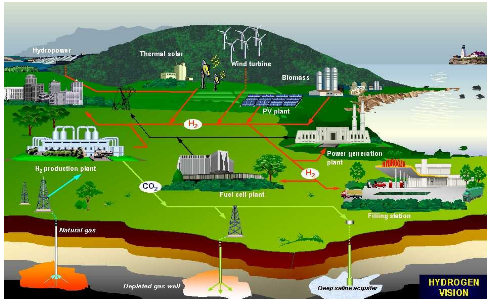
Elektromobilität – Sichtweise des JRC-IE

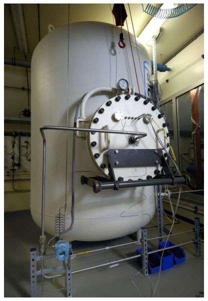
Die geplante Entkarbonisierung der europäischen Transportwege…

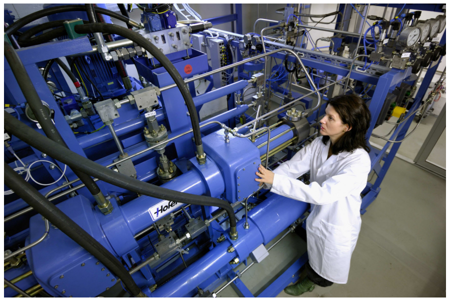
Norbert Frischauf

JRC-IE, Petten, NL

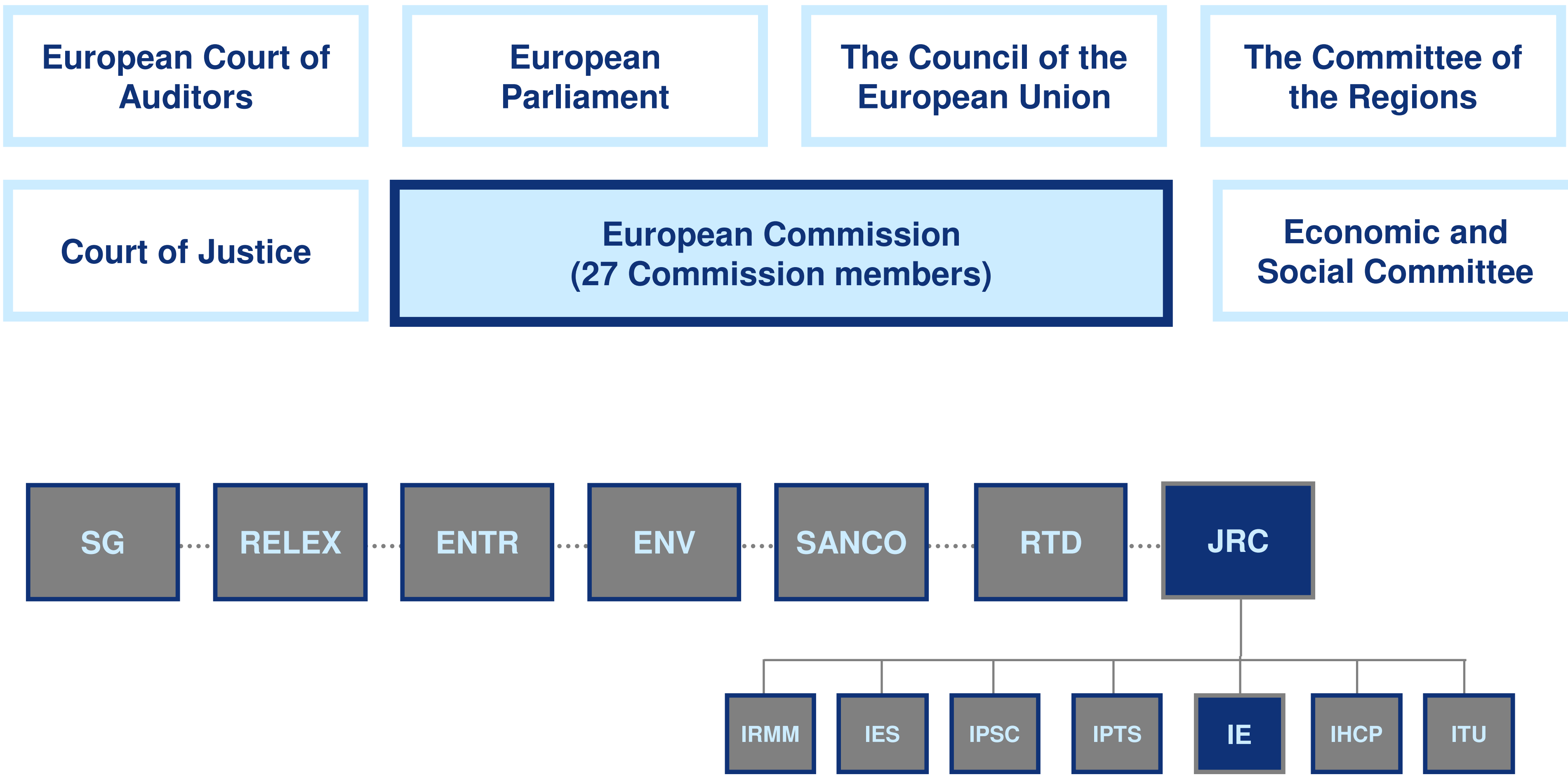
… und die wichtige Rolle der Elektronen und Protonen





