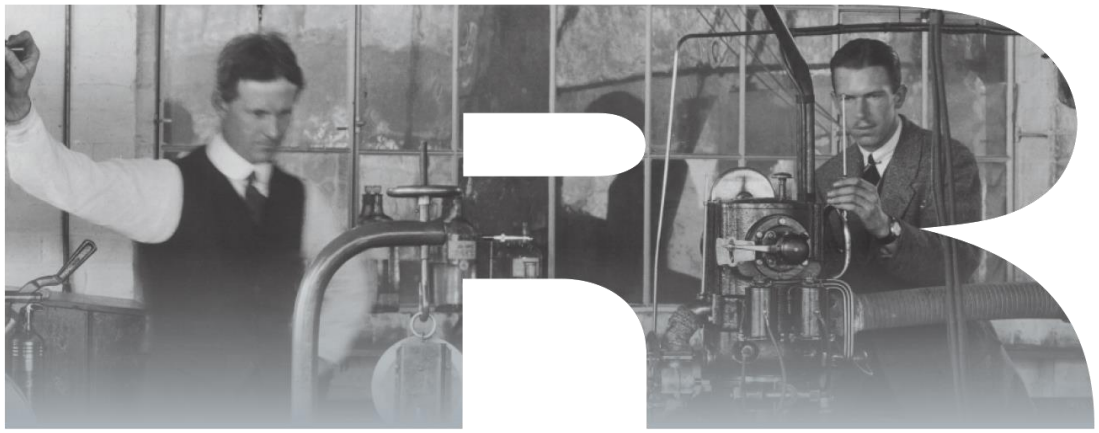
A3PS Eco-Mobility 2022: Efficient Propulsion System for Saving Renewable Energies

Different Propulsion Systems for Different Use Cases

Simon Edwards
Global Director, Technology; Ricardo

24th November, 2022



RICARDO

1915–2015

Passenger cars in the early 1900's – the competition between steam, electric and combustion engines

Steam

Crouch Steam Runabout

Electric

Baker EV

Internal Combustion

Ford's First Petrol Car

Source: Ricardo Centenary Lecture, SAE 2015: "AN INNOVATIVE FUTURE: How 100 Years Of Innovation Can Prepare Us For Tomorrow's Challenges"

Why was the combustion engine the ultimate winner?

Electric Vehicles	
+ Clean, easy start	- Expensive, limited range, performance, charging
Steam Powered Vehicles	
+ Reliable, mature technology	- Inconvenient (delayed start), dirty, performance
Internal Combustion Engine Vehicles	
+ Performance, range, re-fuelling	- Hand crank start, early reliability

Tipping Point:

- Launch of the Ford Model T in 1908
  - Affordable: 1/3 price of electric
  - More reliable
  - Growth of re-fuelling network

Source: Ricardo Centenary Lecture, SAE 2015: “AN INNOVATIVE FUTURE: How 100 Years Of Innovation Can Prepare Us For Tomorrow’s Challenges”

The internal combustion engine won the battle last time, with new boundary conditions which will win this time? Will there be just one “winner”?

ICE Hybrid

Toyota Prius

Electric

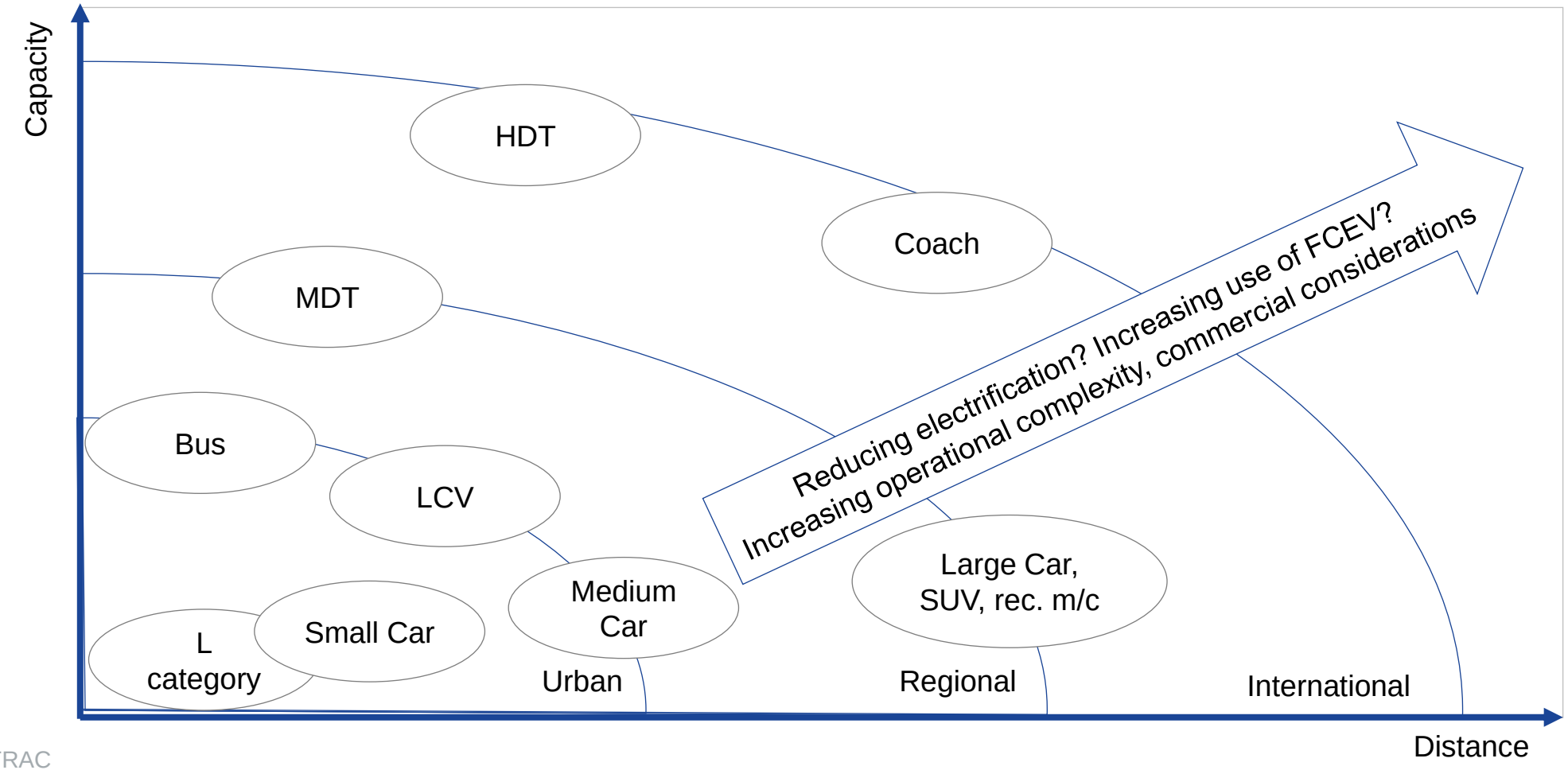
Nissan Leaf

Fuel Cell

Honda Clarity

Source: Ricardo Centenary Lecture, SAE 2015: “AN INNOVATIVE FUTURE: How 100 Years Of Innovation Can Prepare Us For Tomorrow’s Challenges”

And across all vehicle types and use cases? For the next 100 years?



Source: ERTRAC

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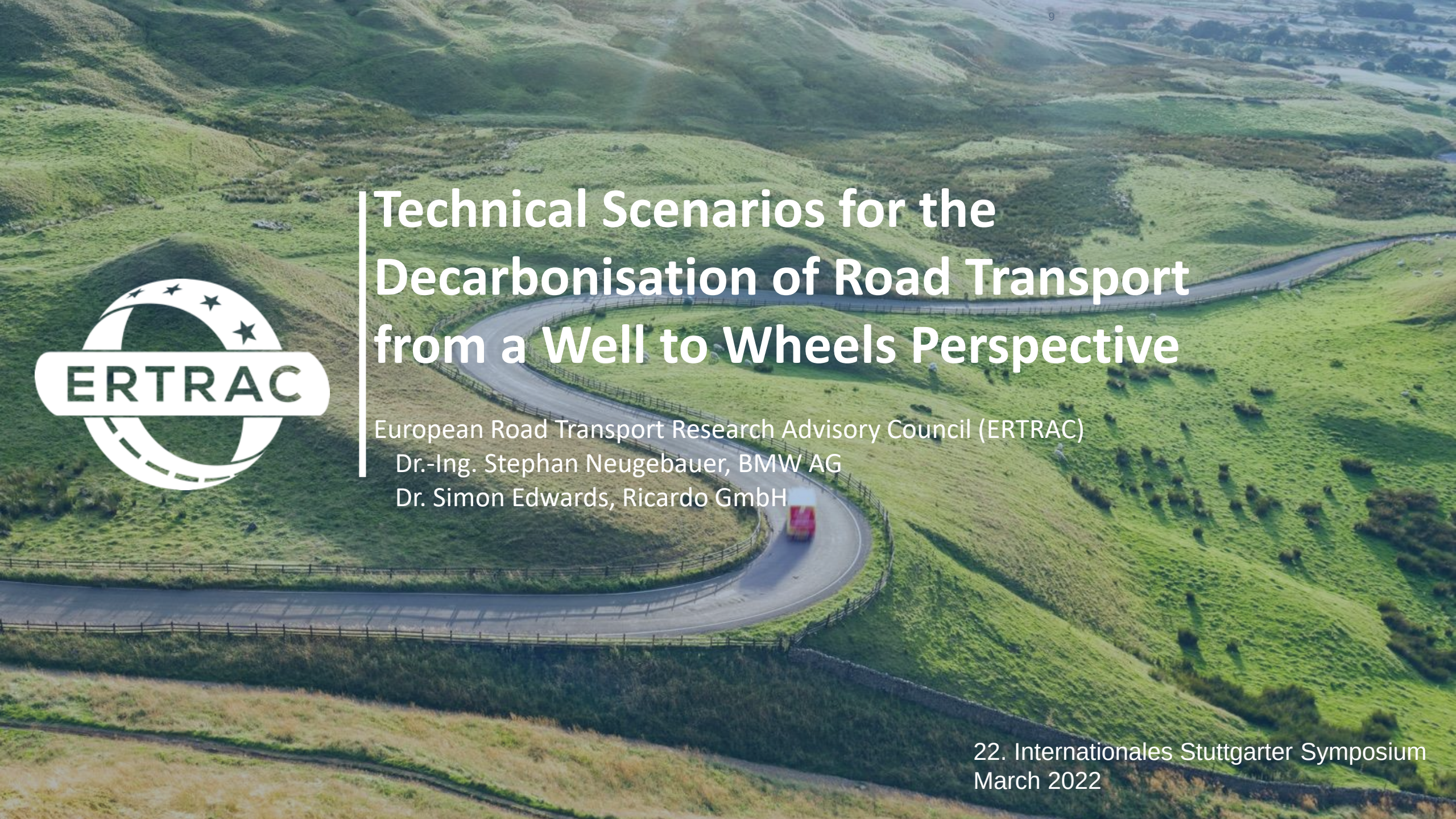


