Note: all scenarios are finally carbon-neutral (WTW) (through the use of negative emissions by means of BECCS as example as/if needed)

Reminder of the previous study

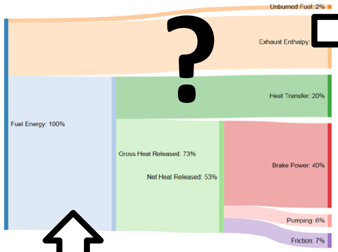


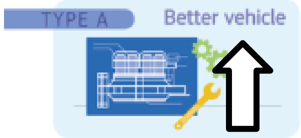
CO_2-Measure sheet of the different type of technical improvements

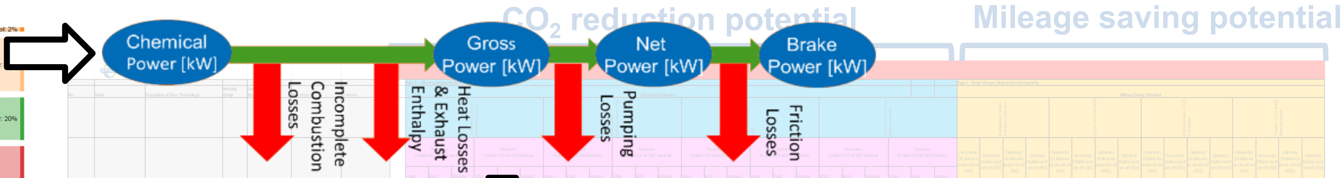


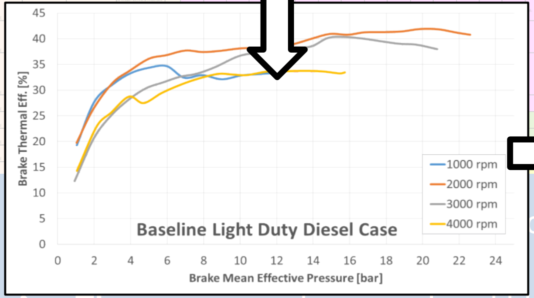
- ➜ **Expert assessment** for the specific potential of each measure.
- ➜ **Optimistic / pessimistic range** for all measures.
- ➜ **Three areas**: urban, rural and highway
- ➜ **Efficiency potential depending on vehicles categories**:
  - – Two-wheelers and small/medium size cars
  - – Large cars, SUV's and light commercial vehicles
  - – Medium Duty Trucks and City Busses
  - – Heavy Duty Trucks and Coaches

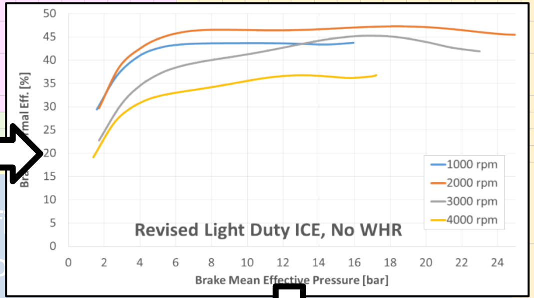
CO_2-Measure sheet of the different type of technical improvements







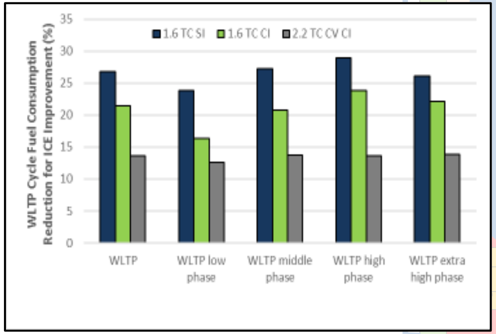




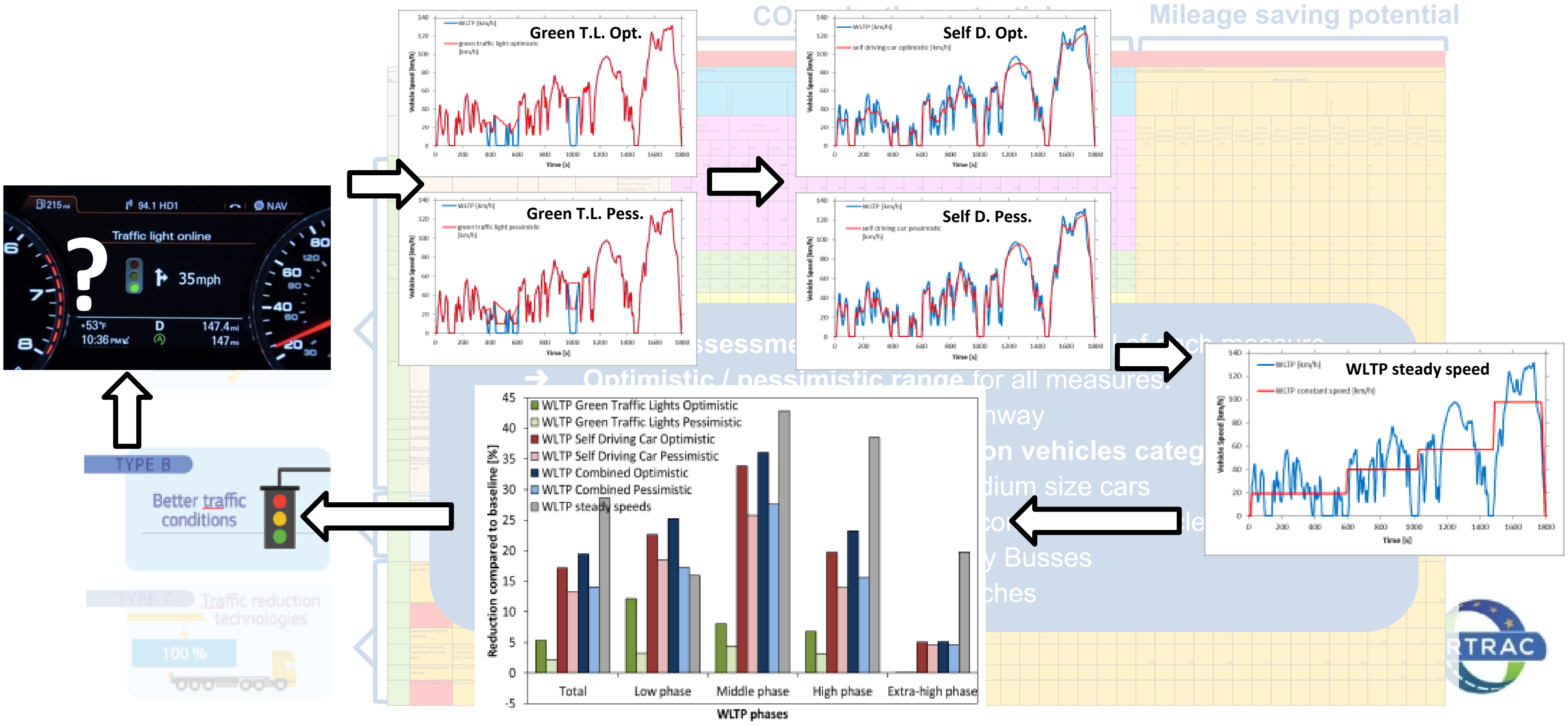
→ Three areas: urban, rural and highway

→ Efficiency potential depending on vehicles categories:

Vehicle description for ICE efficiency and green measures	Fuel [-]	Injection [-]	Aspiration [-]	Start-Stop [-]	Max Power [kW]	Empty Mass [kg]	Friction Coefficient [-]	Drag Coefficient [-]	Frontal Area [m^2]
1.6 TC SI	Gasoline	DI	Turbo	YES	100	1300	0.010	0.31	2.14
1.6 TC CI	Diesel	DI	Turbo	YES	82	1293	0.008	0.29	2.31
2.2 TC CV CI	Diesel	DI	Turbo	YES	125	1970	0.011	0.34	3.9



CO_2-Measure sheet of the different type of technical improvements



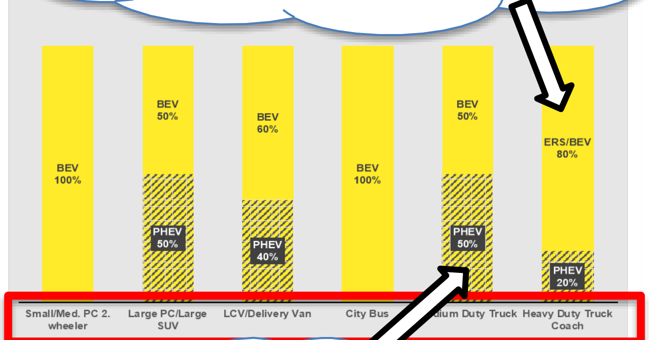
3 Powertrain Scenarios 2050

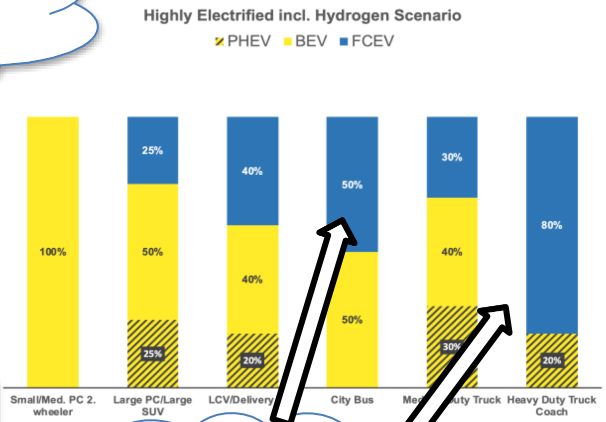
Scenarios assumptions as input for the study:

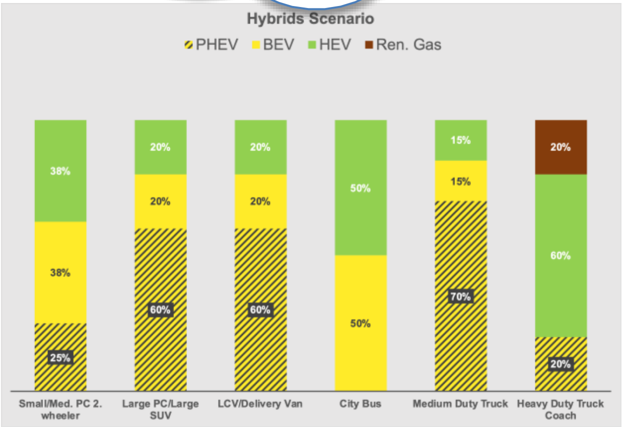
For Heavy duty trucks and Bus coaches:
Electric energy by:
Electric Road System or Battery on-board

Hybrid Scenario, Why?

Maybe the infrastructure will not develop fully for Electric and Hydrogen







PHEV = ability to run a significant distance pure electric

In this scenario the long distance electric vehicles operate with **Hydrogen energy**

…t powertrai… …orner-points):

- Highly Electrifie… …stems (HE-ERS)
- Highly Electrified in… (HE-H)
- Hybrids Scenario (Hyb)

Details Powertrain Scenarios 2050

General assumptions for all scenarios:

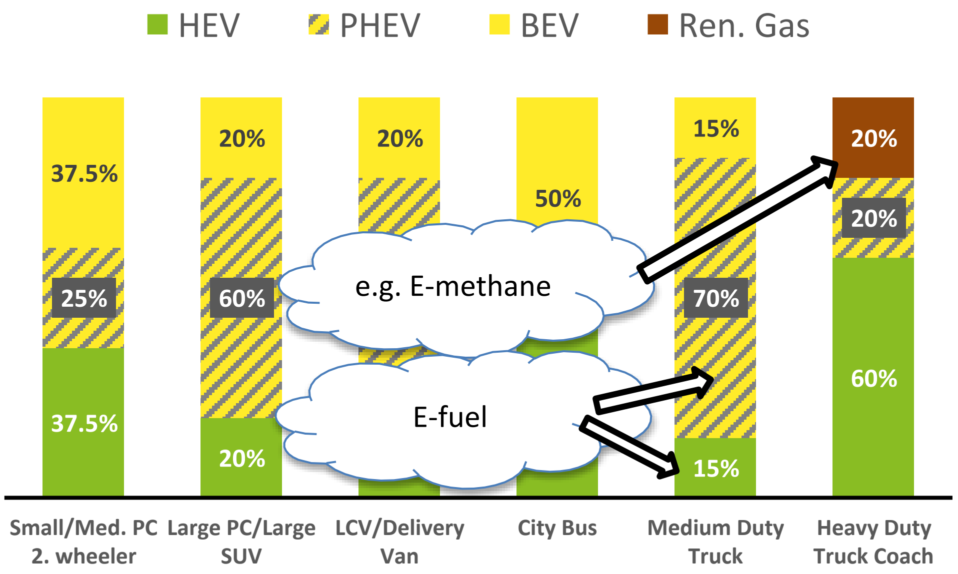
– The different powertrain scenarios <u>are not</u> a projection of market prevalence
– The scenarios are describing “Corner Points”, which are “extreme”

3 different powertrain scenarios (vehicle fleet stock composition)

- All used energy is assumed to be derived from a CO2 neutral origin

Example. Scenario “Hybrid” (HYB)

% share
of each powertrain in total stock in 2050



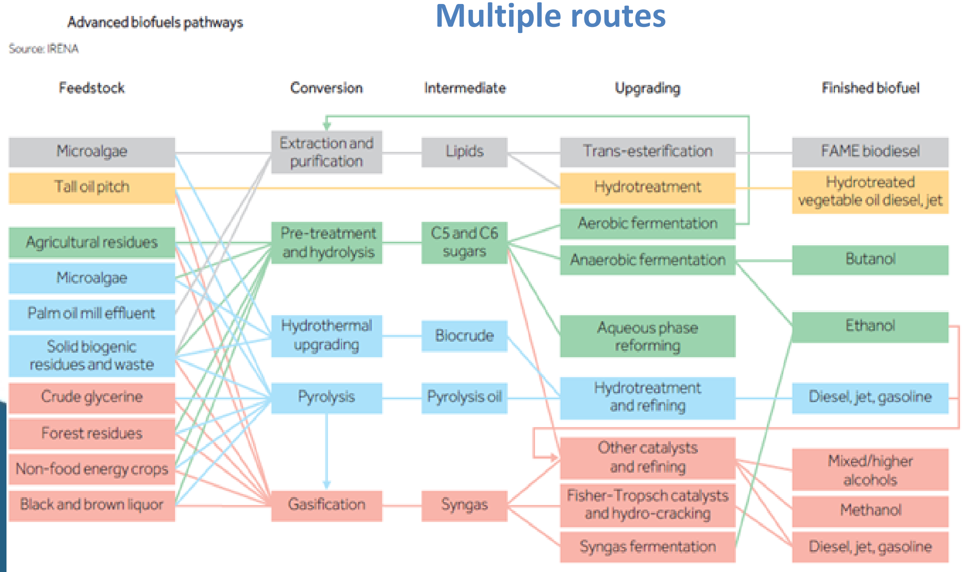
WTT - Fuel pathways per type of fuel

The WTT intensity of a fuel is determined by factors such as feedstock used and production technology

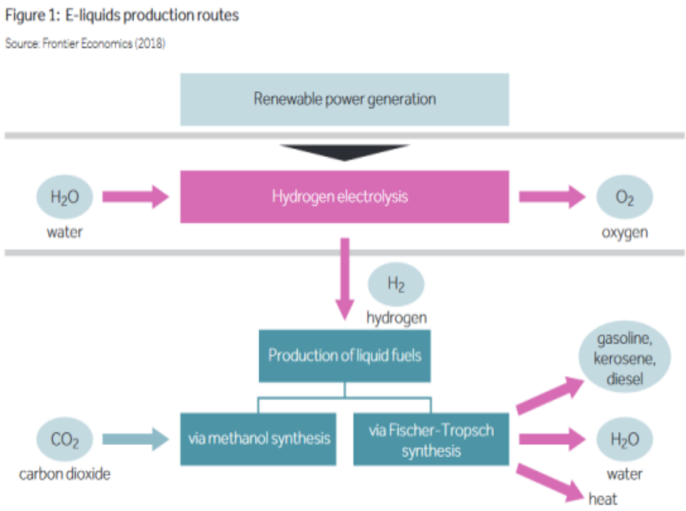
Many fuel routes (WTT) can be considered towards 2050

E.g. Advanced biofuel pathways

Multiple routes



E.g. e-fuels



Fuel Scenarios 2050

Fuel "family" (Feedstock / production technology)

Fuel-Scenario	Biofuel/waste	efuel	Fossil
Advanced biofuels	90%	10%	-
Mixed	50%	50%	-
efuels	-	100%	-
Limited fossil	80%	10%	10%

✓ (BEC)CCS

Note: BECCS refers to biofuel production routes coupled with CCS (allowing negative emissions)

Comparison of different fuel "family" shares being used in the different fuel scenarios (corner-points).

Fuel scenarios have been drafted independently from the powertrains scenarios.

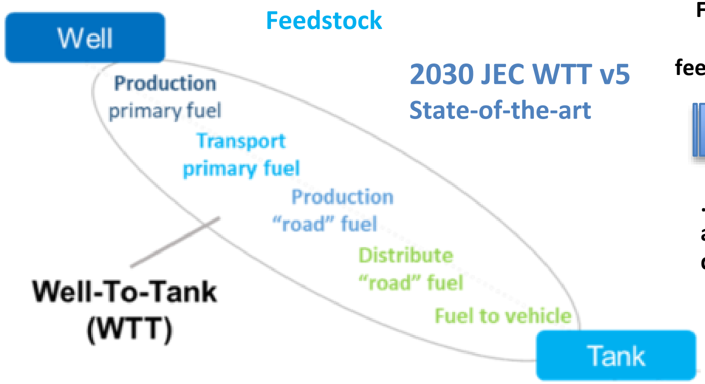
The interactions between these two scenarios will be detailed in the WtW study.

