Sustainable Energies and Powertrains for Road Transport

Towards Electrification and other Renewable Energy Carriers

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Contents of this presentation

- Introduction
- Energy Carriers
- Well-to-wheel evaluation of several fleets & fuels scenarios
- Conclusions

Introduction: who?

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Introduction: why a new, combined roadmap?

- Present an up-to-date perspective on all renewable energies & powertrains options for road transport
  - Provide R&D recommendations for Horizon Europe
  - Input to 2Zero Partnership
- Develop further content based on & beyond existing roadmaps
  - Energy Carriers (2014); ICE Powertrains (2016); Electrification (2017)
  - Taking into account
    - Well-to-Wheels assessment
    - Life Cycle Assessment when available
  - Reaching carbon neutrality by 2050 (net zero CO_2 emissions)
  - Pollutant emissions control for air quality

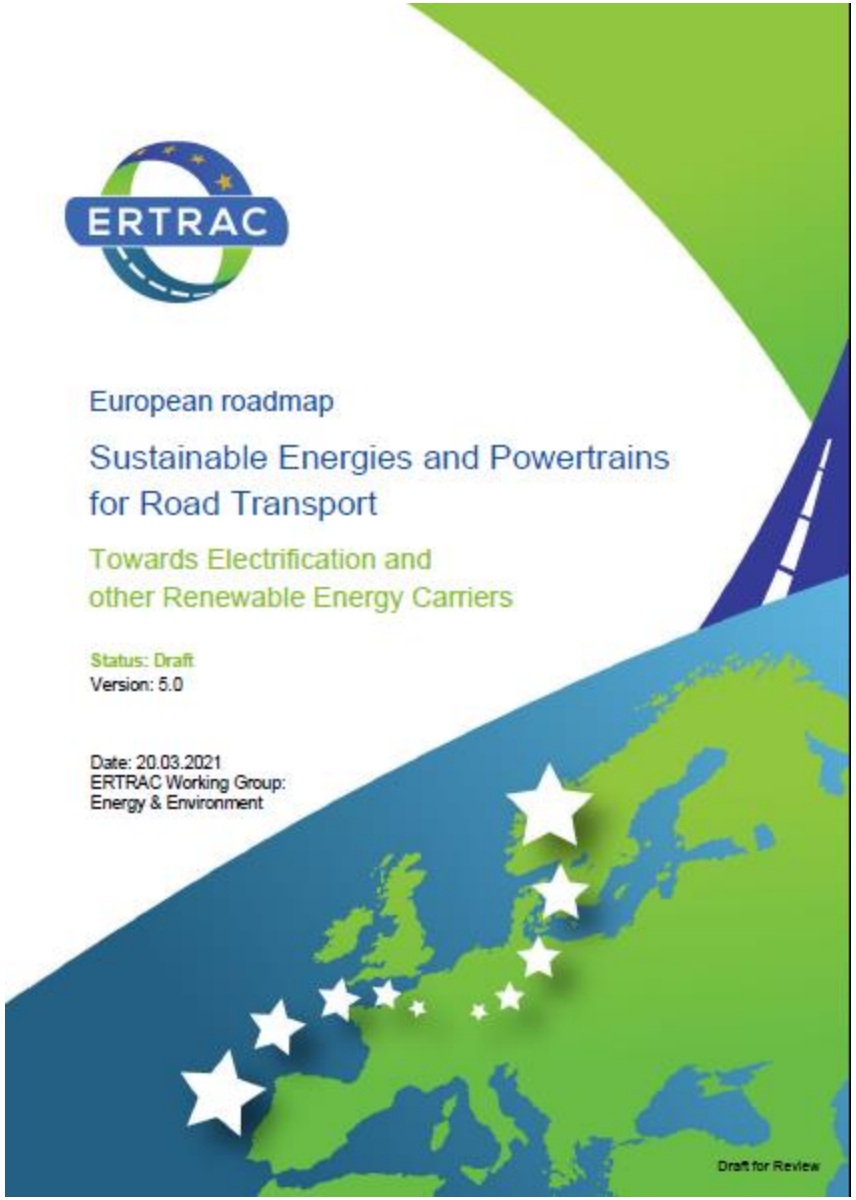
Introduction: how?

- Aiming at understanding
  - The status of the technologies
  - The projections for the penetration of alternative energy carriers & powertrain technologies in the next decades
  - The associated infrastructure developments

  - Identifying main R&D needs for road transport
    - Including a consideration of different use cases

Introduction: what?

- Main chapters:
  1 – Introduction
  2 – Renewable Energy Carriers
  3 – Powertrain Options
  4 – Infrastructures
  5 – A Systemic View
  6 – Research Recommendations



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Energy carriers: Definition

- Definition
  - Not energy sources in themselves (“primary energies”)
  - But intermediates that “carry” energy from the primary energies to their final use – road transport in this instance
  - Three universal steps

Feedstock (or primary energy) ➔ Process ➔ Energy carrier

Availability, cost, carbon intensity, intermittency, water consumption, impact on biodiversity etc.

Technical maturity, cost, yield, water consumption, land use, raw materials needs, pollutants emissions, wastes toxicity etc.

Suitability, storage and transportation, energy density, safety, pollutants emissions, cost, customer acceptance etc.