Technical Scenarios for the Decarbonisation of Road Transport from a Well to Wheels Perspective

European Road Transport Research Advisory Council (ERTRAC)
Dr.-Ing. Stephan Neugebauer, BMW AG
Dr. Simon Edwards, Ricardo GmbH

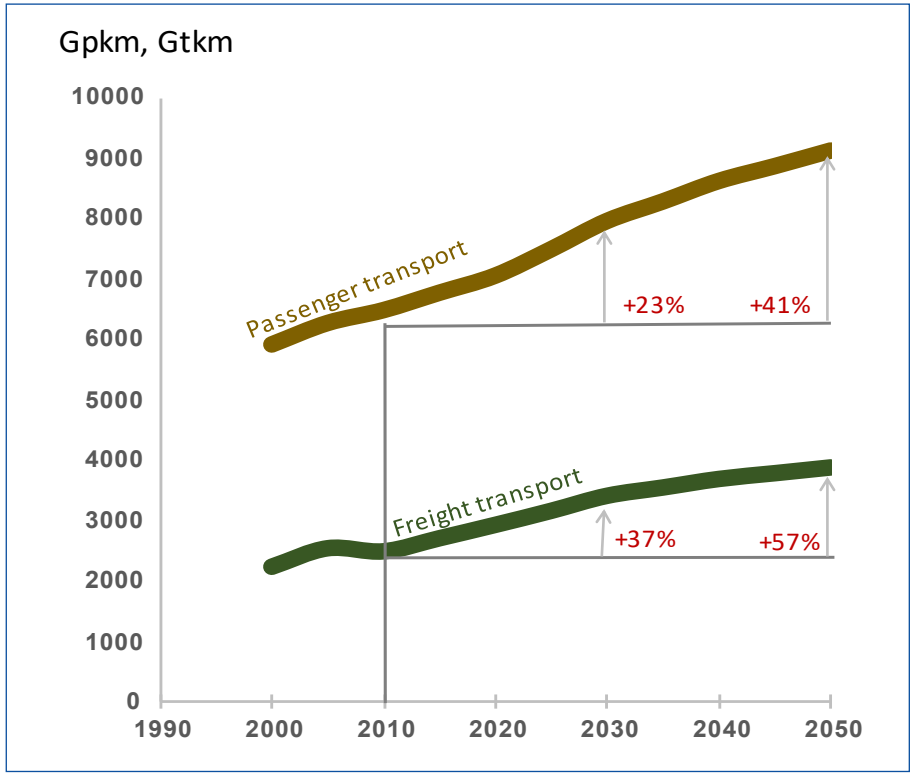
22. Internationales Stuttgarter Symposium
March 2022

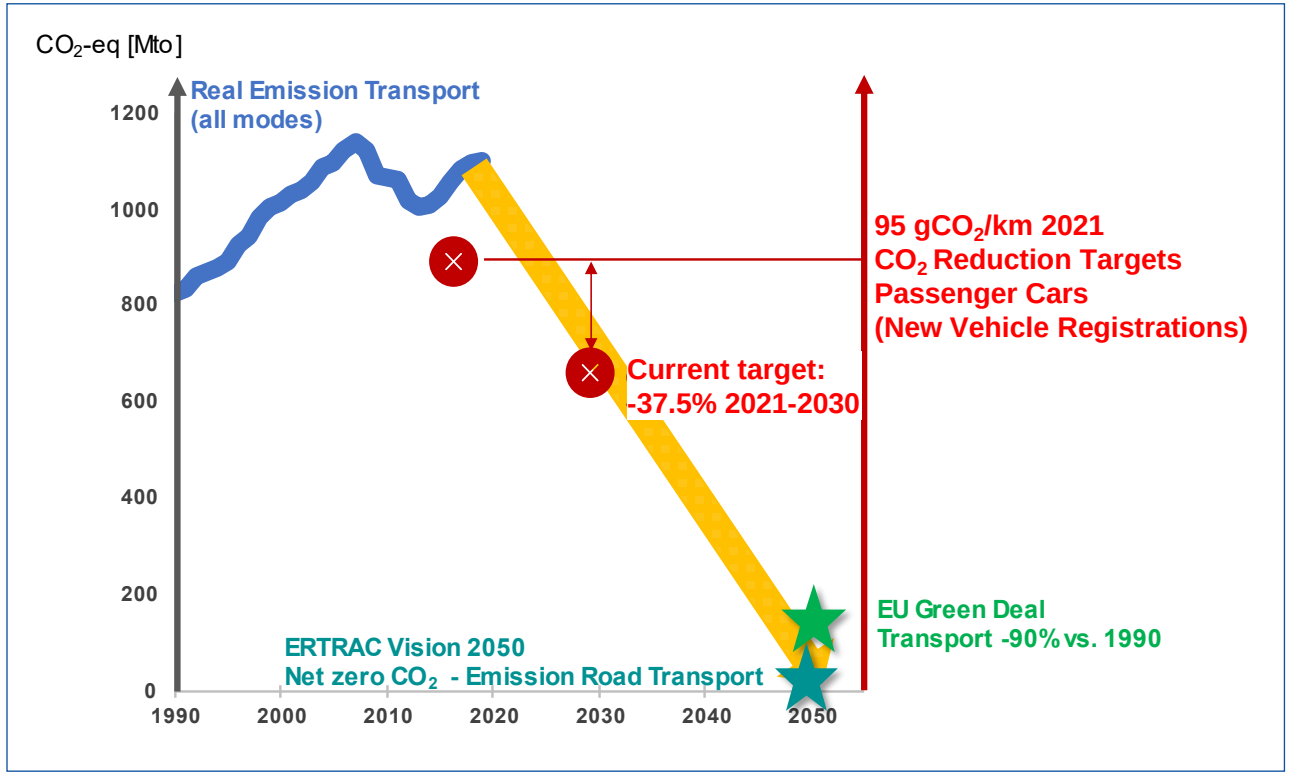
Disclaimer

- The ERTRAC Carbon-Neutrality Study 2050 (WTW) analyses different “extreme” scenarios and compares effects. It does not aim to give a projection or to describe the way to achieve 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 nor 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 ...

Source: ERTRAC, Stuttgarter Symposium, 2022: “Technical Scenarios for the Decarbonisation of Road Transport from a Well to Wheels Perspective”

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

Source: ERTRAC, Stuttgarter Symposium, 2022: "Technical Scenarios for the Decarbonisation of Road Transport from a Well to Wheels Perspective"

ERTRAC System Approach

Source: ERTRAC, Stuttgarter Symposium, 2022: “Technical Scenarios for the Decarbonisation of Road Transport from a Well to Wheels Perspective”

Concept of the study

Tank to Wheels (TTW)

Which powertrains could be used in in 2050?

3 Powertrain Scenarios

Which efficiency improvements are possible by 2050?

Optimistic to Pessimistic Ranges

Well to tank (WTT)

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

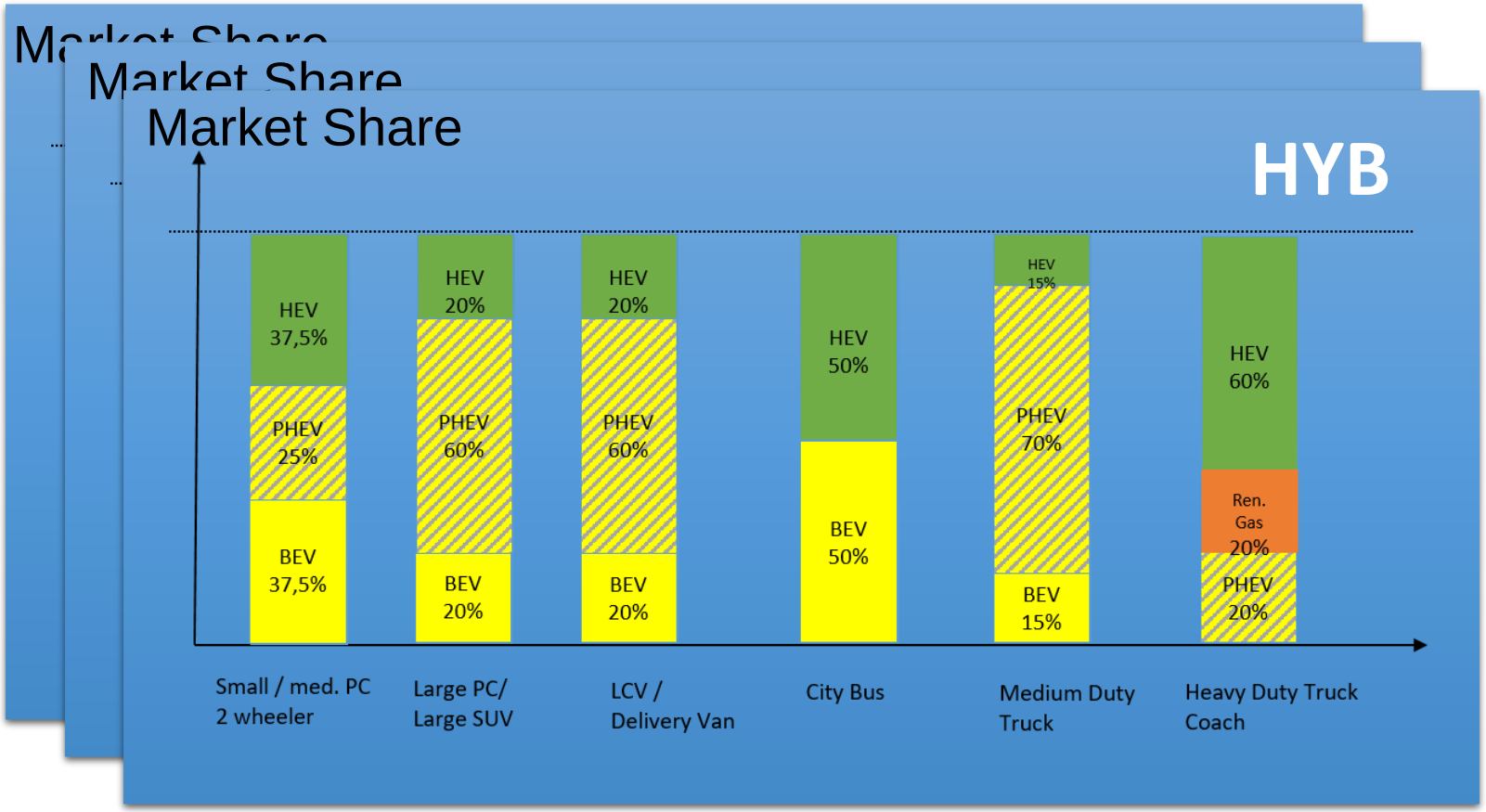
2 Electricity Scenarios: 100% Renewable (RES) & 1.5 Tech

Which fuel production paths could be used in 2050?