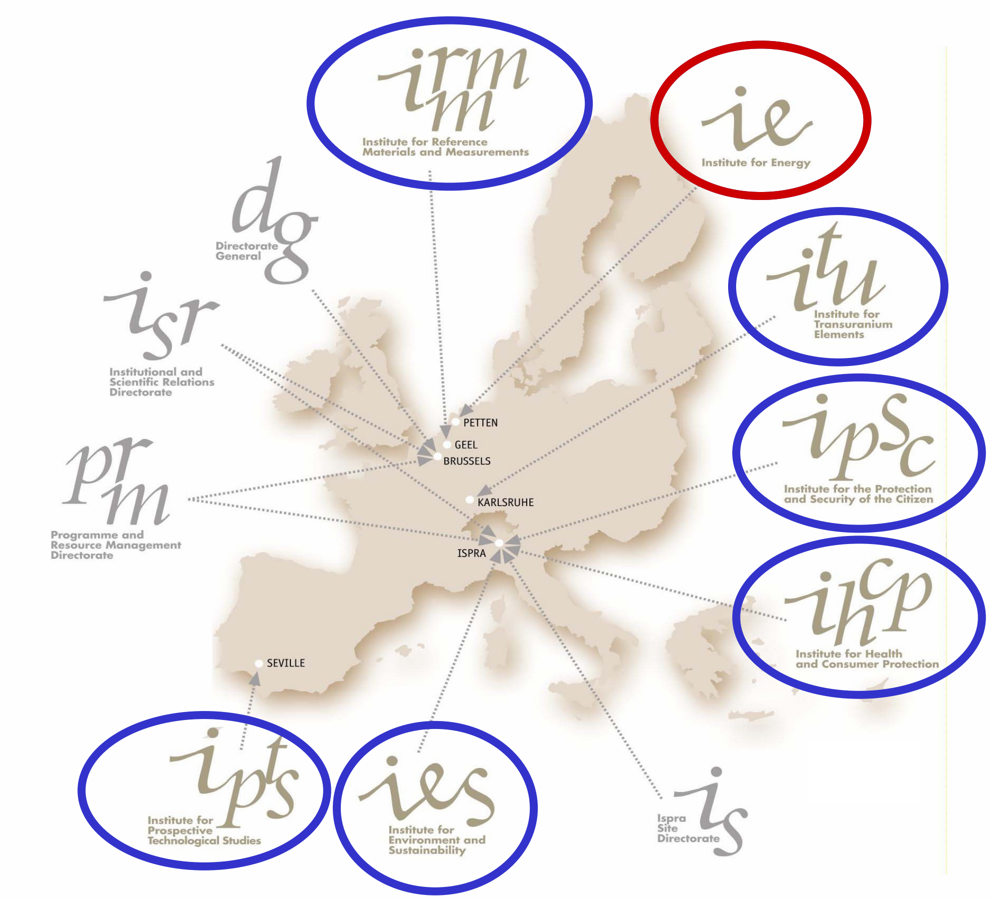


The JRC is one of the DGs of the EC…



… and a peculiar organisation

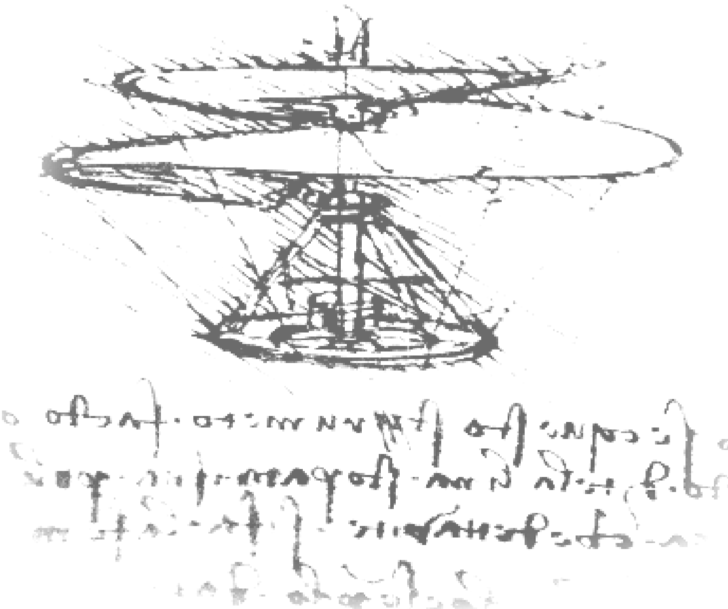
- **General:**
  - DG of the European Commission
  - Founded in 1957
  - 7 institutes in 5 countries
- **Size:**
  - 2750 staff