Energy carriers: Definition

No identified single energy carrier has the best-in-class properties in each of the three steps

- **Relative pros and cons, depending on the specific transport needs**
- **“No silver bullet”**

Feedstock (or primary energy) ➔ Process ➔ Energy carrier

Availability, cost, carbon intensity, intermittency, water consumption, impact on biodiversity etc.

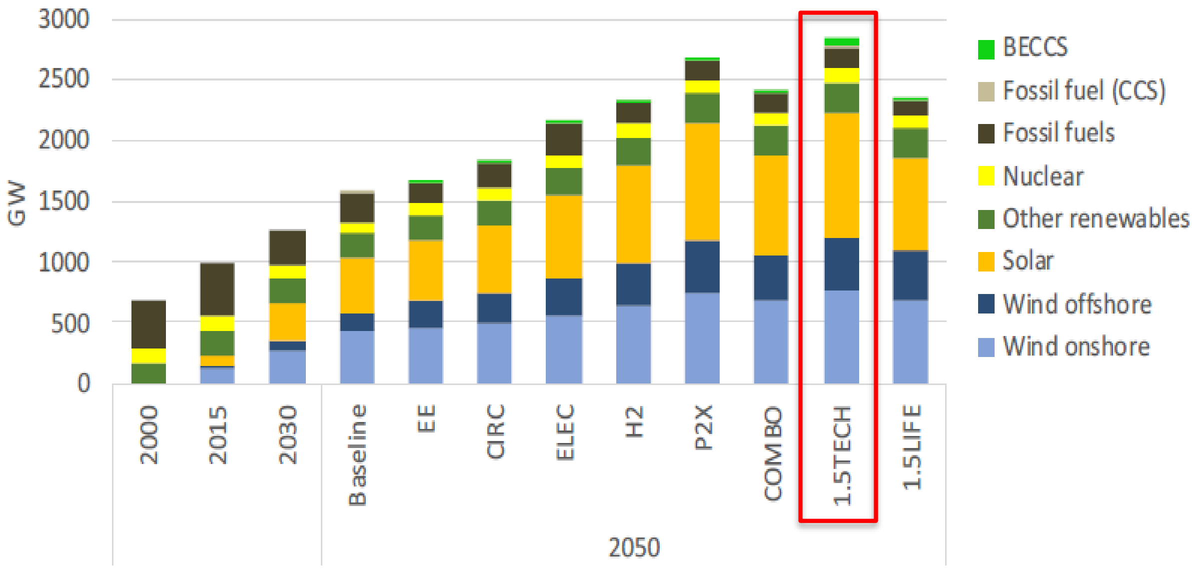
Technical maturity, cost, yield, water consumption, land use, raw materials needs, pollutants emissions, wastes toxicity etc.

Suitability, storage and transportation, energy density, safety, pollutants emissions, cost, customer acceptance etc.

Energy carriers: Electricity – main messages

- 1.5 TECH: from 23% of final energy consumed (2017) to > 50% in 2050
  – Installed capacity multiplied by ~3
- 1.5 TECH scenario from “A Clean Planet For All”
  – Net negative CO_2 emissions (“WtT”)
  – Renewable Energy Sources (RES) power generation capacity: from 31% (2017) to 83% in 2050
    - Wind Energy (onshore/offshore) + Photovoltaic 69%
      – Continuously increasing load factor
    - Biomass with CCS 10%
    - Hydropower 4%
  – Nuclear power plants 12%
  – Natural gas with CCS 4%

Figure 24: Power generation capacity



Source: Eurostat (2000, 2015), PRIMES.

- Alternative Energy mix considered: 100% RES

Energy carriers: Electricity – main messages

- Change of paradigm
  - From electricity production meeting electricity demand on real-time basis…
  - … to grid balancing with
    - Digitalization to promote efficient cooperation between system operators
    - Increase of grid interconnections
    - Development of storage capacity
      - From pumped storage only to a variety of solutions