Note:
- *Basis: JEC WTT v5 – 2030 extended towards 2050*
- *Drop-in fuels compatible with existing powertrains*

WTT - Fuel pathways per type of fuel

The WTT intensity of a fuel is determined by factors such as feedstock used and production technology

2030 (JEC) → 2050 (ERTRAC)



2030 JEC WTT v5
State-of-the-art

From individual fuels (different feedstocks/technologies)

… to fuel scenarios as combinations of different pathways

Improved WTT values for individual fuels (2050 technology + low carbon electricity) grouped in the four fuel scenarios:

Fuel "family" (Feedstock / Technology)

Scenario	Biofuel/waste	efuel	Fossil	(BE)CCS
Advance biofuels	90%	10%	-	✓
Mixed	50%	50%	-	✓
efuels	-	100%	-	✓
Limited fossil	80%	10%	10%	✓

Selected WTT pathways for the 2050 projections

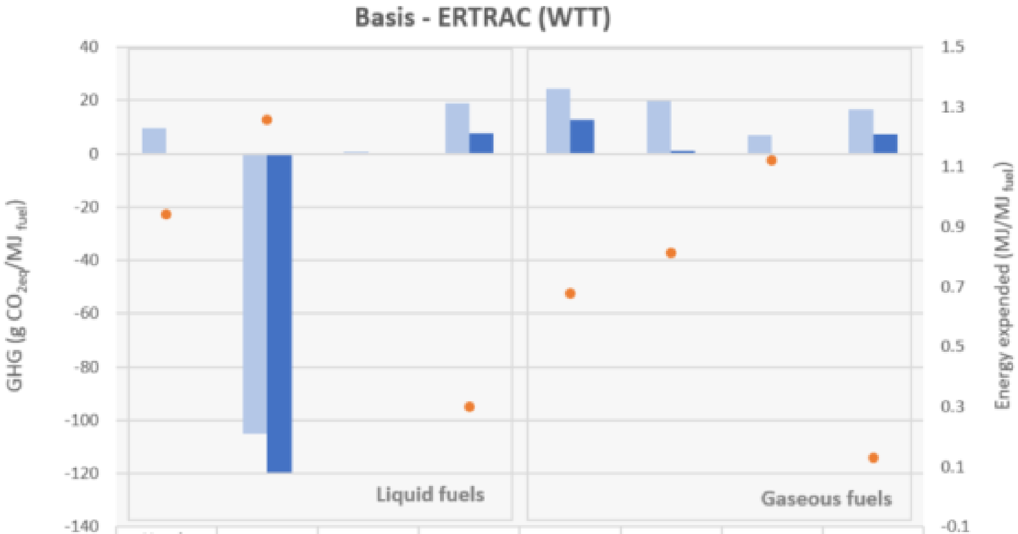
Basis: JEC WTT v5 – 2030 / Drop-in fuels compatible with existing powertrains

- Advanced biofuel / waste from wood & agriculture residue (90%) + Waste e.g. UCO (10%). Ratio based on ENSPRESO [JRC 2019].
- E-fuels: mix of CO_2 from concentrated sources (25%) & Direct Air Capture (75%)
- H_2: 100% electrolytic but in limited fossil scenario (50% electrolytic + 50% SMR+CCS)
- Natural gas: Depending on the fuel scenario, NG, biomethane (from municipal waste and waste wood gasification) or e-methane have been considered.

WTT - Fuel pathways per type of fuel

The WTT intensity of a fuel is determined by factors such as feedstock used and production technology

2030 (JEC) → 2050 (ERTRAC)



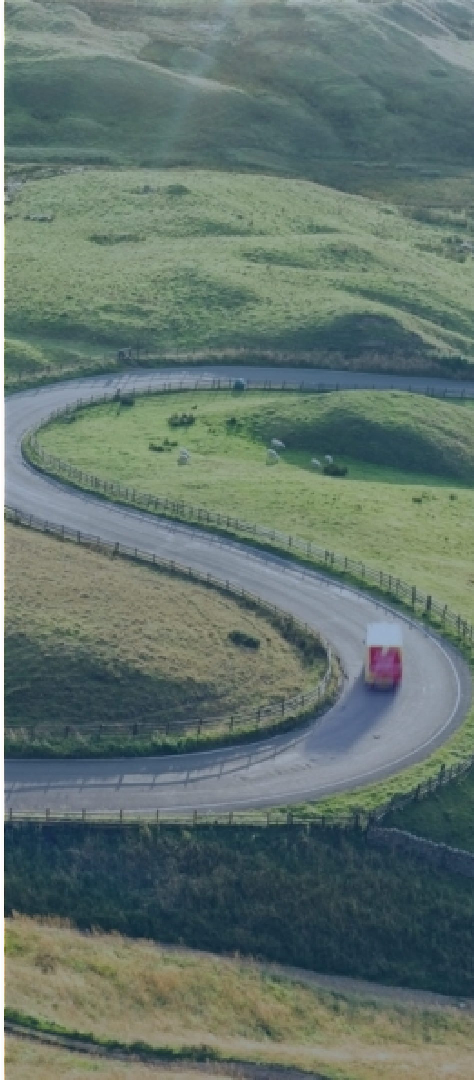
	Liq adv biofuel	BECCS	e-fuel (liq)	Fossil liq	H2	LBM	e-LNG	Fossil NG
JEC, 2030, GHG	9.4	-105.1	0.73	18.9	24.6	19.55	6.7	16.6
ERTRAC, 2050, GHG	0.05	-119.4	0.1	7.8	12.7	0.9	0.0	7.2
ERTRAC, 2050, Energ exp	0.94152	1.2565	1.675	0.2989	0.67795	0.81525	1.122675996	0.13125

Improvements modelled towards 2050 show GHG reduction due to:

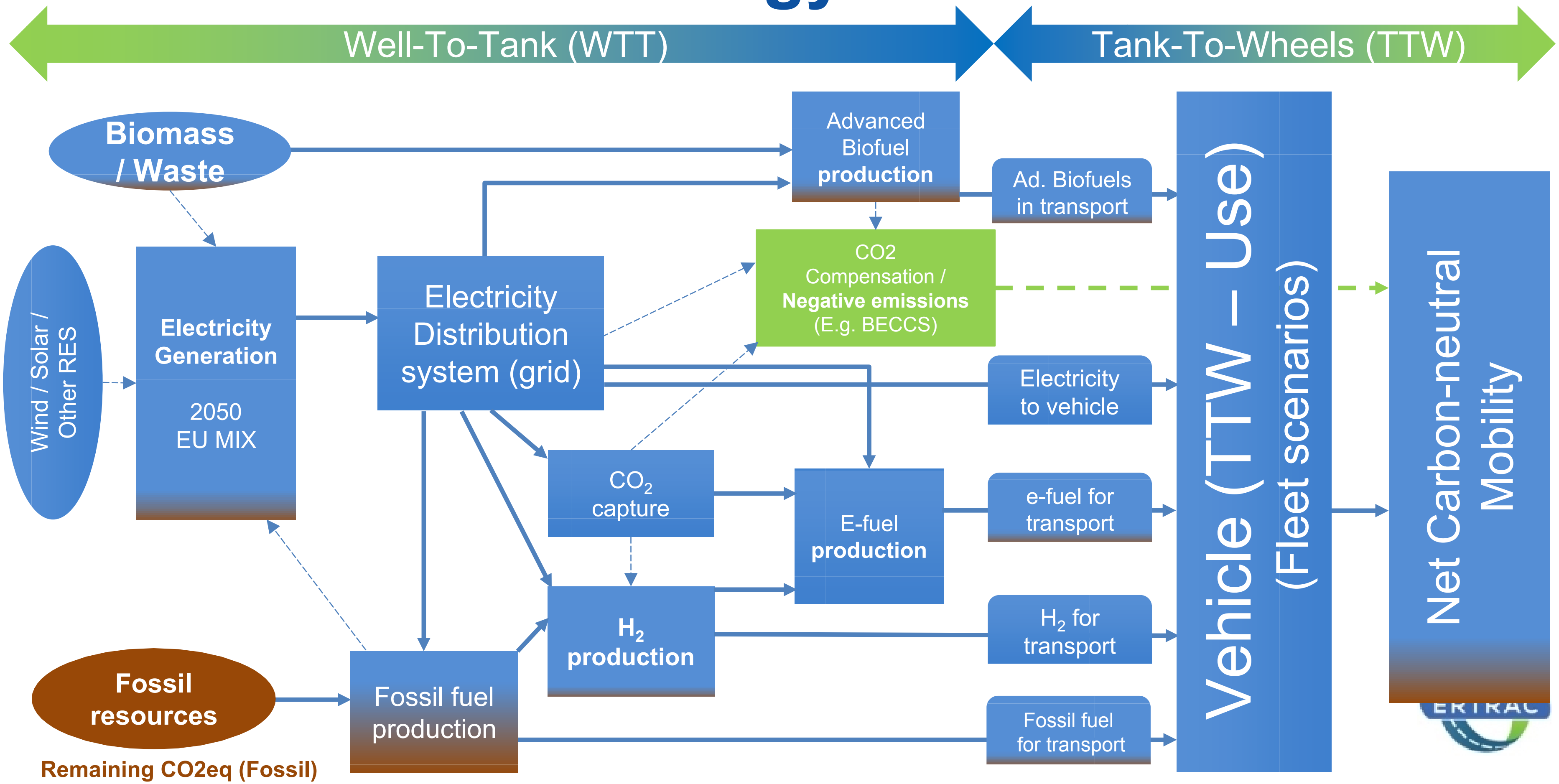
- Process electrification
- GHG reduction upstream/refining based on external reports
- Transport steps with ~50% lower GHG emissions (e.g. maritime / IMO)