  - More than 1000 partner organisations
- **Finances:**
  - Total budget 2008: 333 M€
  - Income 2008: 48 M€



JRC – Gemeinsame Forschungsstelle

Institute for Energy

The Mission of the JRC



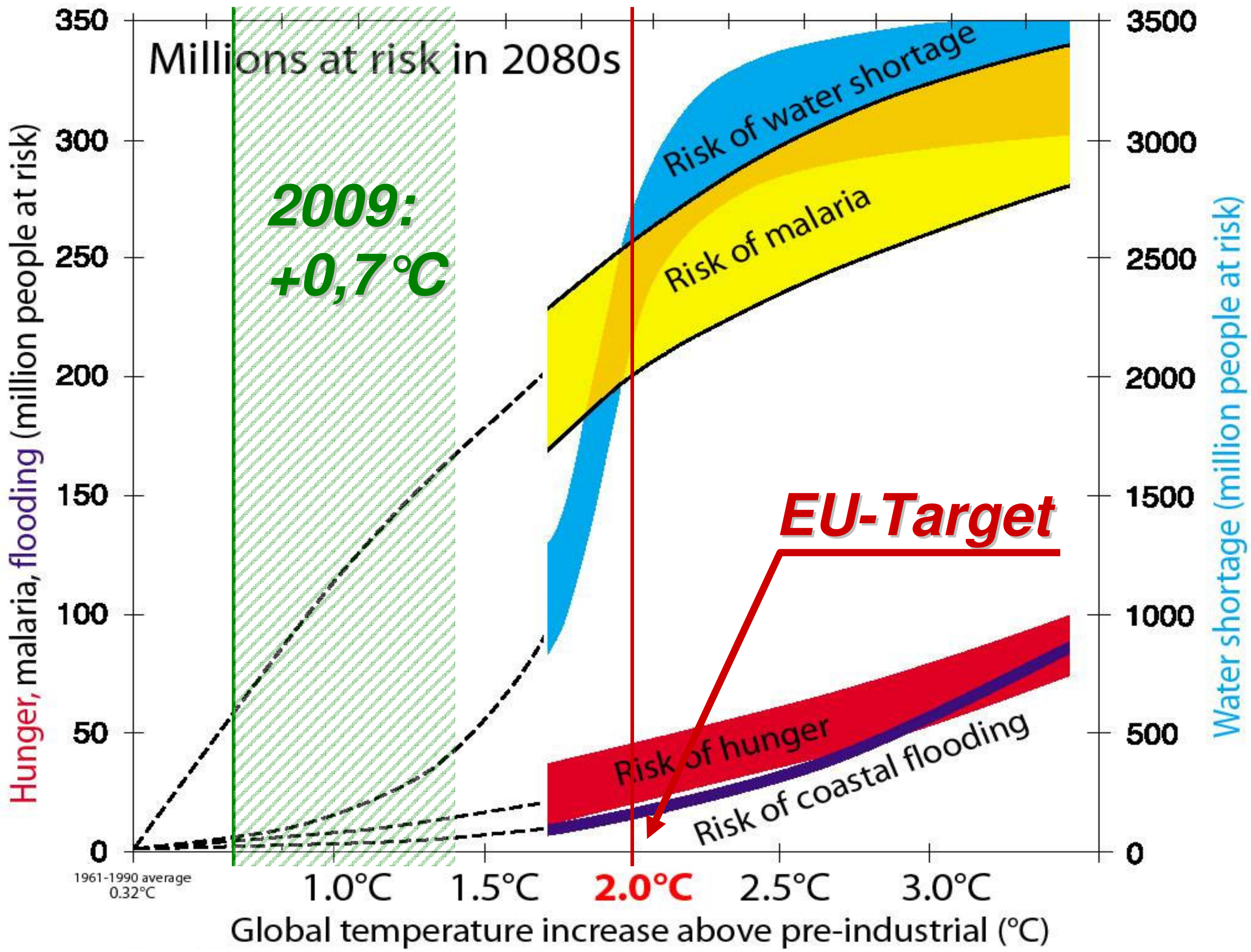
… to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies …