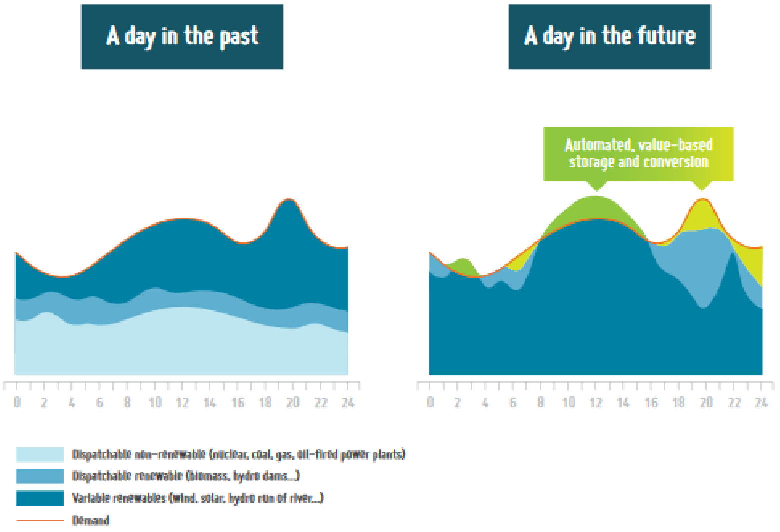
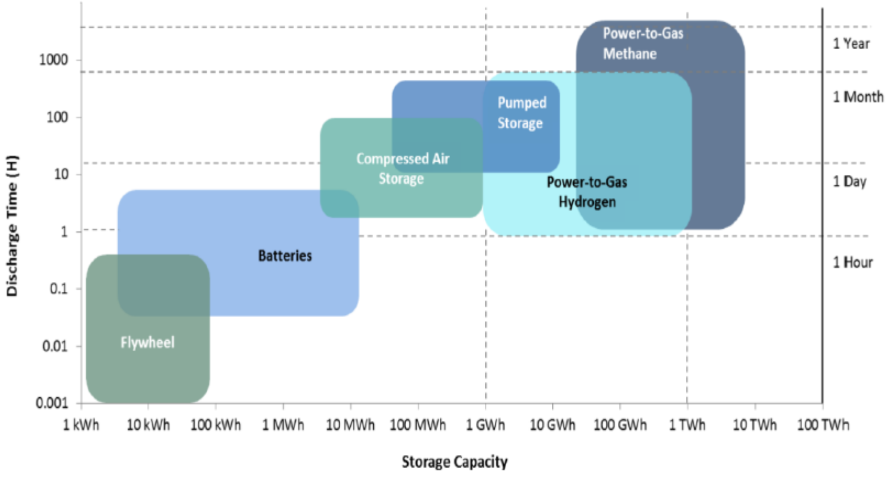
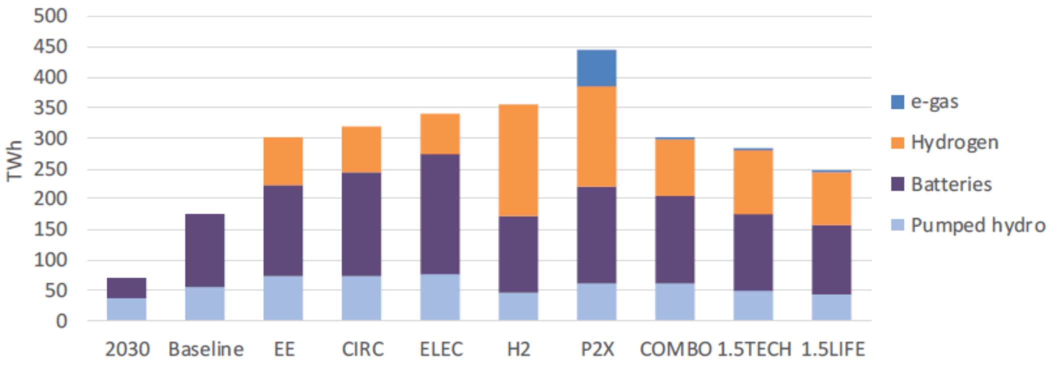


Figure 15: Overview of different electricity storage technologies



Source: European Commission (2017), Energy storage – the role of electricity[178].

Figure 26: Electricity storage in 2050

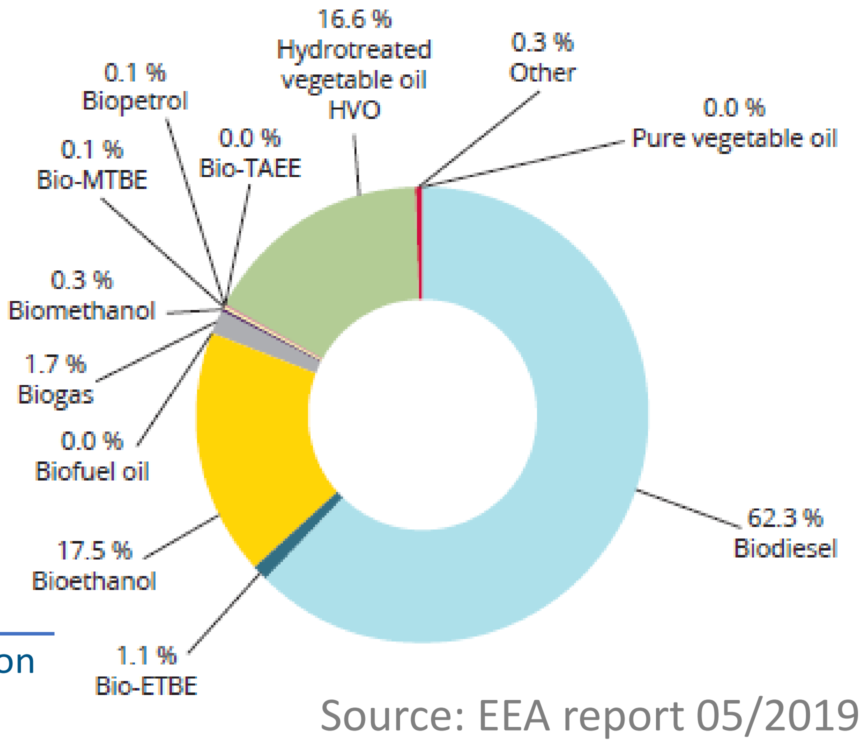


Source: PRIMES.