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

Source: ERTRAC, Stuttgarter Symposium, 2022: “Technical Scenarios for the Decarbonisation of Road Transport from a Well to Wheels Perspective”

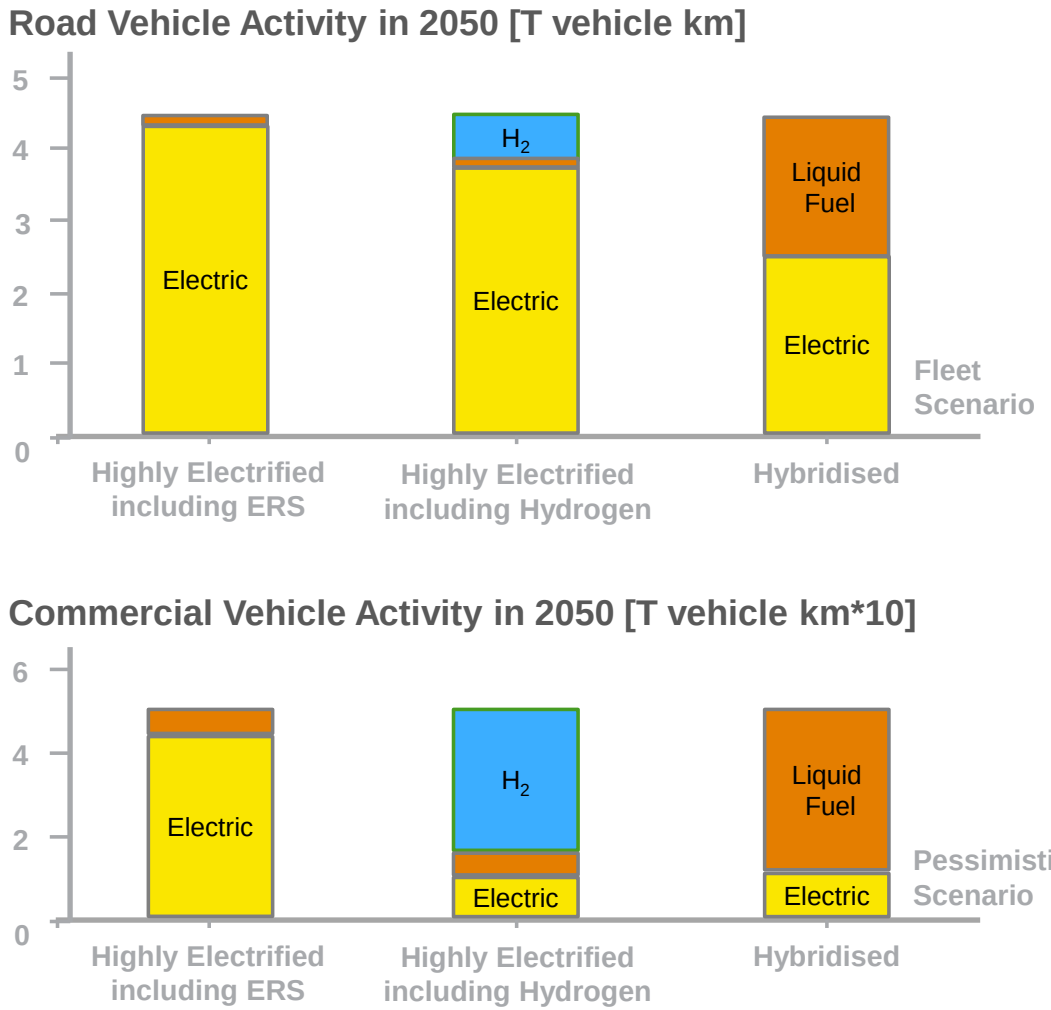
3 Powertrain Scenarios 2050



- Highly-Electrified with Electrified Road Systems
- Highly-Electrified with Hydrogen as a energy carrier
- Hybrid scenario retaining a majority proportion of internal combustion engines used in hybrid vehicles

Source: ERTRAC, Stuttgarter Symposium, 2022: “Technical Scenarios for the Decarbonisation of Road Transport from a Well to Wheels Perspective”

3 Powertrain Scenarios 2050



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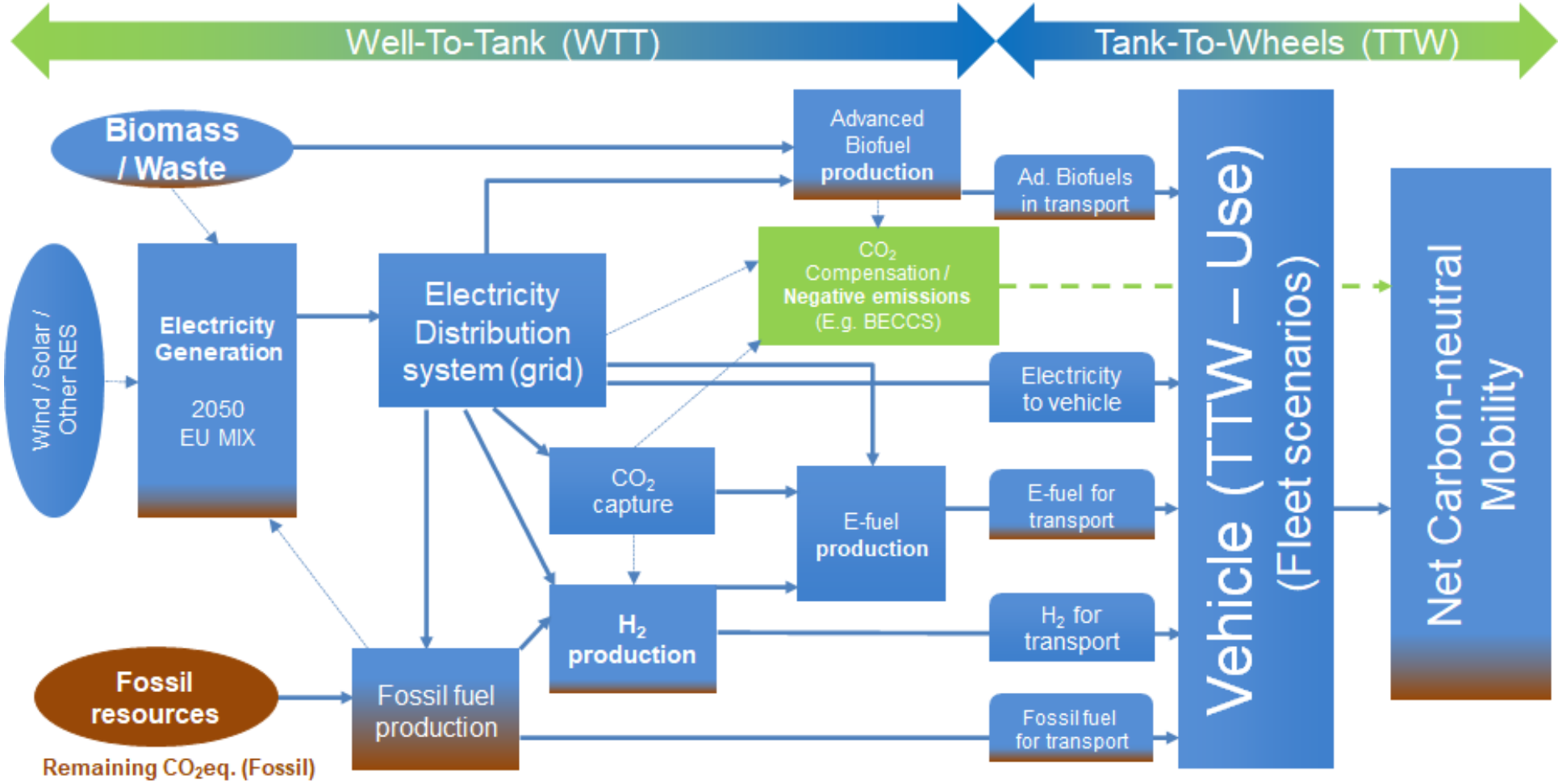
Well to Tank, Tank to Wheels Energetic Analysis

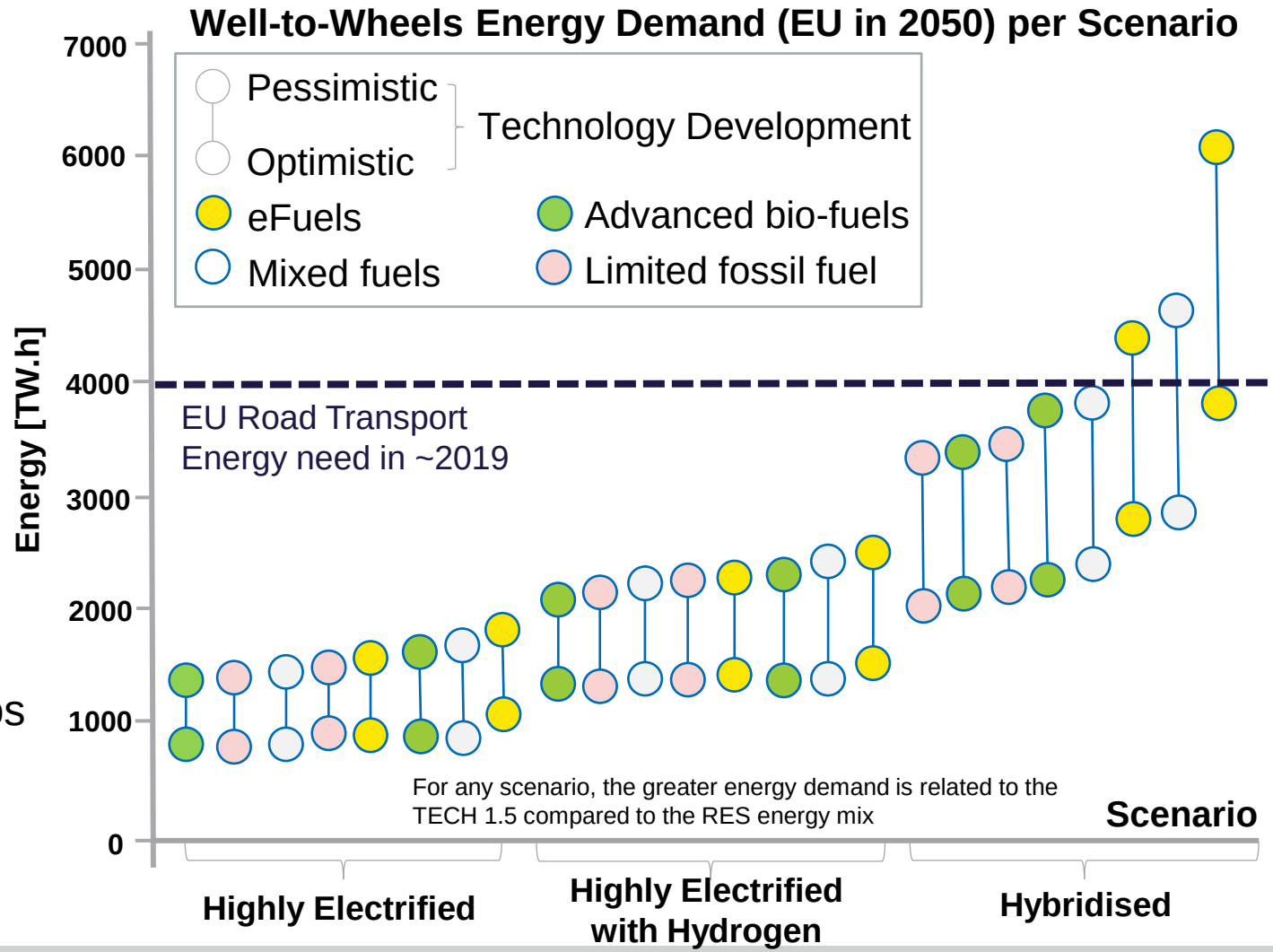


Source: ERTRAC, Stuttgarter Symposium, 2022: “Technical Scenarios for the Decarbonisation of Road Transport from a Well to Wheels Perspective”

EU27+UK

How much renewable energy is needed in 2050 (part 1)?