N2O and CH4 emissions linked to biofuel production processes kept as in 2030 state-of-the-art (JEC WTT v5)

Overview of the WTT study



Results Fleet & Energy scenarios



Results Fleet & Energy scenarios

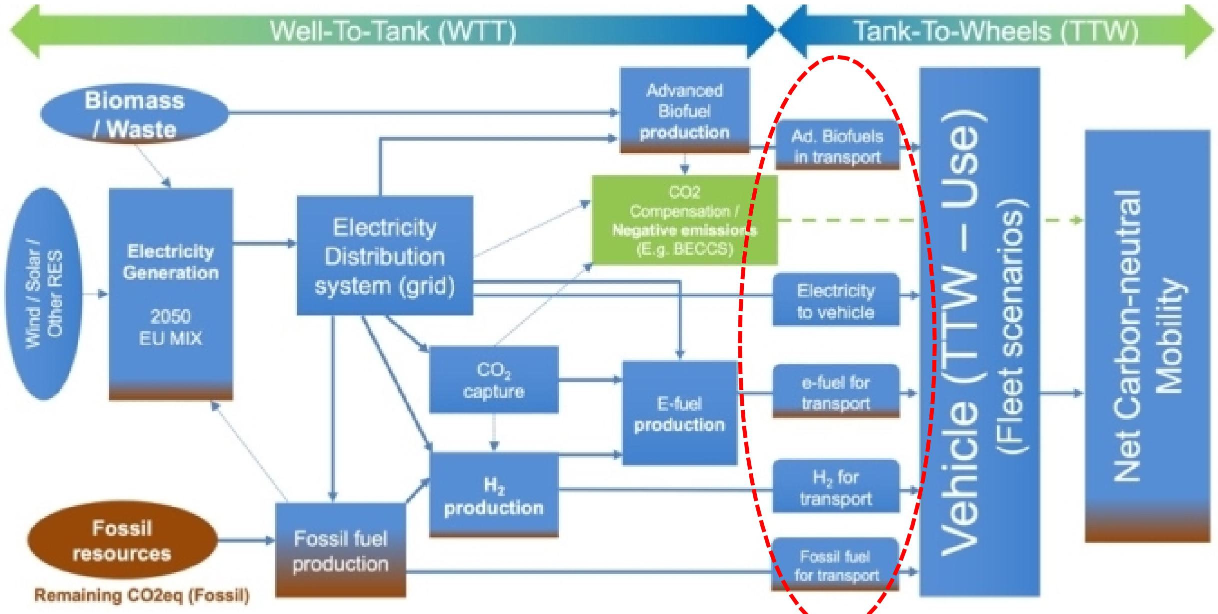
?

Question 1:

How much

- **fuel**
- **hydrogen**
- **electricity**

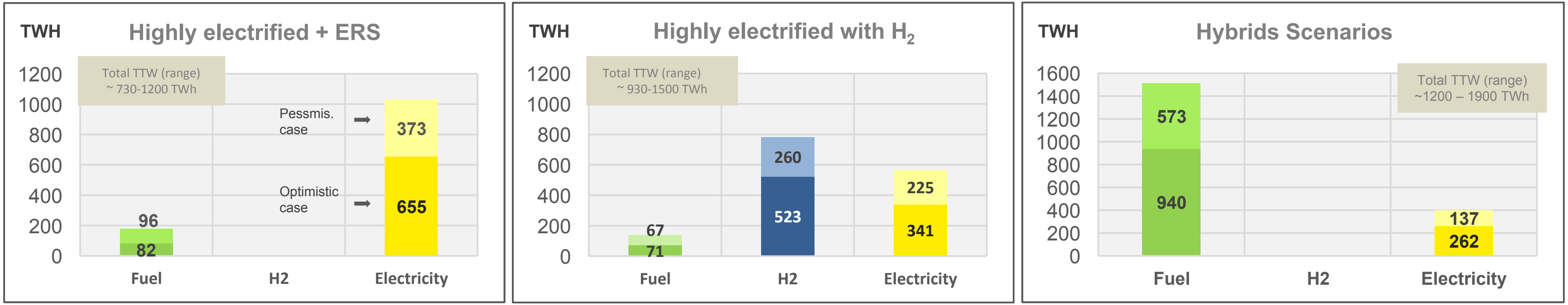
could be required (use) in EU Road Transport by 2050? (TtW, TWh).



ERTRAC

Question 1:

How much **fuel/hydrogen/electricity** could be required (use) in EU Road Transport by 2050? (TtW, TWh).



Significant reduction of fleet-average TTW Energy Consumption:

The total TTW energy consumption could range between ~730 and 1900 TWh. A significant reduction is shown in all scenarios considered **(45% to 80% savings)** in total energy requirement versus 2015.
(As a reference, 290 Mtoe consumed in the EU road transp. 2015 <> 3400 TWh).

Fuel: **Significant reduction** compared to EU road transport sector in 2015.

In the highly electrified scenarios the savings in fuel consumption are up to 98%.
The highest use of fuel (Hybrids-Scenario) varies between 940 and 1510 TWh
→ 55% to 70% savings

Hydrogen:

The use of Hydrogen ranges between 520 and 780 TWh (Highly electrified with H2 scenario).

Electricity: Road Vehicles consume directly up to 35% of total 2015 EU final electricity consumption.

The use of electricity ranges from ~260 up to 1000 TWh (the latter in the highest electrified scenario (HE + ERS scenario) which represents ~35% of total EU-wide electricity consumption in 2015).

Efficiency is paramount (Delta "Optimistic-Pessimistic")

Technical measures (A,B and C) targeting efficiency improvement
- Vehicle
- Traffic condition
- System improvements

Potential to reduce the energy consumption by ~35-40%, showing the importance of boosting R&D in these areas.

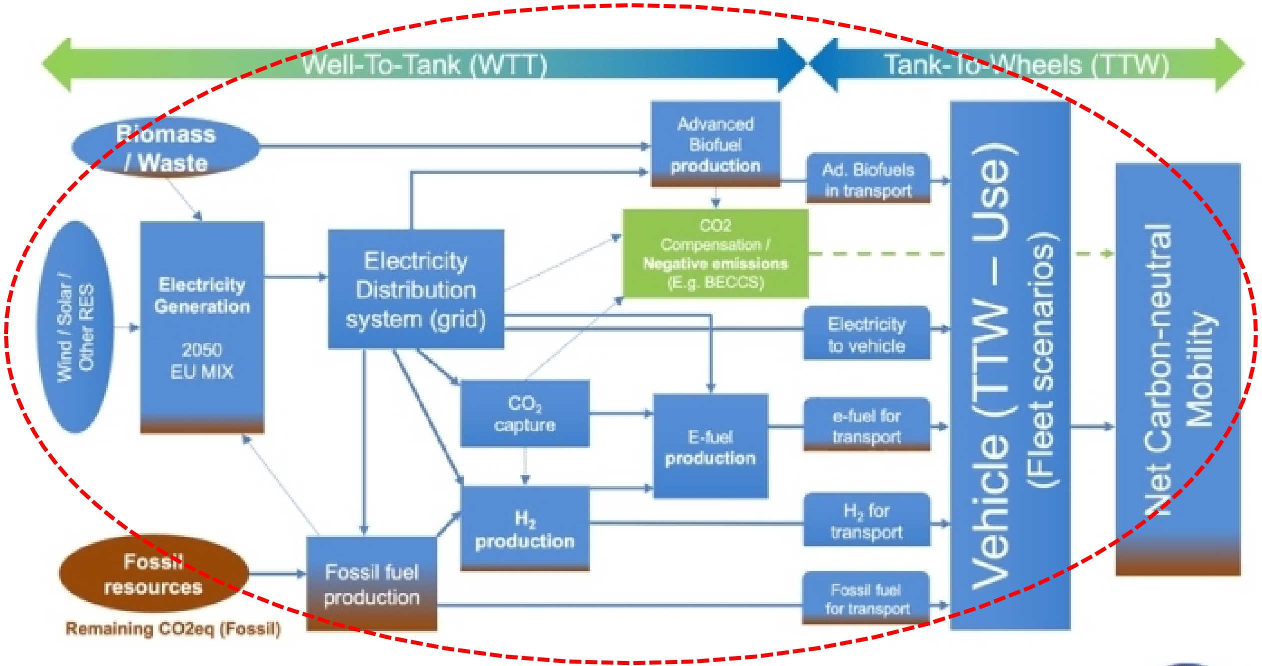
Results Fleet & Energy scenarios

?