Energy carriers: Liquid fuels – main messages

- Description of the nature and production pathways of biofuels
  - ‘Food & Feed’/‘First generation’/‘State of the art’ biofuels
    - Ethanol, biodiesel (FAME), HVO
  - Advanced biofuels
    - Biomass to Liquid, Sugar to Diesel, Advanced ethanol and other alcohols, Algae to liquid, Bio-technological fuel production, tailor-made fuels from biomass
    - Biomethanol
    - MTBE, DME, OME

Overview of the biofuel supply (by type) in Europe in 2017



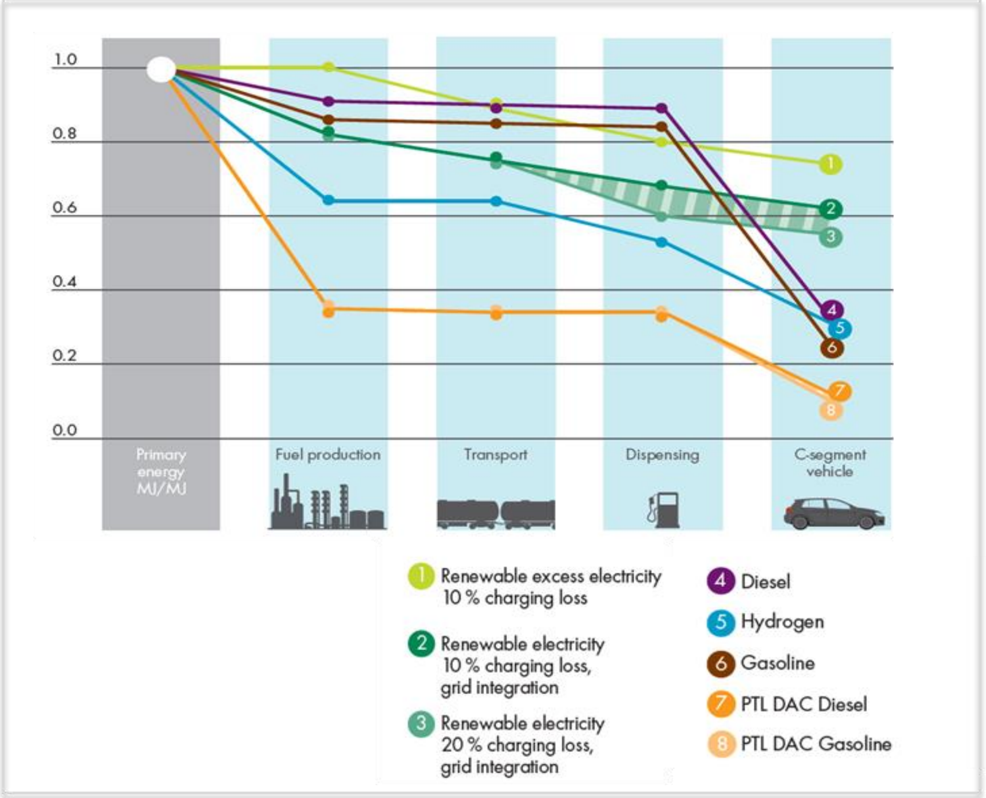
Source: EEA report 05/2019

Potential primary uses of biofuels

	Biofuels	Passenger Cars	Heavy Duty	Maritime	Aviation
Gas	Biomethane	X	XX	XX	
Liquids	FAME	XXX	XXX		
	HVO / HEFA	XXX	XXX	X	XXX
	Ethanol / alcohols	XXX	X	X	
	Synthetic Fuel (Gasification + FT, pyrolysis, HTL, etc)	XXX	XXX	XXX	XXX

Energy carriers: Liquid fuels – main messages

- Description of the nature & production paths of e-fuels
  - Hydrogen
  - CO_2 capture
  - E-fuels related technologies
    - Methanol and its derivatives: DME, OME, Methanol to Gasoline, Kerosene or Diesel
    - Fischer-Tropsch products
    - Olefins to Alcohols



Potential primary uses of e-fuels

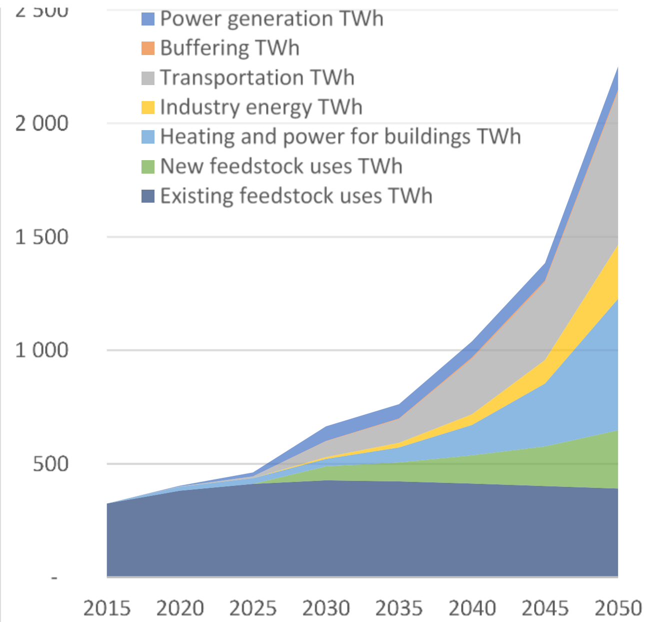
	E-fuels	Passenger Cars	Heavy Duty	Maritime	Aviation	Other sectors (not transport)
Gas	e-Methane (CH_4)	X	XX	XX		XXX
	e-Hydrogen (H_2)	XX	XX	X	X	X
Liquids	e-Ammonia (NH_3)		X	XXX		
	e-Methanol (CH_3OH)	XX	X	X		
	e-DME / e-OME	X	XX	XX		
	e-Gasoline	X				
	e-Diesel	X	XXX	XX		
	e-Jet				XXX	