The JRC functions as a centre of science and technology (S/T) reference for the European Union, independent of special interests, private or national ...

JRC

EUROPEAN COMMISSION

Climate Change is a top issue for the EU…



Quelle: Parry et al., 2001

… as is the topic of energy security

Nuon Windpark in Egmond aan Zee, NL

Decarbonisation is THE buzz word of today

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The evolution of the Policy Context (Lisbon Treaty, December 2009)

Europe 2020 Strategy (March 2010) → Smart/Sustainable/Inclusive Growth

Flagship Initiative "Resource-efficient Europe" → To decouple growth/energy & resource use

Towards an energy strategy for Europe 2011-2020 (DG ENER)

→ Towards a new Action Plan (spring Council 2011)

Roadmap for low carbon energy system by 2050 (DG ENER)

→ 80-95% CO_2 reduction (2050)

Transport Whitepaper (2010-2020) (DG MOVE)

→ Decarbonisation of Transport as one main priority

Beyond 20% CO_2 reduction by 2020 (DG CLIMA)

Clean and efficient vehicles are a must!

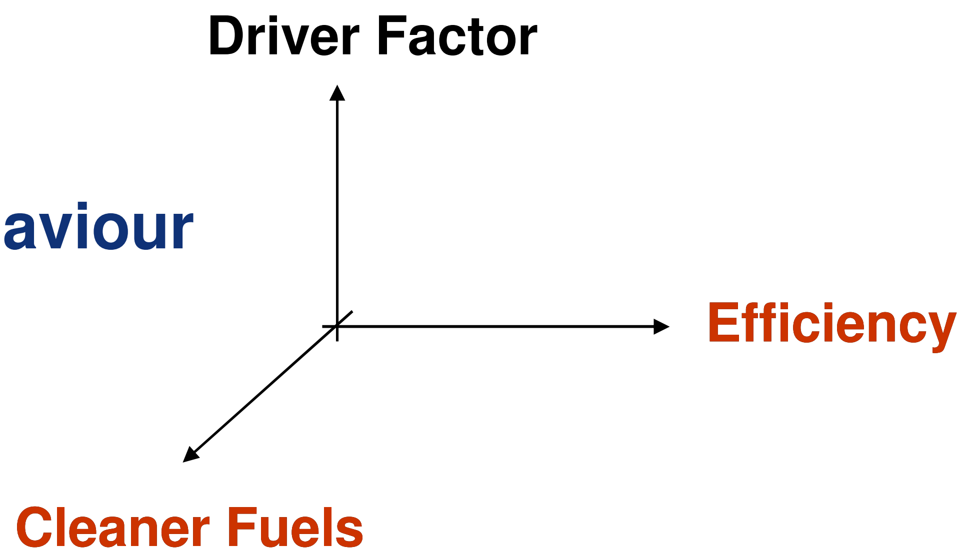
- EU Commitment: 80% GHG reduction by 2050
- But: Road transport relies practically exclusively on oil
- And: transport related GHG account today for 25% of the global GHG emissions (2050: 50%!)