Question 2:

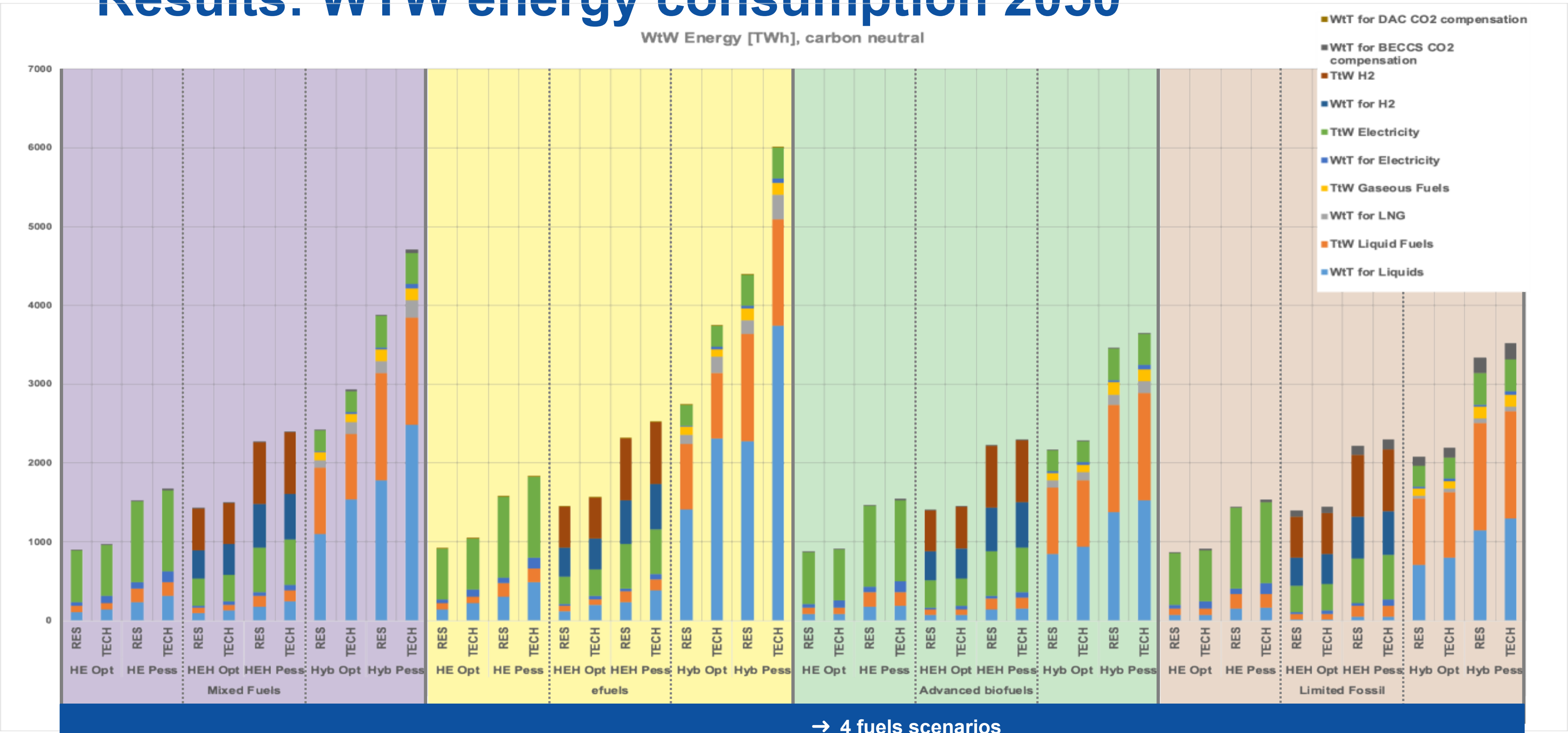
How much energy could be required to reach a net CO_{2eq} neutral road transport in Europe? (WtW, TWh)

What leverage have the different scenarios?



ERTRAC

Results: WTW energy consumption 2050



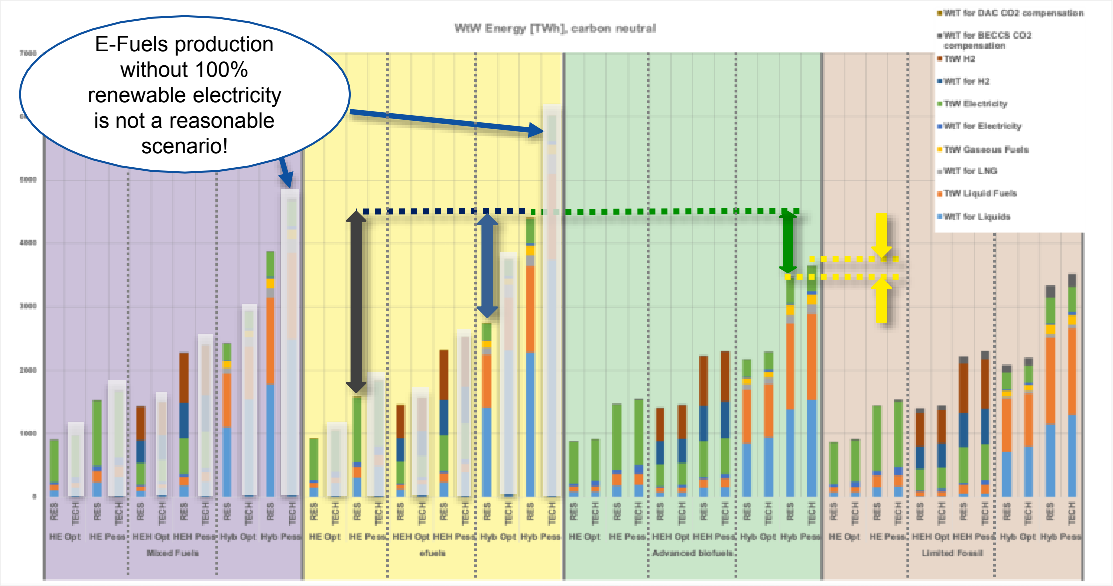
Energy consumption by fuel, WTT and TTW, shown for

- → **4 fuels scenarios**
- → **3 Fleet scenarios** combined with Optimistic and Pessimistic measures
- → **2 Electricity production scenarios**

Results Fleet & Energy scenarios

? Question 2:

How much energy could be required to reach a net CO_{2eq} neutral road transport in Europe?
What leverage have the different scenarios? (WtW, TWh, CO_2 neutral)



The **variation in the WTW Energy** demand between

the fleet scenarios is up to	**~3000 TWh**
the optimistic–pessimistic case is up to	**~1500 TWh**
the fuel scenarios is about	**~1000 TWh**
electricity production scenarios up to	**~250 TWh**

Growing leverage

The share of TTW in the whole WTW energy consumption varies between **~50% up to 90%,** increasing with the level of fleet electrification.

DISCLAIMER
ERTRAC 2050 CO_2-Study
RESULTS

➜E-Fuels production without 100% renewable electricity is not a resonable scenario!
➜In the following slides we mainly focus on the 100% renewable electricity scenario (RES), combined with all fleet and fuel scenarios.