- ERTRAC WtW study for 2050 carbon neutral road transport assessed ~48 scenarios considering:
  - Powertrain mix
  - Technology for efficiency
  - Electricity supply mix
  - Fuel scenarios
- The overall **WtW energy demand decreases significantly with fleet electrification**
- Energy consumption can be reduced by up to **40% by efficiency measures**
- The demand for fuels decreases in all scenarios
- WtW differences in energy consumption between high electrified scenarios are small

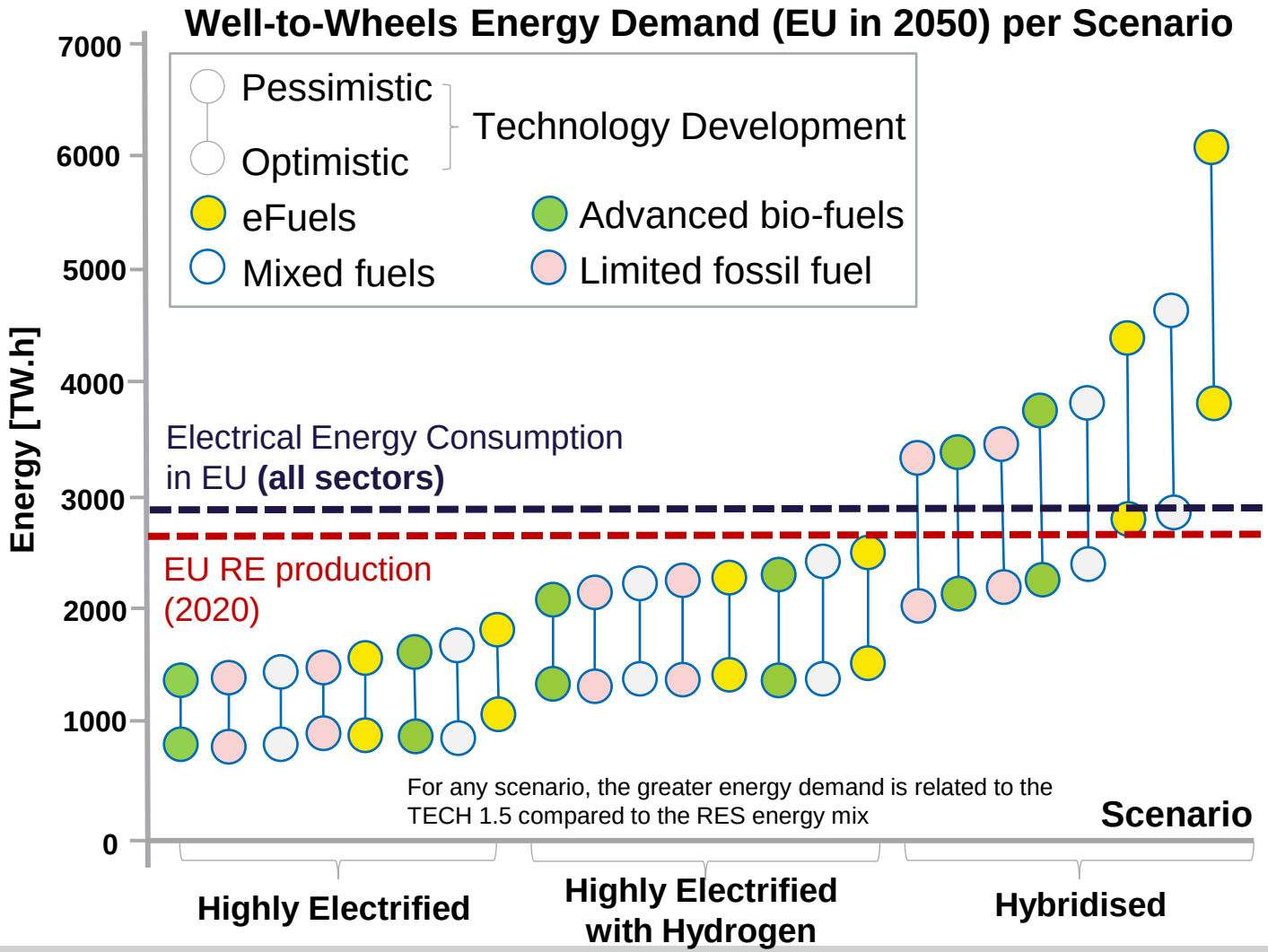


Source: ERTRAC; Ricardo analysis

EU27+UK

How much renewable energy is needed in 2050 (part 2)?

- The **total demand for electricity** in road transport **will increase** (energy production + use in vehicle)
  - 20%-30% of total EU28 electricity consumption 2019 in advanced biofuels or limited fossil scenarios combined with hybrid fleet
  - 35%-50% of total EU28 electricity consumption 2019 in highly electrified scenarios
  - up to 1.4x of total EU28 electricity consumption in 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 scenarios



Source: ERTRAC; Ricardo analysis

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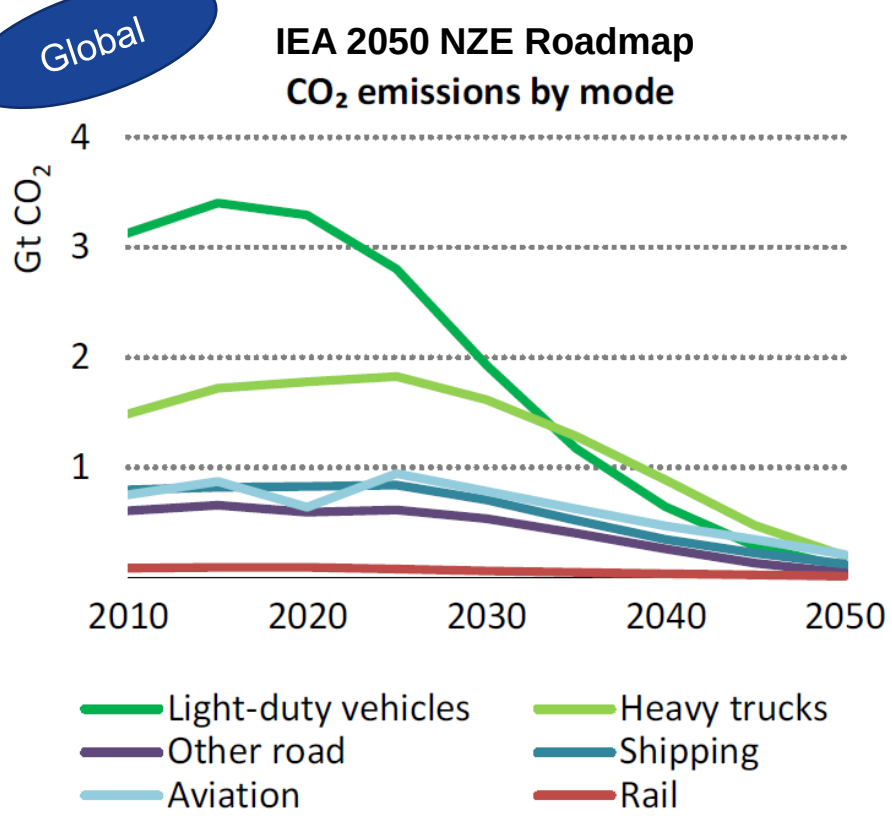
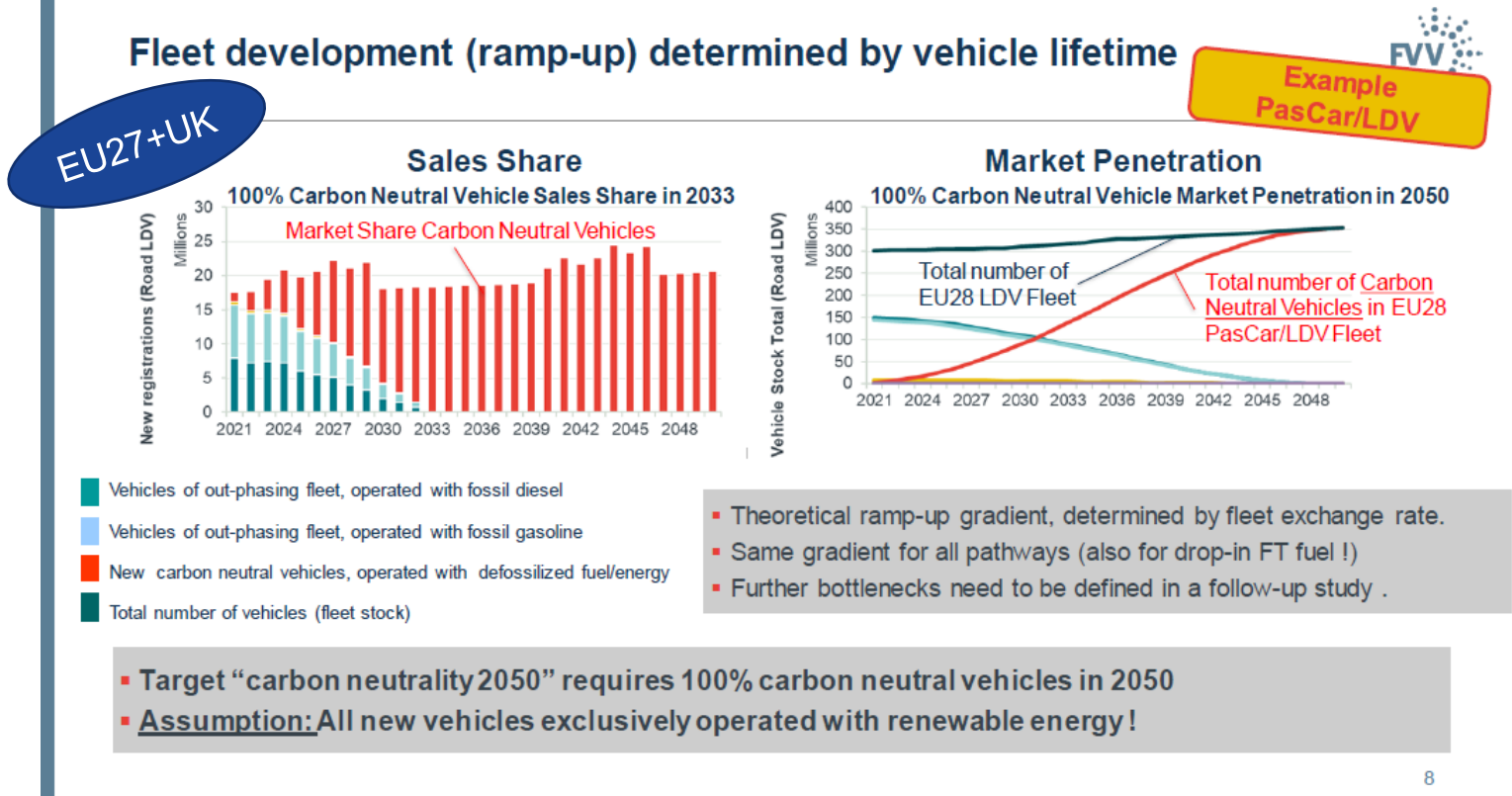
Light duty vehicles contribute most to transport CO_2 emissions today: it is the fleet exchange rate that drives the needs for new vehicle sales