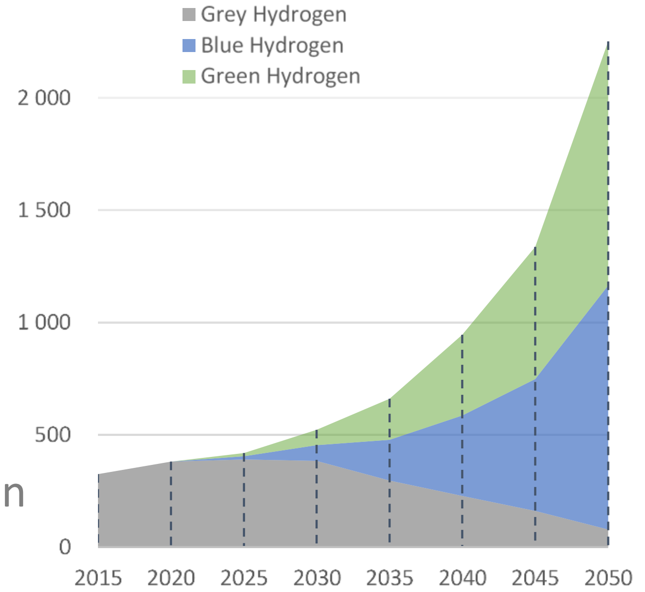
Source: Concawe Review, 2019

Energy carriers: Gaseous fuels – main messages

- Description of the nature and production pathways of Biomethane
  - Anaerobic digestion
    - Simultaneous production of biogas and fertiliser
  - Thermal Gasification
- Description of the production pathways of Power to Gas
- Hydrogen
  - From Renewable electricity (‘green)
  - From Steam Methane Reforming + Carbon Capture & Storage (‘blu
  - From Nuclear power plants (‘pink’)
  - From other renewable energy sources (e.g. biogas)
  - Its role as a masterpiece in the future energy system
    - Grid balancing and seasonal storage
    - Energy carrier in itself (e.g. for FCEV)
    - Unavoidable step for e-fuels production
  - Economics: importance of
    - The market critical size as capital costs are high
    - The price of renewable electricity

The possible share of different hydrogen types in different markets





Source: Hydrogen Europe, 2019

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Concept of the study

48 scenarios!

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

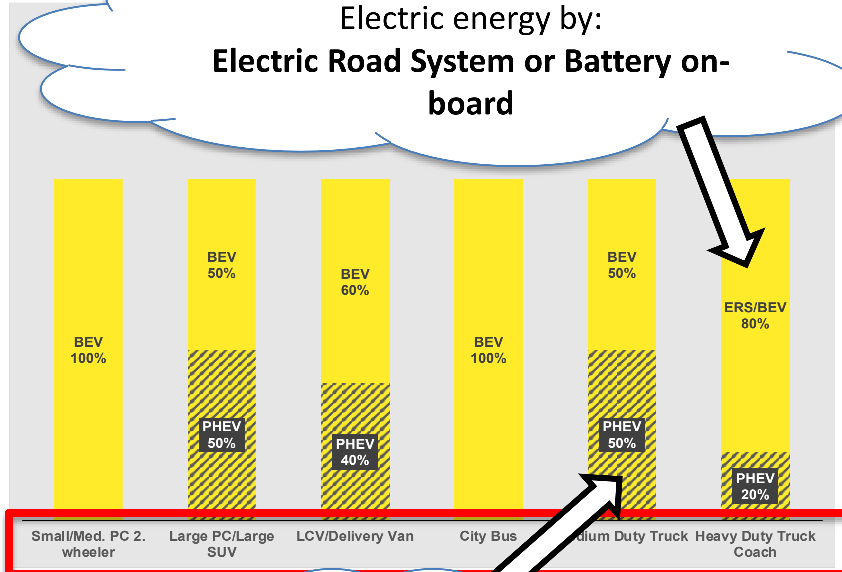
3 Powertrain Scenarios 2050

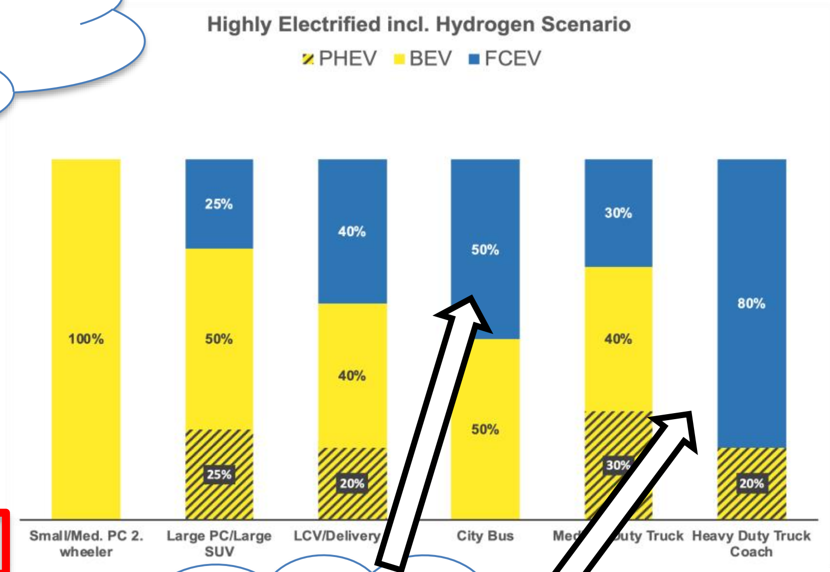
Scenarios assumptions as input for the study:

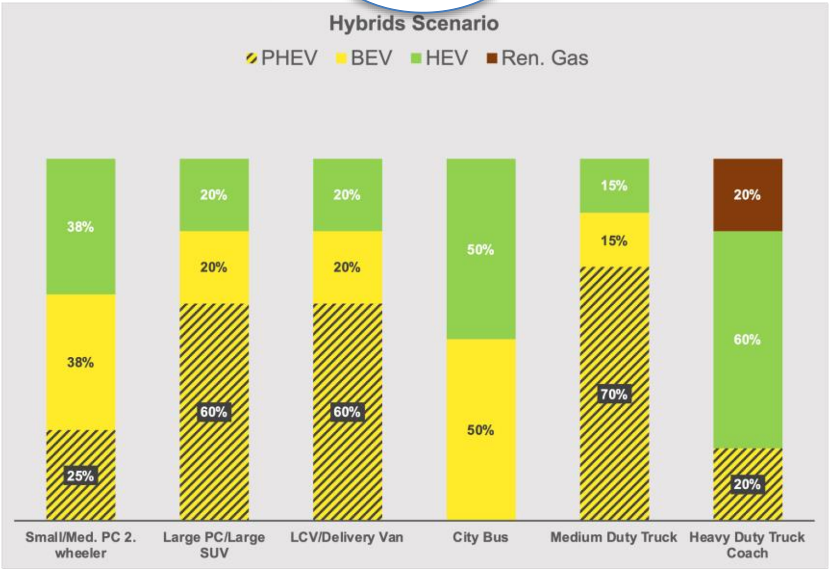
Hybrid Scenario, Why?

Maybe the infrastructure will not develop fully for Electric and Hydrogen

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







PHEV = ability to run a significant distance pure electric

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

...t powertrai... ...rner-points):

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

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%

✓ (BE)CCS

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

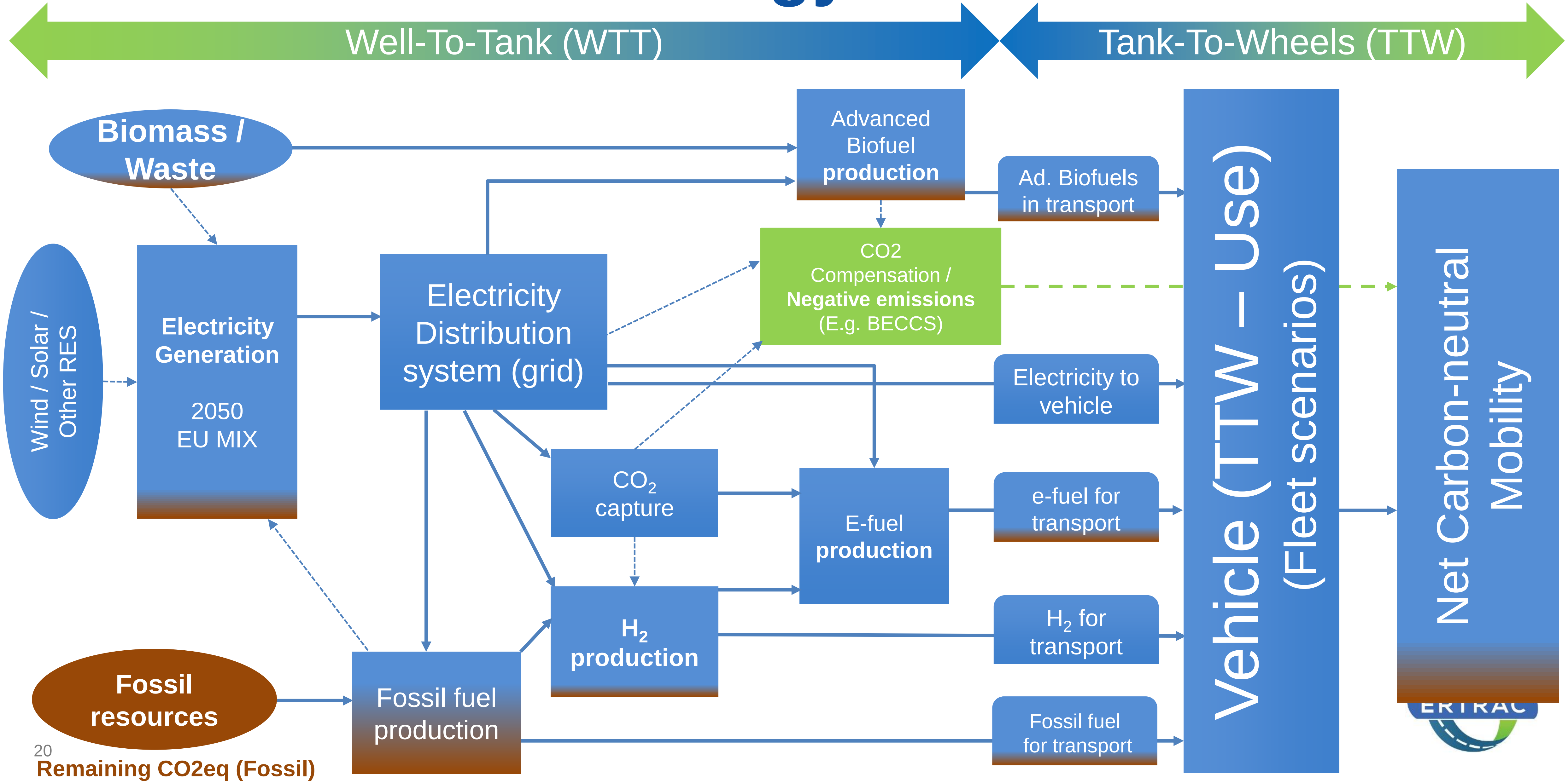
Comparison of different fuel "family" shares being used in the different fuel scenarios (corner-points).