ERTRAC

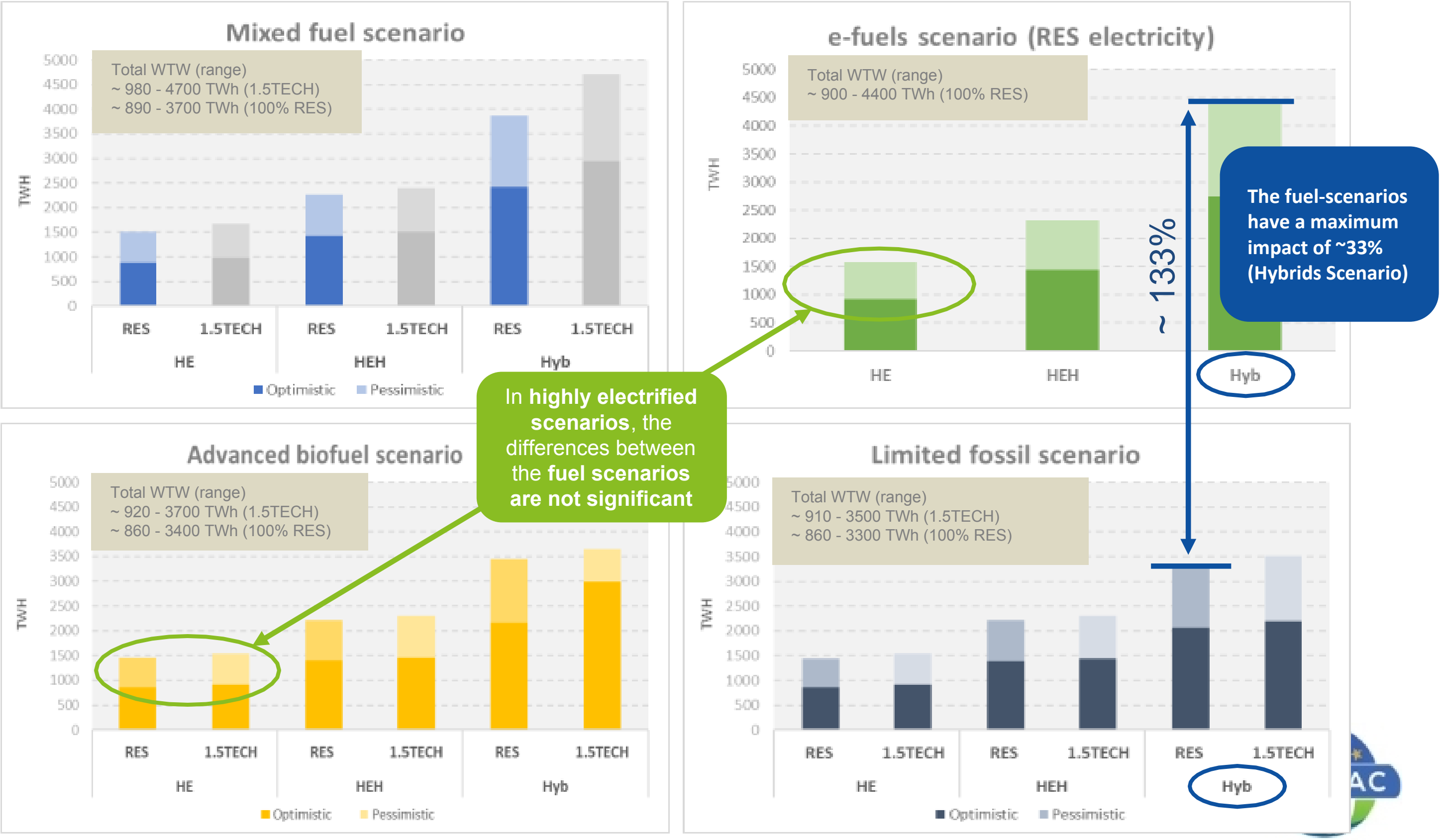
Results Fleet & Fuel scenarios

?

Question 3:

How does the fuel-scenarios influence the energy request in a net CO_{2eq} neutral road transport?

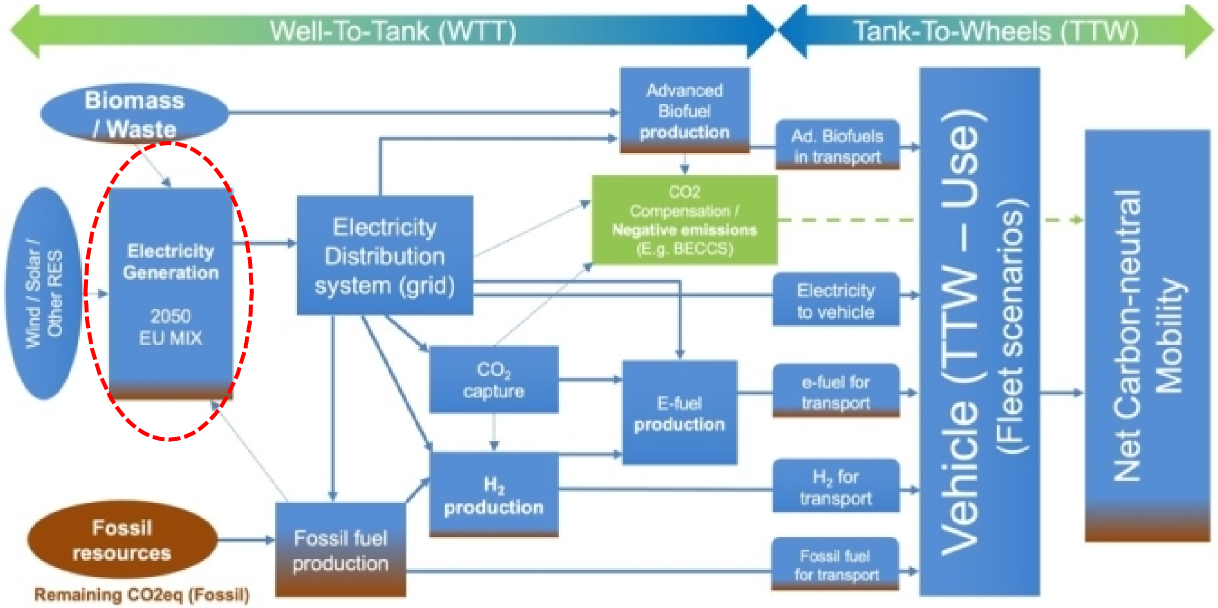
(WtW, TWh, CO_2 neutral)



Results Fleet & Energy scenarios

?

Question 4:
How much electricity is needed in the scenarios overall?

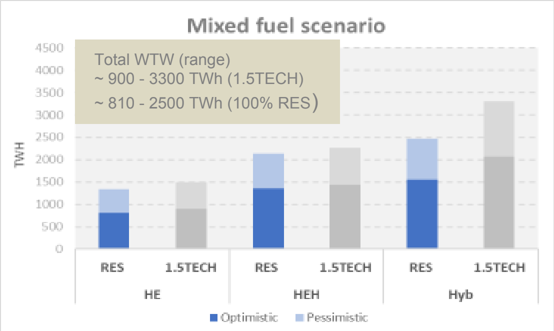


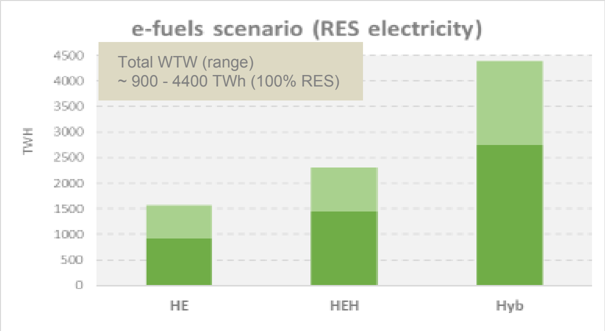
ERTRAC

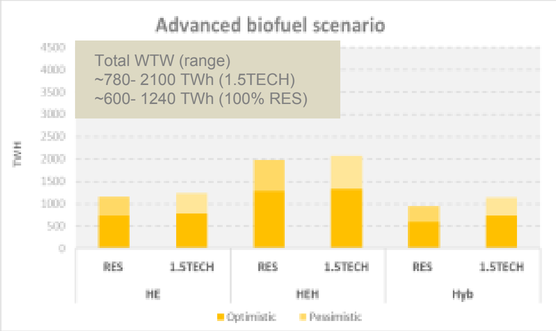
Results Fleet & Energy scenarios

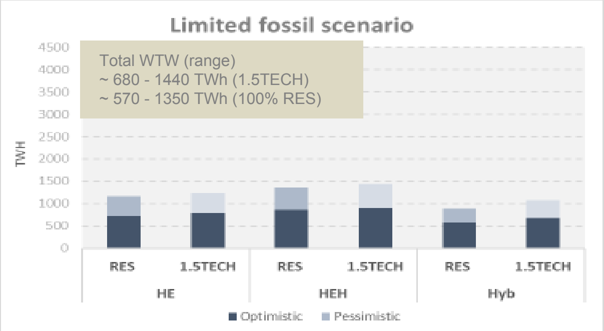
Question 4:

How much electricity is needed in the scenarios overall?









→ The total electricity generated responds to the needs for electricity in the fuel production (WTT) as well as the final use in the directly electrified powertrains (BEVs) or indirectly electrified (ICE with e-fuels / FCHEV with green H2).

→ **Wide variation in total electricity request:**
Range between **600 TWh up to 4400 TWh** (representing from **~20% up to ~160% of** total EU-28 final electricity consumption in 2019 (2800 TWh).