An 80% reduction in CO_2 emissions from road transport in the EU requires an almost complete decarbonisation of all cars on European streets

Progress is required in all areas…

Three axes of developments are essential:

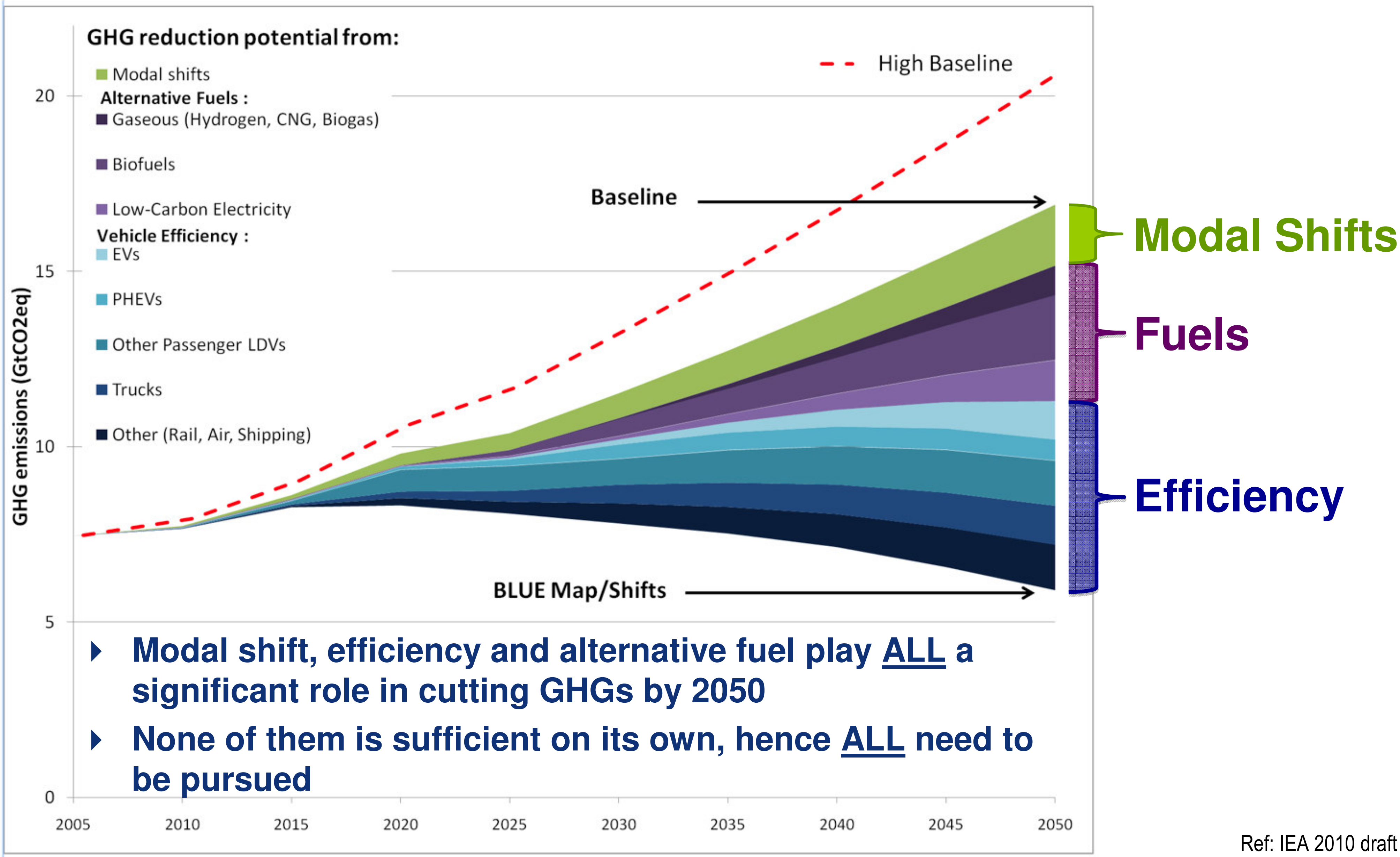
- More efficient vehicles
- Switching to cleaner fuels
- Smart driver choices and behaviour