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*

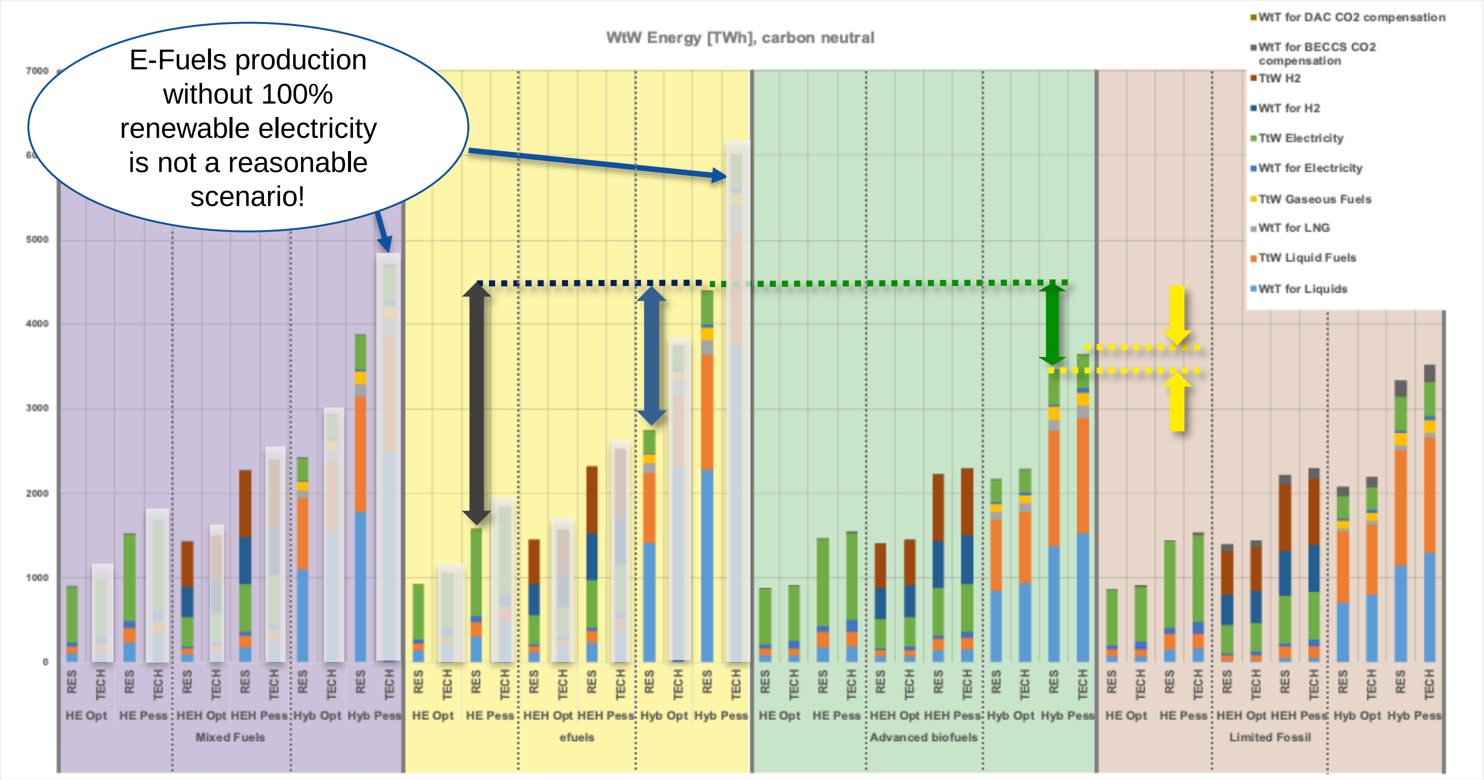
Results Fleet & Energy scenarios



Results Fleet & Energy scenarios

Question:

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

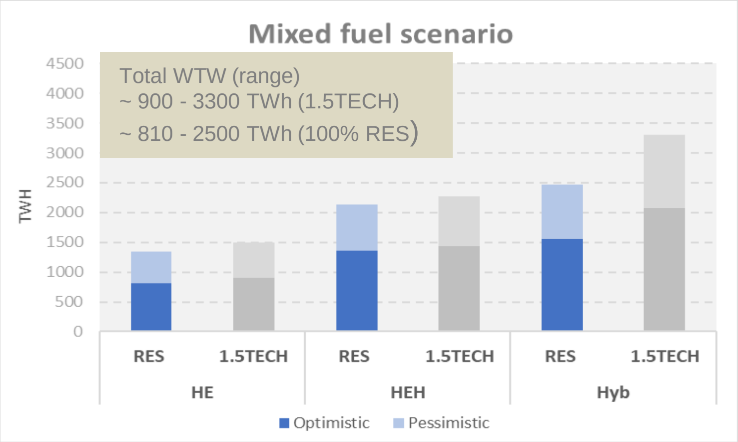
The share of TTW in the whole WTW energy consumption varies between **~50% up to 90%,** increasing with the level of fleet electrification.