Global



EU27+UK



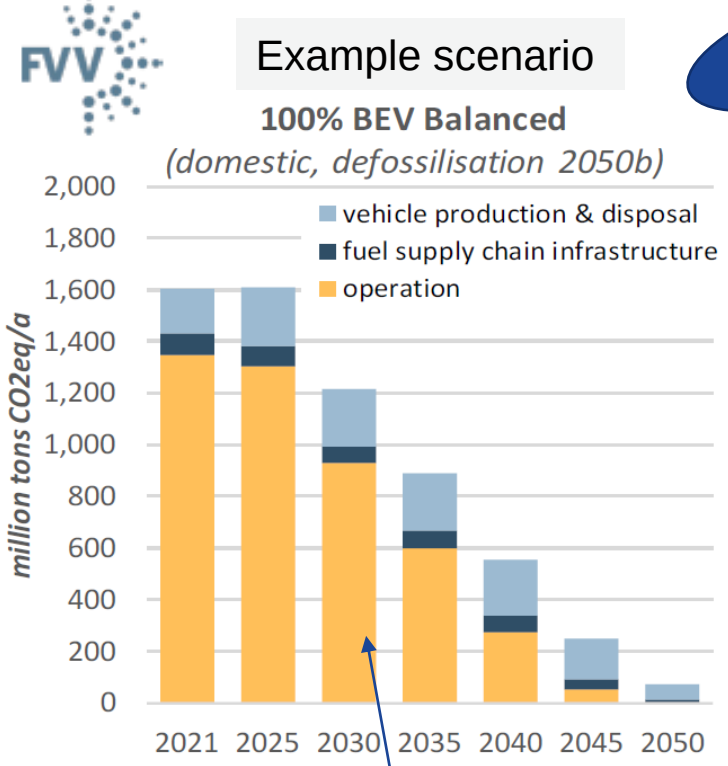
- FVV study considered energy, environment, materials and economics
- It used WtW & C2G analysis for energy pathway transitions to fossil free mobility
- It was a scenario-based analysis considering the transition from 2021 to 2050
  - Using 100% scenarios as the end point

Sources:: IEA 2021; FVV Future Fuels IV study; Ricardo analysis

The environmental analysis shows the significance of the existing fleet on the cumulative GHG emissions versus the available budget

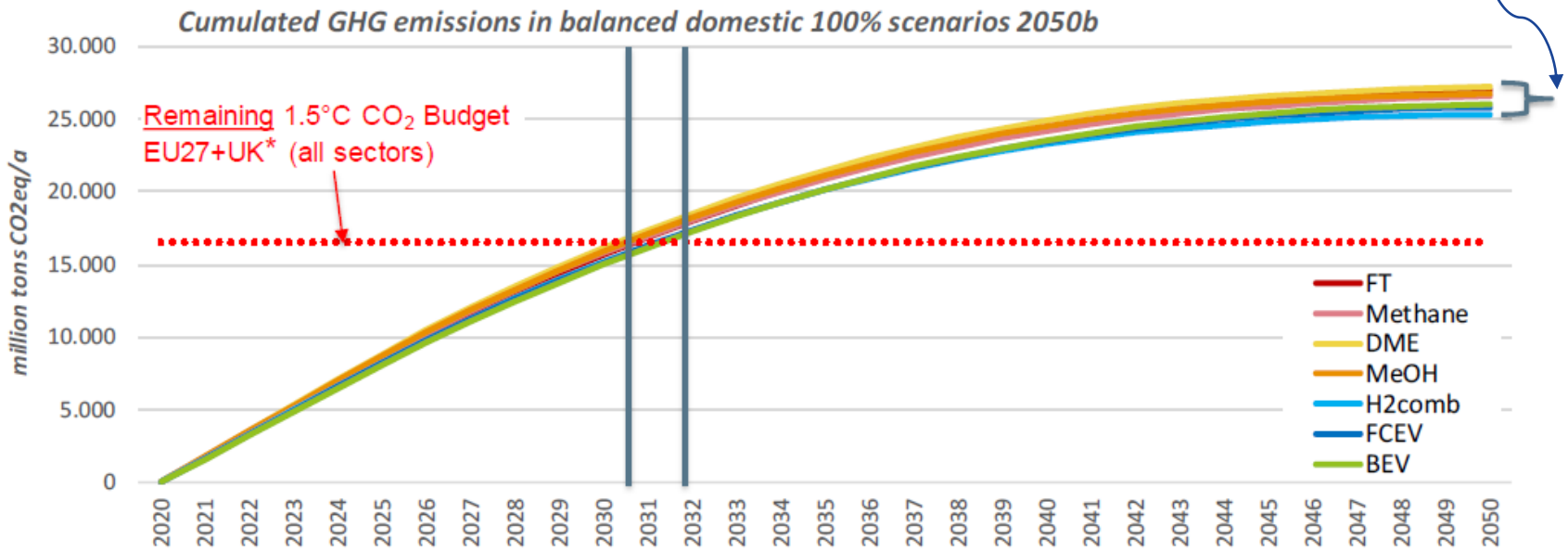
Example scenario

EU27+UK



Operation of out-phasing fleet with fossil gasoline/diesel (including 7% biofuel)

Cumulative bandwidth of future fuel & powertrain 100% pathways with identical ramp-up speed



- With assumed ramp-up speed:
  - EU27+UK's 1.5°C CO_2 budget* for all sectors will be exceeded soon (2031/32) just by transport
  - Are different propulsion systems for different use cases of any relevance?

Sources:: FVV Future Fuels IV study; Ricardo analysis

Yet, in a world of constraints, of bottlenecks, is a single, prescribed powertrain technology approach the best way forward?

Presented results are based on the FVV Fuel Study IV and the forthcoming FVV Fuel Study IVb

Future fuels
FVV Fuel study IV

Analysis of 42 different single fuel / powertrain combinations regarding GHG emissions and costs

Published Oct. 2021

https://www.fvv-net.de/fileadmin/Downloads/Publikationen/FVV__Future_Fuels__StudyIV_The_Transformation_of_Mobility__H1269_2021-10__EN.pdf

Transformation of mobility to the GHG neutral post fossil age
FVV Fuel study IVb

Forthcoming

Dr.-Ing. Ulrich Kramer
(Ford-Werke GmbH)
Dr. rer. pol. David Bothe
Dr. Christoph Gatzen
André Pfannenschmidt
Carolin Baum
Fabian Schrogl
Osama Mahmood
(alle Frontier Economics Ltd.)

+ >45 Counsellors

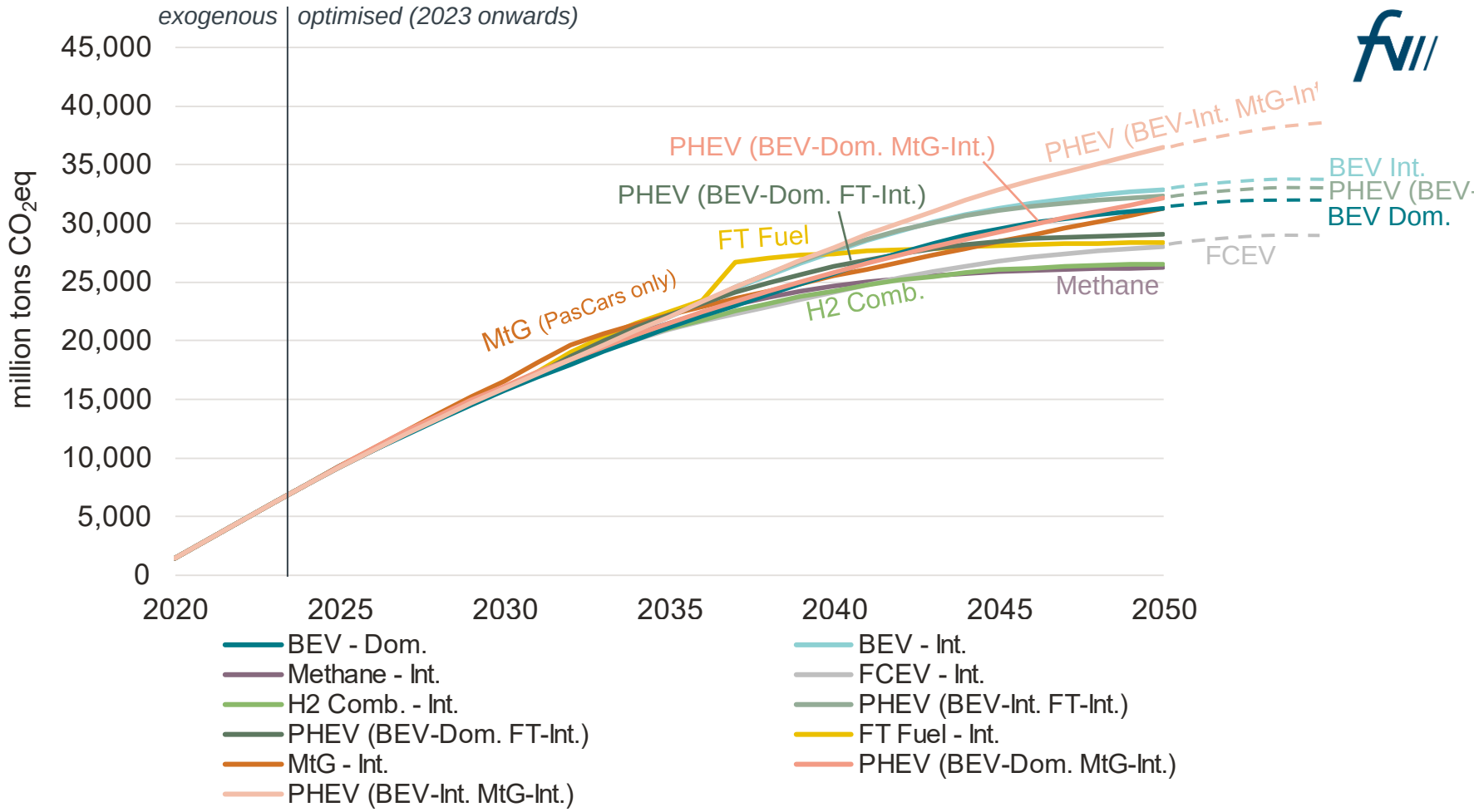
25

H2-ICEV - Fuels Study IV / IV b | 20 Oct. 2022

Sources: FVV Future Fuels IV study; FVV Future Fuels IVb study; H_2-ICEV.Environmental Impact Assessment and Economic Analysis based on FVV Fuels Studies IV / IV b "Transformation of mobility to the GHG neutral post fossil age"