- Enhancing security of EU energy supply by
  - Diversification
  - Lower consumption
- Enhancing knowledge and innovation for EU competitiveness

win-win-win situation

… so that a GHG reduction can be achieved



- Modal shift, efficiency and alternative fuel play <u>ALL</u> a significant role in cutting GHGs by 2050
- None of them is sufficient on its own, hence <u>ALL</u> need to be pursued

Ref: IEA 2010 draft

Efficiency improvements bring swift benefits

Up to 50% reduction in fuel use per km for average new LDV reachable by 2030

Through combination of

- Technology improvements
  (direct injection, OBD, transmission, reduced drag, lightweight materials, …)
- Hybridisation
  including more efficient (electric) drive train + regenerative braking

Provided that efficiency gains are not used for larger, heavier and faster cars!

Efficiency improvement

- is cost-effective (even at relatively low oil prices)
- has immediate pay-off in reduction of GHG emissions
- net negative CO2 reduction costs are possible

- **Immediate contribution, absolutely needed**
- **However, not enough CO_2 reduction potential**

Gasoline/Diesel will not be easily replaced

Current fuels: Gasoline/Diesel

Major advantage: High energy density, which has enabled present-day

- passenger car configuration (weight, space, performance)
- fuel distribution infrastructure

These fuels are rather "cheap"

(mainly because lack of internalisation of external costs)

"But how long still available?"

Selecting the right fuel is key…

Liquid biofuels (Bio-ethanol, Bio-diesel)

- No major changes needed in vehicle stock or in fuelling infrastructure
- Can be implemented in short-term

BUT

- Sustainability criteria, incl. ILUC
- 2nd generation technologies needed for adequate balance between food-feed-fuel
- Still carbon-containing ⇒ not enough GHG emission reduction potential
  even when combined with improved efficiency measures
- "Reserve" liquid biofuels preferentially for aviation
  where current liquid fuels are much more difficult to substitute (both at engine and infrastructure level)
- Biomass conversion to power/heat has better CO_2 balance than to 2nd generation liquid fuels