→ **The limited fossil and advanced biofuel scenario result in the lowest electricity needs (between ~20% to 30% of EU-28 final electricity consumption 2019).**

→ **The absolute extreme values for electricity request are always linked with the Hybrid Fleet: In combination with e-Fuels the absolute maximum is reached, in combination with "adv. biofuels" or "limited fossil" the absolute minimum is reached.**

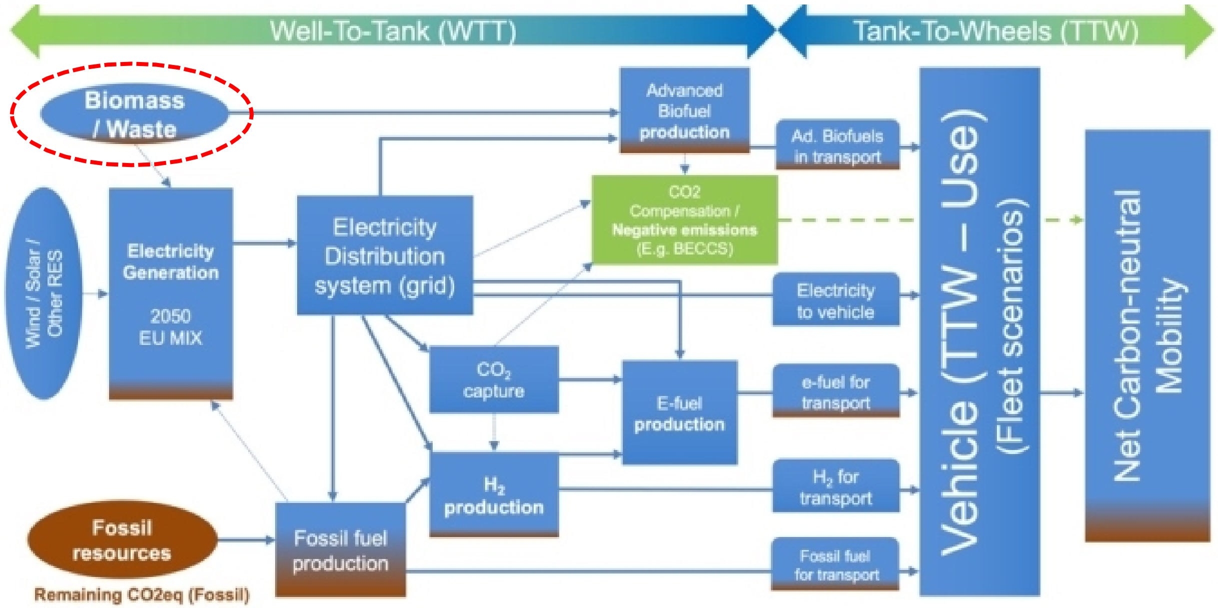
→ **In the highly electrified scenarios, the electricity demand is towards the lower-end of the different explored scenarios (~40% to 55% of EU28 el. Cons. 2019).**

→ **The differences between the electricity scenarios (RES and 1.5TECH) are pretty small.**

Results Fleet & Energy scenarios

?

Question 5:
How much "bio-mass, waste" is required in all the scenarios?
(WtW, TWh, CO_2 neutral)



Results Fleet & Energy scenarios

Question 5:

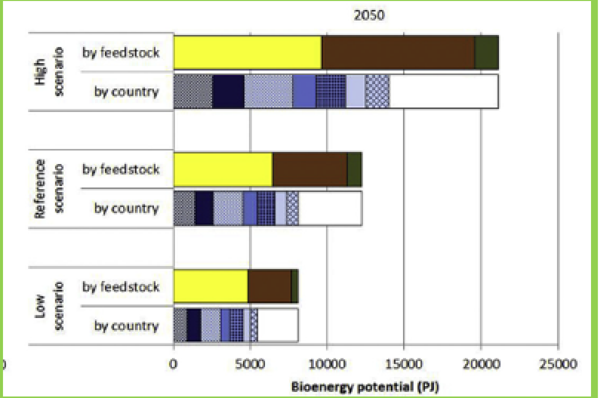
How much „biomass and/or waste“ may be required in all the scenarios? (TWh)

The **demand from Road Transport for Biomass and/or Waste** for the production of advanced biofuels could range from **~5 -100 Mtoe/y.**

➜ The highest consumption refers to the Hybrids scenario (~65 Mtoe/y up to ~100 Mtoe/y opt. /pess. case)

➜ The limited fossil scenario (10% fossil share) reduces a little bit (~10 Mtoe/y) the pressure on biomass.

According to the ENSPRESO REPORT [JRC 2019], the **total sustainable bioenergy supply potential at European level (2050)** could range from to **~190 Mtoe/y** (~ 8,000 PJ) up to **500 Mtoe/y** (~21,000 PJ/y).

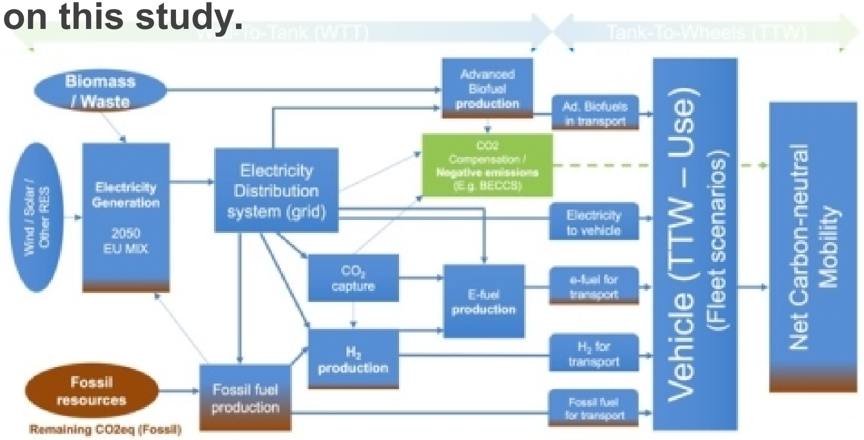


Additional investigations will be needed to verify the potential considering the needs of other sectors.

Results Fleet & Energy scenarios

? Question 6:
What is the best fuel/fleet combination?

This question cannot be answered relying only on this study.

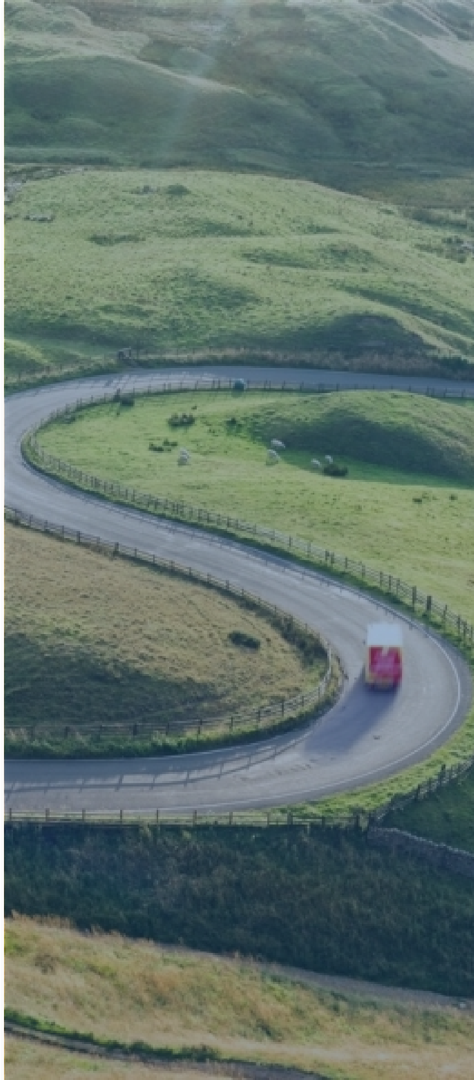


System optimization cannot be based on an extreme scenario approach.
Further research, innovation and development work will be needed to assess and establish the optimal solutions, on the basis of various criteria.

Such criteria might be those listed below (out of the scope of the CO_2 evaluation group):

- Production and storage capacity
- Life Cycle Assessment (LCA) to account for the emissions and energy required for infrastructure and vehicle production
- Investments in infrastructure and energy production facilities
- Cost of energy production and distribution as well as vehicle technology development
- Land use, water use and needed resources; and their allocation between different sectors
- Different locations for energy production (EU or MENA-Region)
- Customer acceptance of specific vehicle types and fuels
- Acceptance of CCS

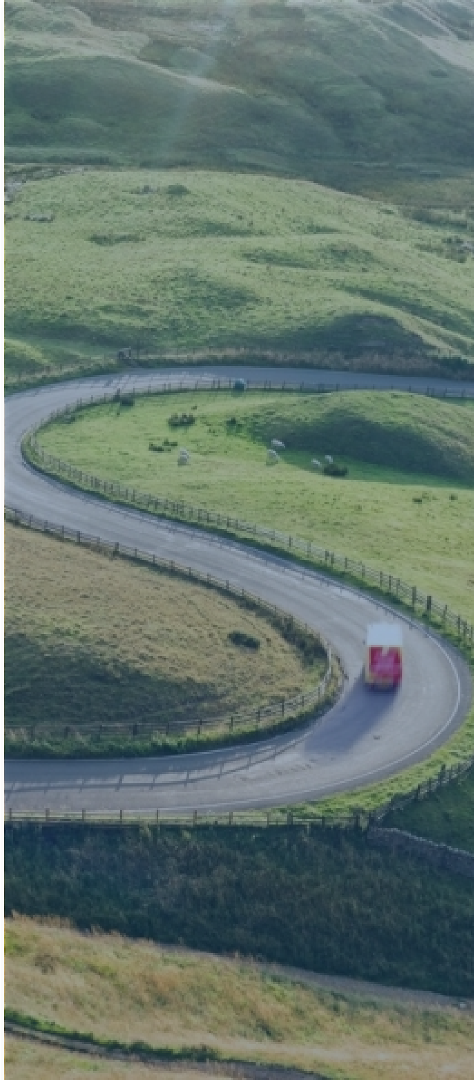
CONCLUSIONS



Conclusions

- To achieve "carbon-neutral" road transport (WtW) in 2050, **drastic changes** are needed in all three areas:
  - Vehicle fleet and efficiency, powertrains and traffic technology,
  - Infrastructure
  - Energy Production (electricity, hydrogen and renewable fuels)
- **The complete and robust carbon-neutrality** of road transport could be achieved with a **mix of technologies, where electrification** is the **key element** for the reduction of the CO_2 emissions.
  - BEV (possibly combined with ERS),
  - PHEV,
  - FCEV and Advanced Hybrid powertrains.