The results suggest that there are some prescribed, single powertrain technology approaches that will not reach the targets

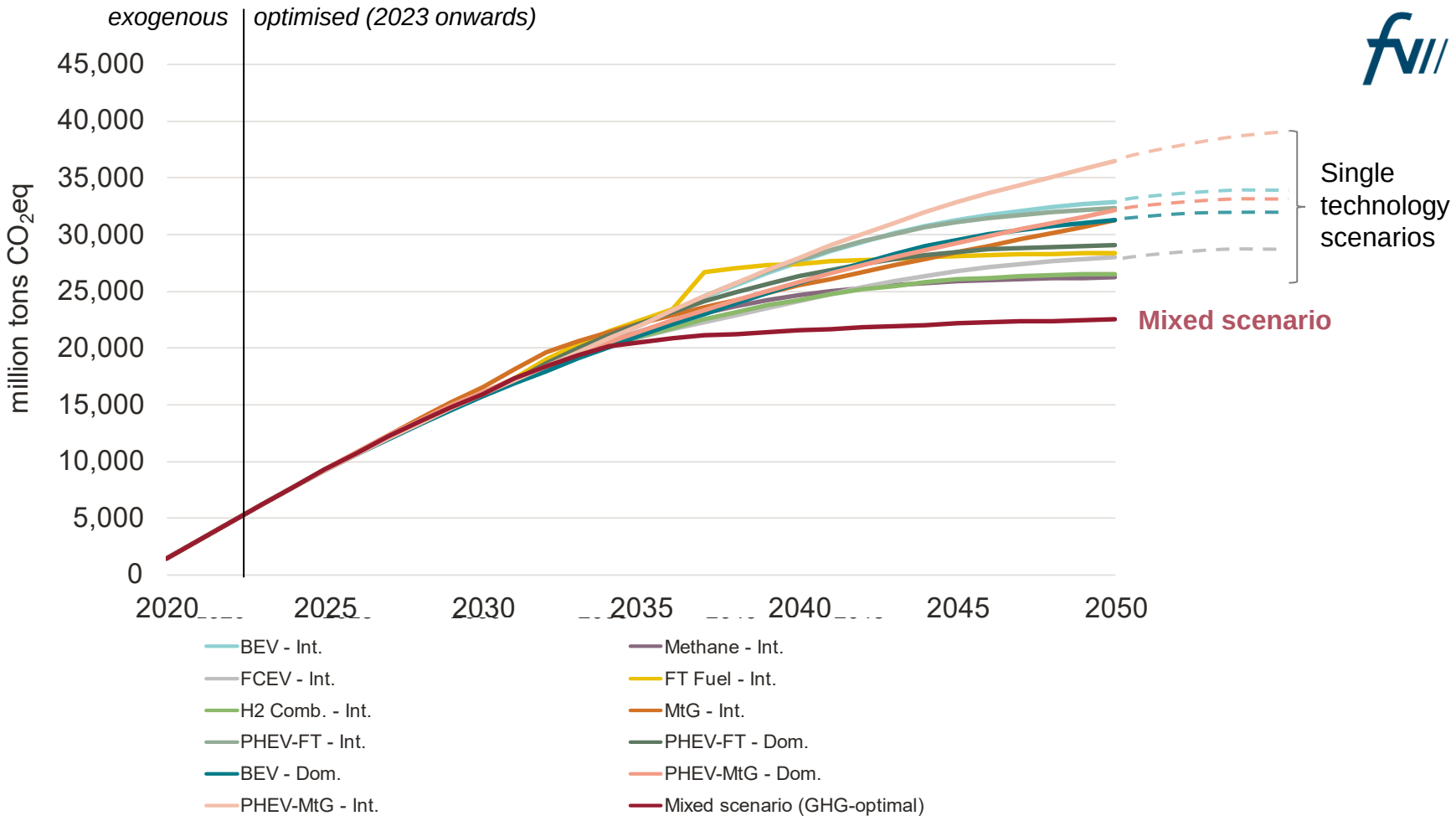
- Some single technology scenarios, e.g. 100% BEV or 100% FCEV do not “flatten-out”, i.e. reach full defossilisation in 2050



Sources: FVV Future Fuels IVb study; H_2-ICEV.Environmental Impact Assessment and Economic Analysis based on FVV Fuels Studies IV / IV b “Transformation of mobility to the GHG neutral post fossil age”

…but that a mixed technology scenario, aimed at minimizing the GHG emissions, will reach carbon-neutrality and sooner than a single, prescribed approach

- With a mixed technology scenario the cumulated GHG emissions until 2050 are ≈3,700 Mt $CO_{2eq.}$ lower than best full defossilised single technology scenario
  - equivalent to ~5 years of total German GHG emissions
  - Quasi*-climate neutrality can be achieved 2039 already
- Allowing different propulsion systems for different use cases is the better way forward



Sources: FVV Future Fuels IVb study; H_2-ICEV.Environmental Impact Assessment and Economic Analysis based on FVV Fuels Studies IV / IV b "Transformation of mobility to the GHG neutral post fossil age" . *only unavoidable GHG emissions left

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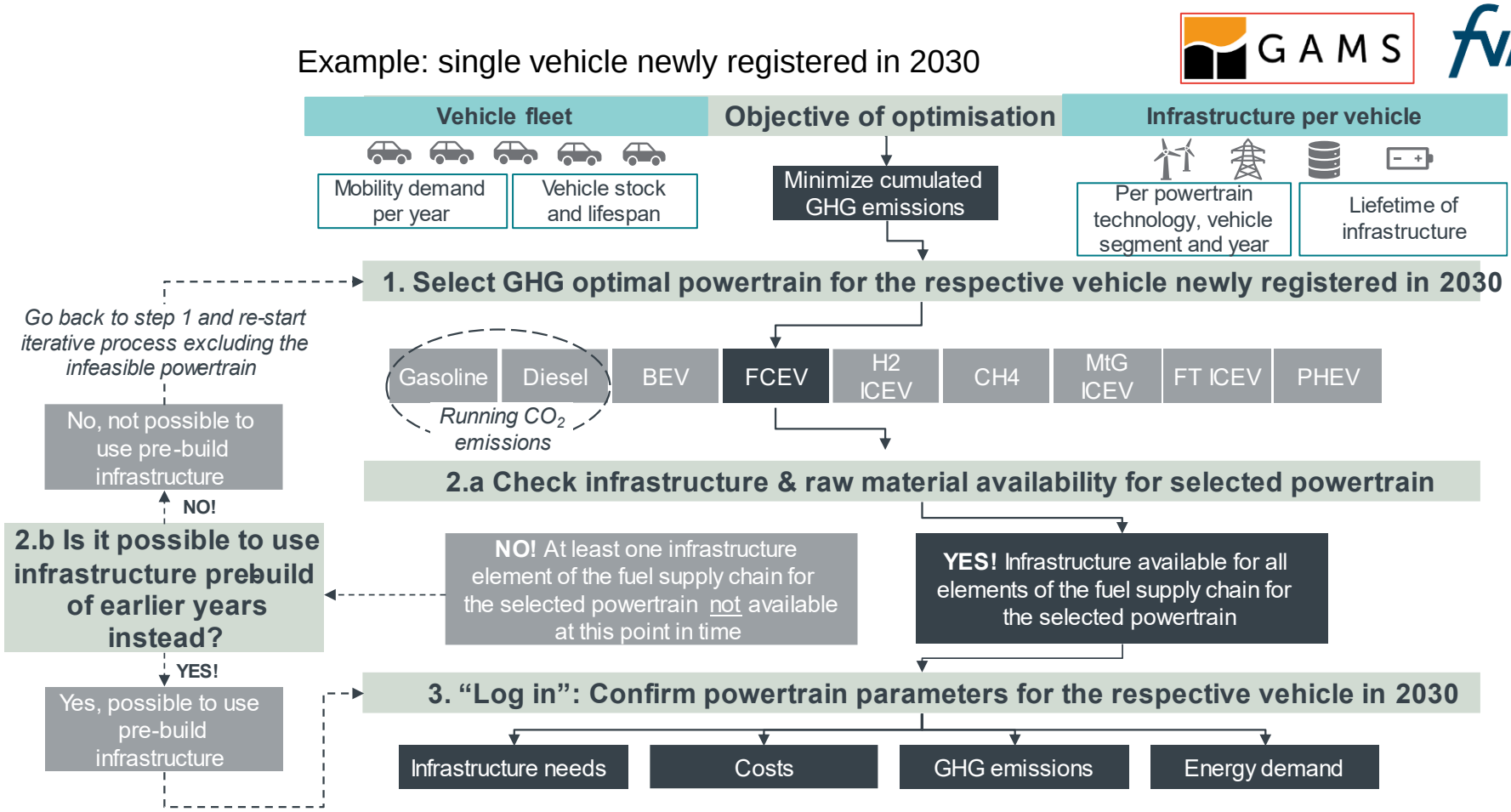
The “optimal”, FVV mixed technology scenario relies on complex decision making for each vehicle propulsion system choice