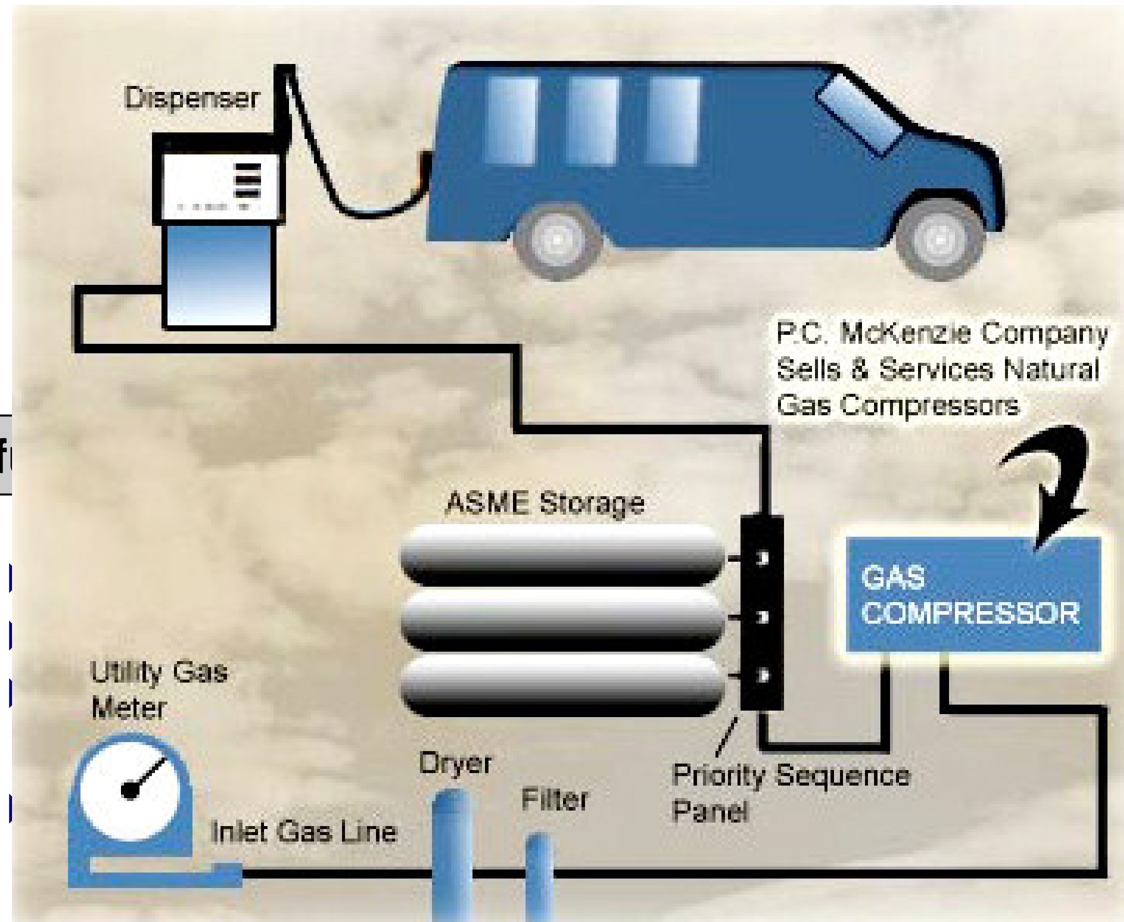
Can contribute moderately in the near term, but not enough

Note: synthetic liquid fuels from coal and gas do not offer GHG benefits unless combined with CCS

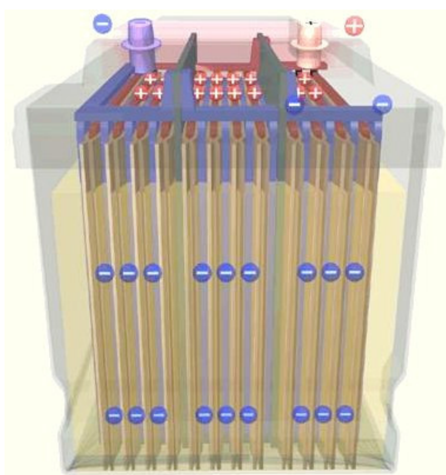
… to decarbonise the transport sector

Gaseous fuels (Compressed Natural Gas, Liquefied Petroleum Gas)

Require modifications to engine and to infrastructure



Non-C containing “f



- Must be used in high-efficiency drive trains

If WtW/LCA are used as assessment tools...

Life Cycle Analysis (LCA)

Covers the full chain in terms of

- Emissions (gCO_2eq/km) (New European Driving Cycle - NEDC)
- Energy requirements (MJ/km) (NEDC)

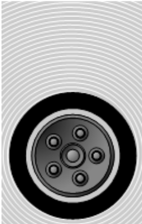
Extraction/ harvesting → Production/ Processing → Distribution → Tailpipe

+ disposal/ recycling should in principle also be considered

Well-to-Tank WtT (fuel)

Tank-to-Wheel TtW (drive train, auxiliaries..)