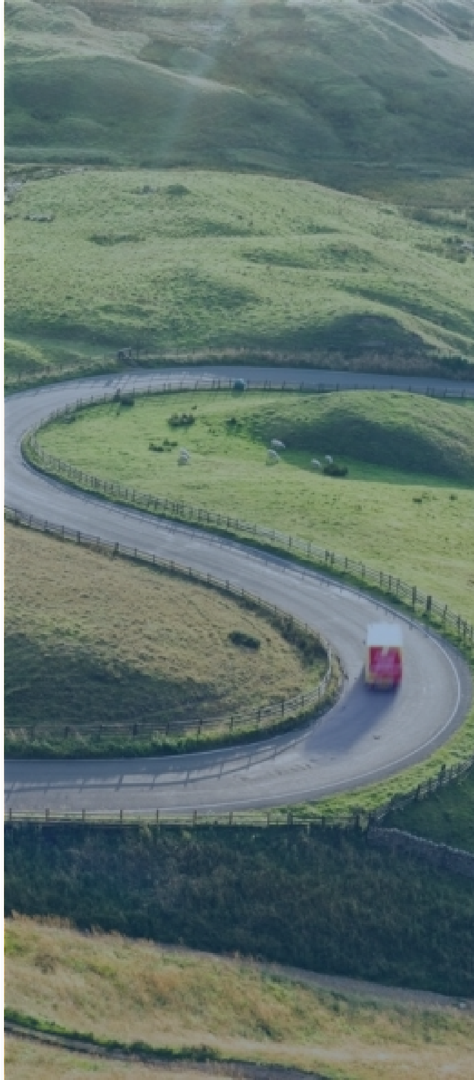
  *Note: the mix of these powertrain options **will strongly depend** on the development of the infrastructure (charging infrastructure, ERS, hydrogen filling stations, production capacities for renewable fuels etc.)*
- The overall **WtW energy demand decreases drastically with fleet electrification**



Conclusions

- The **energy efficiency measures identified** (A, B and C) **reduce the energy / fuel consumption in all scenarios in a very significant way.**
- The **demand for fuels decreases massively in all scenarios**

  (in highly electrified scenarios up to 95% savings).
- **In strongly electrified scenarios**, the **WtW differences in energy consumption** between the fuel scenarios are quite **small.**
- The total **demand for electricity** in road transport will **increase** (energy production + use in vehicle)
  - **20%-30% of total EU28** el.cons. 2019 in advanced biofuels or limited fossil scenarios combined with hybrid fleet.
  - **40%-55% of total EU28** el. cons. 2019 in highly electrified scenarios
  - **up to 1.6 time of total EU28** el. cons. 2019 if e-fuels are used along with a hybrid fleet
- The largely **Carbon-Neutral production of electricity** is a prerequisite for “carbon-neutral” road transport in all fleet and fuel scenarios.



Conclusions

Research Recommendations and Priorities:

1. Enable fleet mix change by

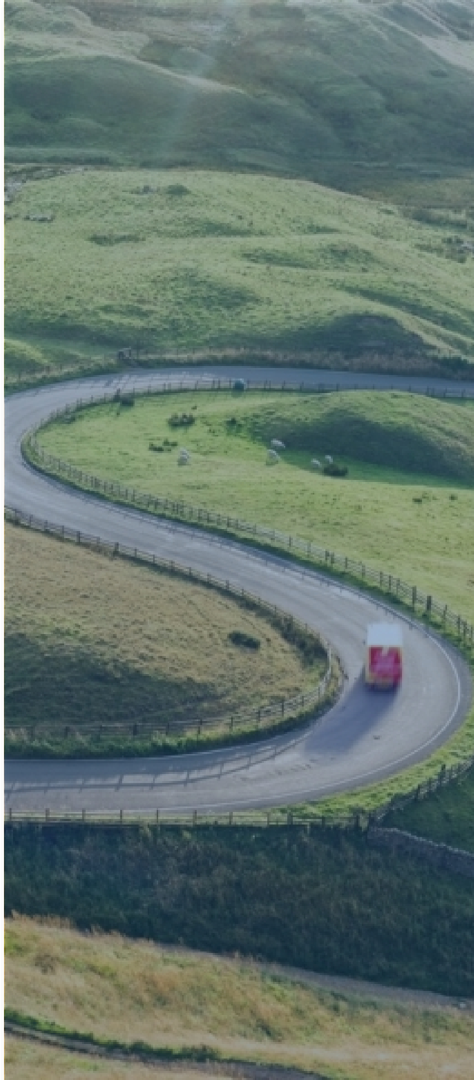
- ➜ Improving powertrain technology: cost, range, functionality, …
- ➜ Adapting infrastructure technology and concepts

2. Efficiency improvements by

- ➜ Measure A: Vehicle
- ➜ Measure B: Traffic conditions
- ➜ Measure C: Traffic Reduction Technologies

Beside Road Transport:

- ➜ Renewable electricity generation capacity (inside and outside of Europe)
- ➜ Net carbon-neutral H2 and fuel production (inside and outside of Europe)
- ➜ Technology and capacity of CCS and DAC
- ➜ Availability of raw materials and sustainable feedstocks (appraised in a life-cycle analysis perspective)

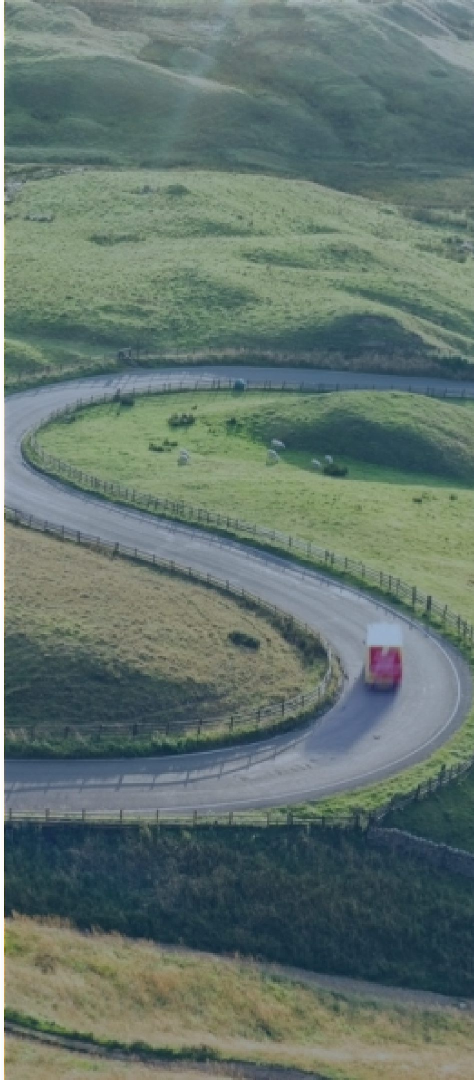


Next steps

➜Stay tuned for the detailed presentation to ERTRAC members (tentative date: 29th April)

➜The publication is under finalization.

In the meantime, you can find the previous publication online: *EU road vehicle energy consumption and CO2 emissions by 2050 – Expert-based scenarios*



ERTRAC CO_2 Evaluation Group*

Zissis Samaras
Aristotle University
Academia

Staffan Lundgren
Volvo (trucks)
OEM

Christophe Petitjean
Valeo
Supplier

Peter Prenninger
AVL
Research Provider

Simon Edwards
Ricardo
Research Provider

Marko Gernuks
Volkswagen(cars)
OEM

Gaetano de-Paola
IFPEN
Cities and Regions

Holger Heinfelder
Umweltbundesamt (AT)
Member States

Stephan Neugebauer
BMW
Chair

Georgios Fontaras
JRC
CO_2 assessment for the fleet

Jette Krause
JRC
CO_2 assessment for the fleet

Marta Yugo
Concawe
Energy / CO_2 assessment for the WTT / fuel scenarios

Roland Dauphin
Concawe
Energy / CO_2 assessment for the WTT / fuel scenarios

** Each Member of ERTRAC Executive Group nominated specific experts*

Thank you!