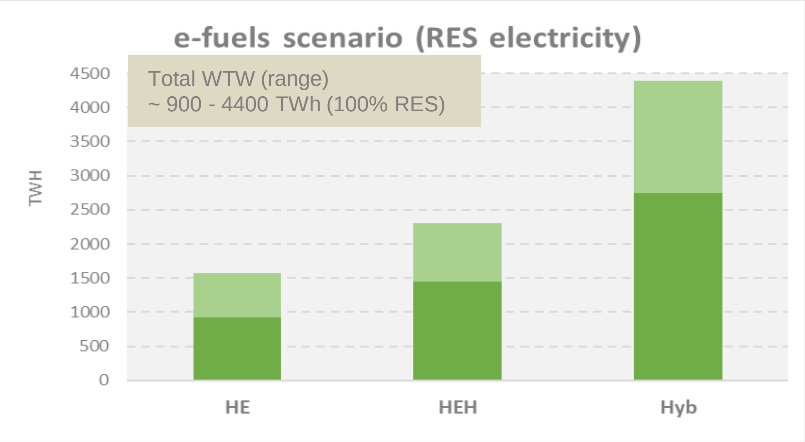
➜E-Fuels production without 100% renewable electricity is not a resonable scenario!
➜In the following slides we mainly focus on the 100% renewable electricity scenario (RES), combined with all fleet and fuel scenarios.

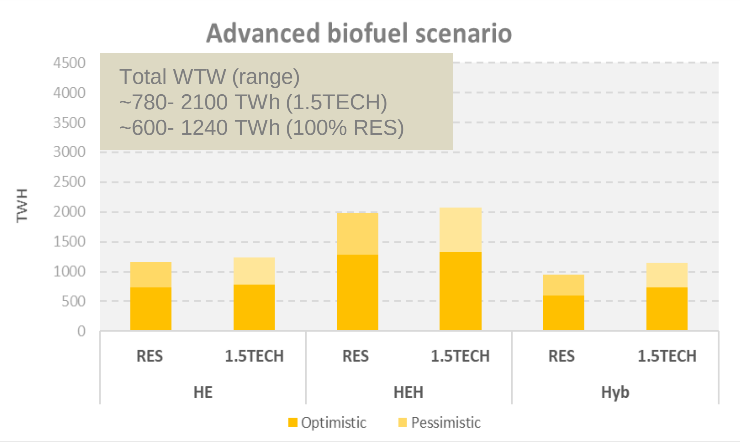
Results Fleet & Energy scenarios

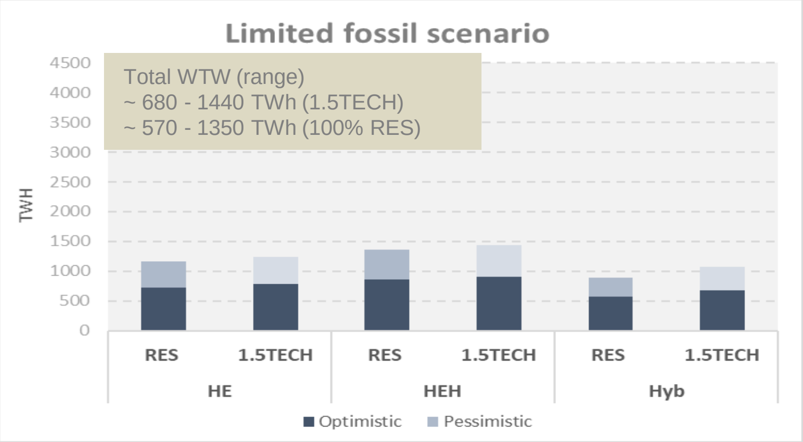
Question:

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.**

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Conclusions

- Developing a "carbon-neutral" road transport is highly **complex**, beyond WtW evaluations
  - **Scalability** must be granted: availability of critical minerals, biomass, water supply, land, etc.
  - **Energy supply must be secured**, in spite of intermittent RES
  - **Customer acceptance** is key: ease of use, cost etc.
  - **Systemic evaluation** is needed to ensure that the whole system is viable ➔ Current limit of this work and source of **uncertainty**
- 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)
- **A mix of technologies ensures a more robust solution, 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.

Conclusions

- The overall **WtW energy demand decreases drastically with fleet electrification**
- 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).
- The total **demand for electricity** in road transport will **increase** (energy production + use in vehicle)
  - **20% - 160% of total EU28** el.cons. 2019 depending on the scenarios
- The largely **Carbon-Neutral production of electricity** is a prerequisite for “carbon-neutral” road transport in all fleet and fuel scenarios.
- **Hydrogen could play a 3-way key role in the energy system** as
  - Final energy carrier
  - Chemical intermediate
  - Energy storage

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Thank you!