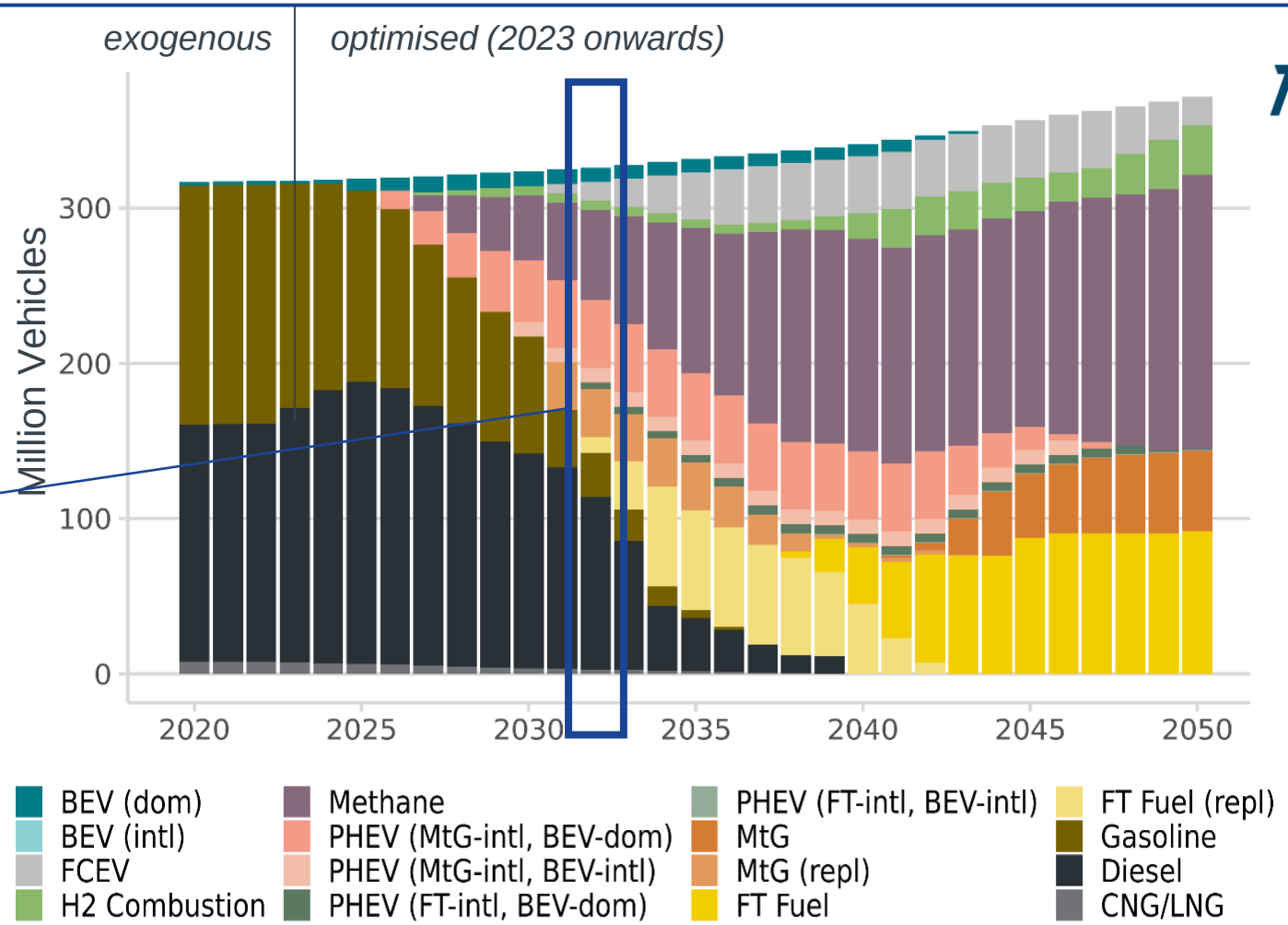
- The diagram on the right represents the “GHG Minimisation - simplified model decision making process” used in the FVV study
- In practice, the model has “perfect foresight”, implying that it optimises the selection of powertrain technologies, across all segments and all years, in parallel



Sources: FVV Future Fuels IVb study; H_2-ICEV.Environmental Impact Assessment and Economic Analysis based on FVV Fuels Studies IV / IV b “Transformation of mobility to the GHG neutral post fossil age”

... and the resultant market, the vehicle parc composition is similarly complex during the transision

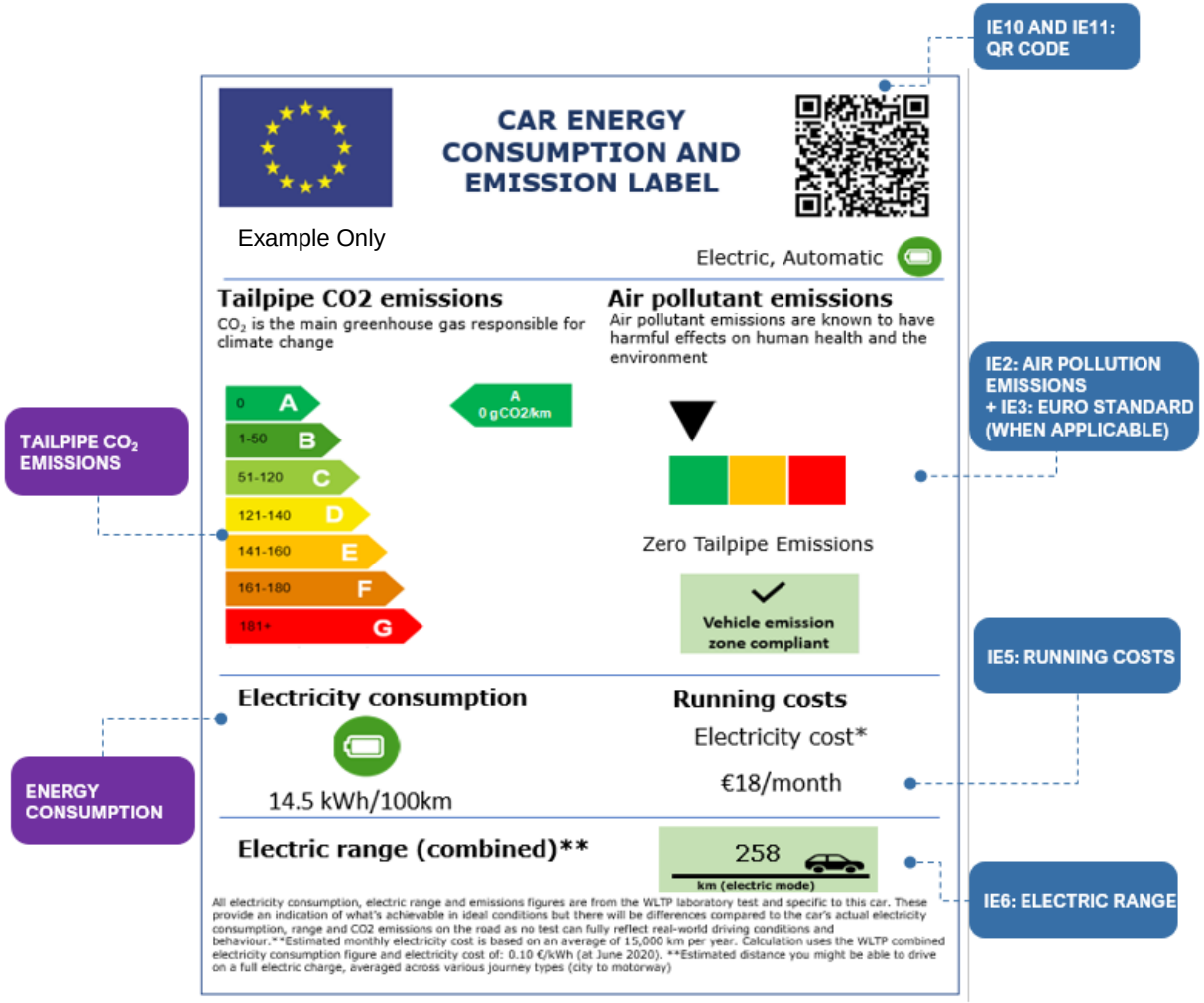
- The diagram on the right represents the Fleet Development (vehicle Stock) of LDV (PasCar + N1)
- The dominating LDV vehicle & powertrain pathways at 2050 are
  - Methane-ICEV
  - FT- & MTG-ICEV
  - H_2-ICEV
- But during the transition, see for example that in 2032, the passenger car market may have up to eleven “optimal” powertrain choices



Source: FVV Future Fuels IVb study; H_2-ICEV.Environmental Impact Assessment and Economic Analysis based on FVV Fuels Studies IV / IV b “Transformation of mobility to the GHG neutral post fossil age”

Are existing or proposed methods for, e.g., “car labelling” sufficient to help, to enable the market, the user make “optimal” vehicle replacement decisions?

- Detailed analysis of the potential impacts of measures was undertaken for three main categories: economic, environmental and social impacts. The measures were grouped into the topics that they address, reflecting different policy elements:
  - Changes to the communication channels
  - Changes to the information elements communicated
  - Extension of the scope of the Car Labelling Directive
  - Increase in the level of harmonisation of implementation of the Directive in the Member States
- Literature research, stakeholder inputs, consumer experiments, SULTAN modelling etc.
- How much can you move the markets through improved information?
- Additional information, labelling and guides on-line, harmonization around the EU
- Consideration of websites for vehicle comparisons

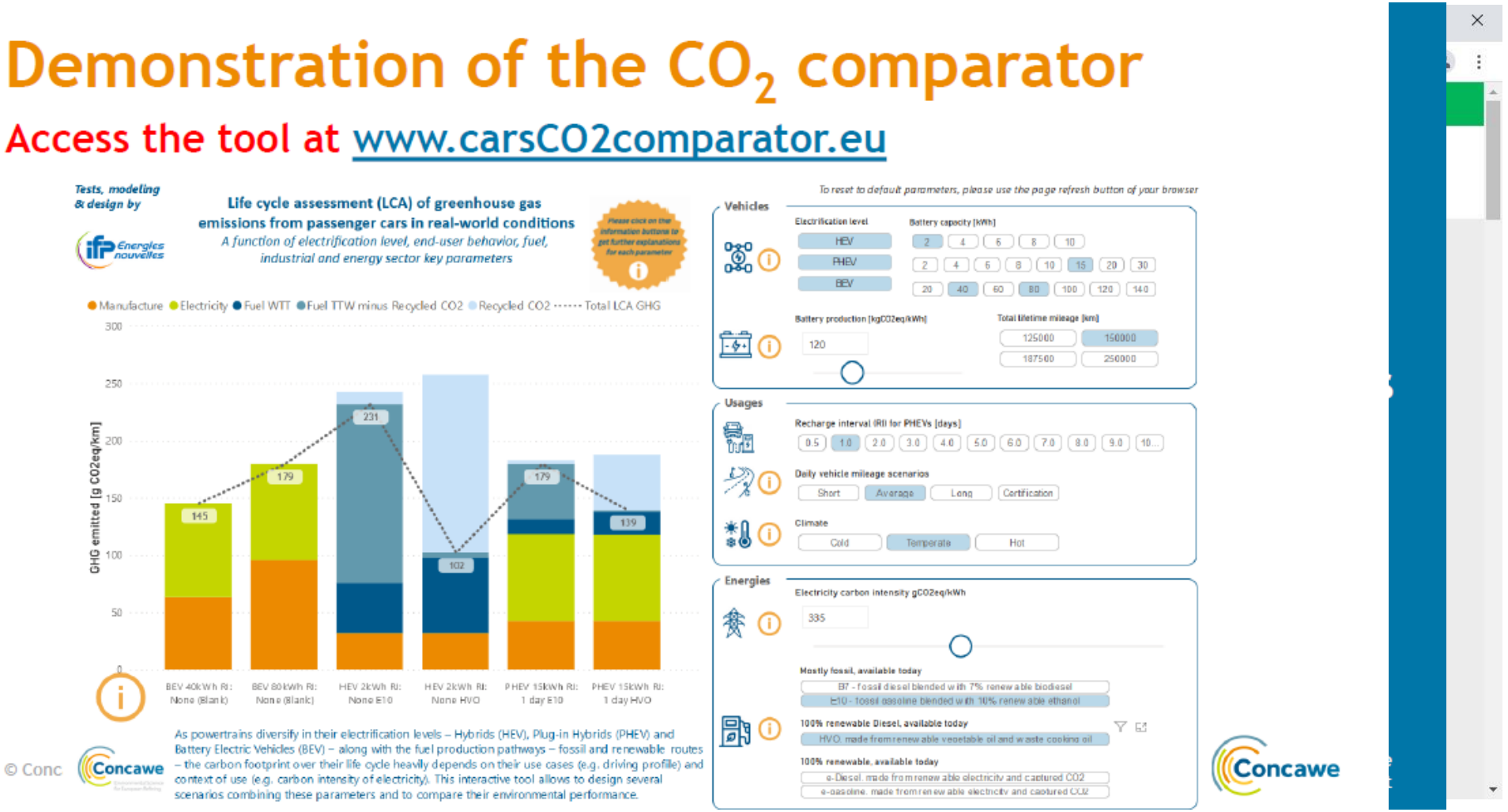


Source: “Technical analysis of measures to improve consumer awareness of emissions and fuel consumption of vehicles”.
See: https://op.europa.eu/en/publication-detail/-/publication/88148b8d-b91d-11eb-8aca-01aa75ed71a1/language-en/format-PDF/source-209951397

Alternative, user-group rating systems are proliferating: a consistent, dynamic, EU-wide, LCA based toolset will be beneficial ...

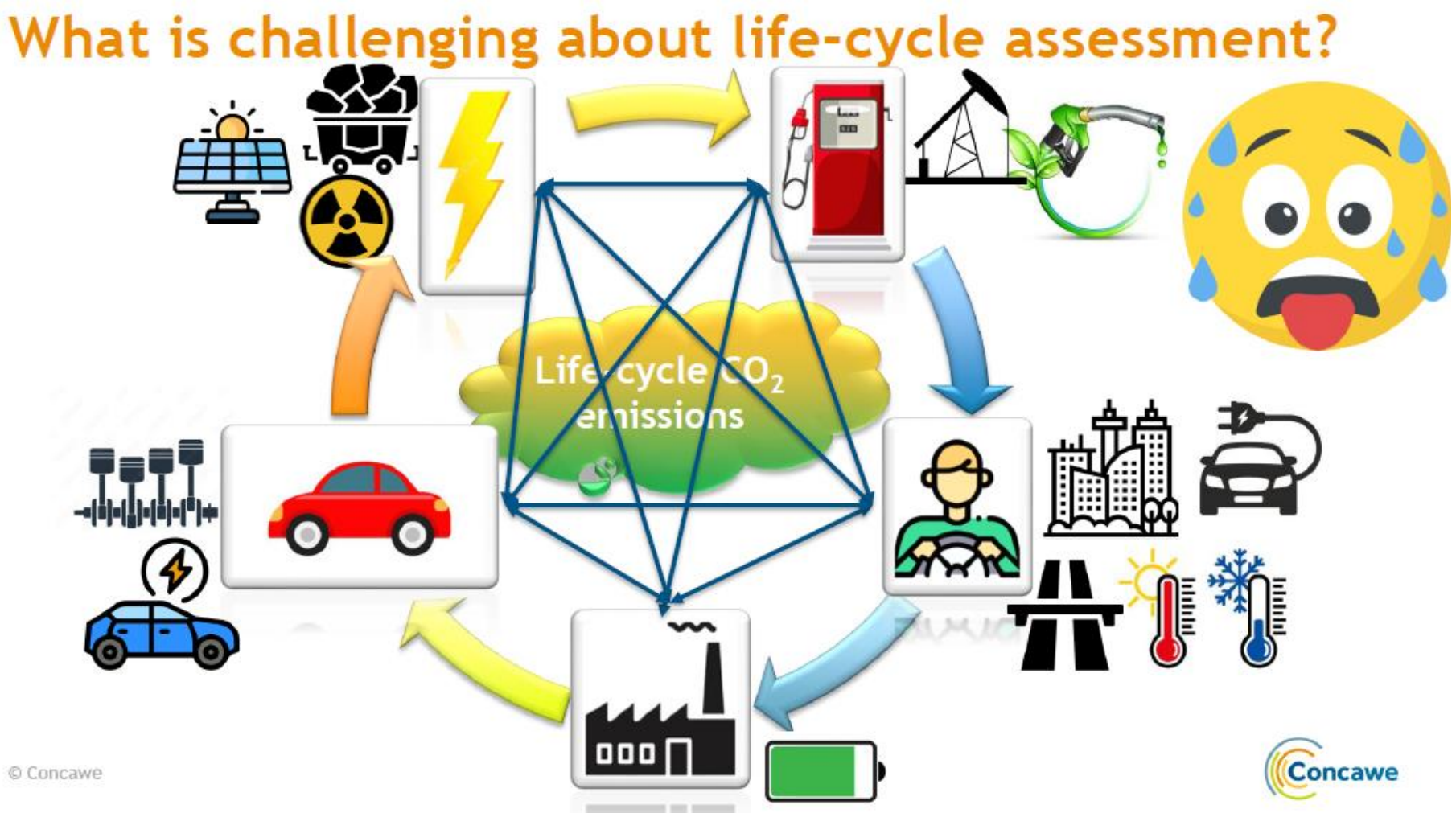
Demonstration of the CO_2 comparator

Access the tool at www.carsCO2comparator.eu



Source: GreenNCAP; CONCAWE

... a consistent, dynamic, EU-wide, LCA based toolset will be beneficial
... to keep the user on-board during the transistion



Source: “CONCAWE

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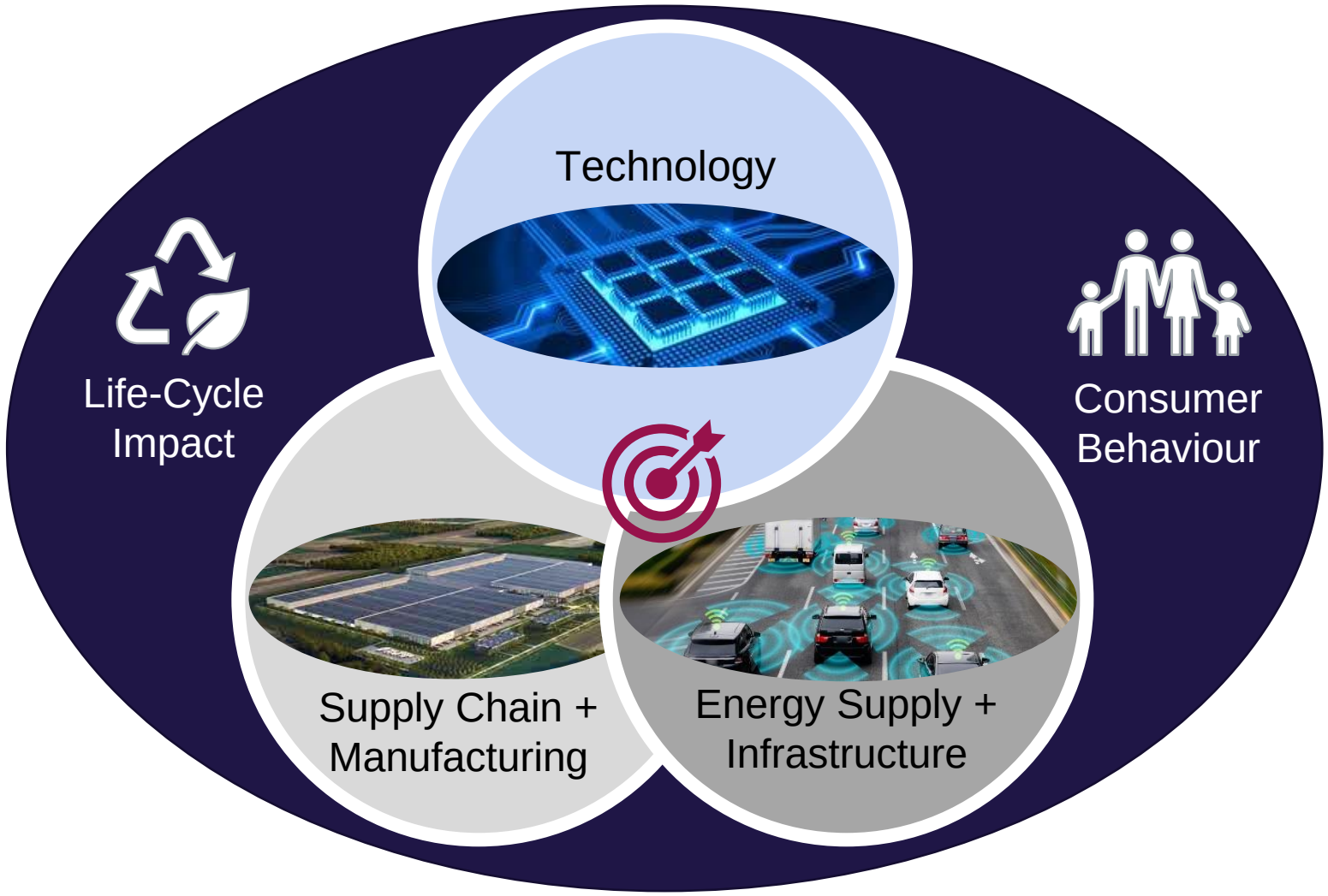
Summary

- The **‘net-zero’ targets for road transport in Europe are technically feasible**, based upon a large proportion of electrified vehicles & the majority of journeys being so ‘zero-emission’
- The existing **vehicle parc is the primary determinant of the GHG emissions** related to road transport on the way to 2050
  - without changes, the **remaining carbon-budget** for Europe could be ‘**consumed**’ by road transport alone **by the middle of the coming decade**
  - such that the **provision of net-lower carbon fuels for the existing vehicle parc is a significant lever** for budget control
- The introduction of battery and fuel cell electric vehicles will need to ramp-up as quickly as possible, but **infrastructure and/or resource bottlenecks will constrain progress throughout this decade** and beyond, particularly if singular technical solutions are prescribed
- A **multiple-technology solution offers the possibility for quicker, more robust progress** but the **user needs to be kept in-the-loop**, brought on-board via the availability of a consistent, dynamic, EU-wide, LCA based toolset **to allow informed choices to be made every step of the way**

Carbon neutrality is a complex multi-dimensional problem with many variables and user choices…



A3PS Eco-Mobility 2022: Efficient Propulsion System for Saving Renewable Energies

Different Propulsion Systems for Different Use Cases

Thank you for your attention

24th November, 2022