Well-to-Wheel WtW



http://ies.jrc.ec.europa.eu/WTW

… various pathways have to be considered

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Resource

Crude oil

Coal

Natural Gas

Biomass

Wind

Nuclear

Fuels

Conventional Gasoline/Diesel/Naphtha

Synthetic Diesel

CNG (inc. biogas)

LPG

MTBE/ETBE

Hydrogen
(compressed / liquid)

Methanol

DME

Ethanol

Bio-diesel (inc. FAEE)

Powertrains

Spark Ignition*:*
Gasoline, LPG, CNG, Ethanol, H_2

Compression Ignition:
Diesel, DME, Bio-diesel

Fuel Cell

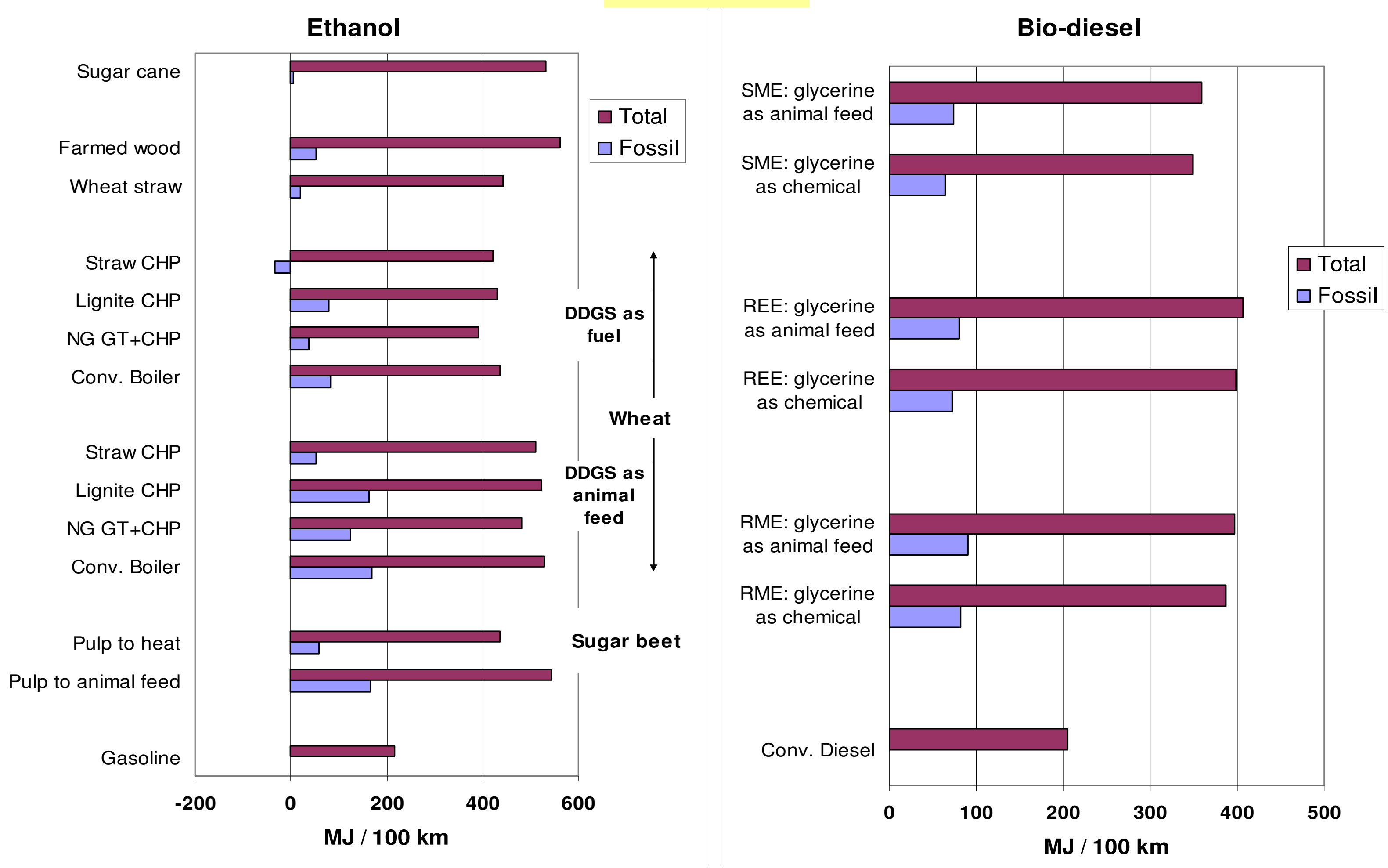
Hybrids: *SI, CI*, FC

Hybrid Fuel Cell + Reformer

Ref: JEC study

WtW analysis: Bio-fuels

2010+ vehicles

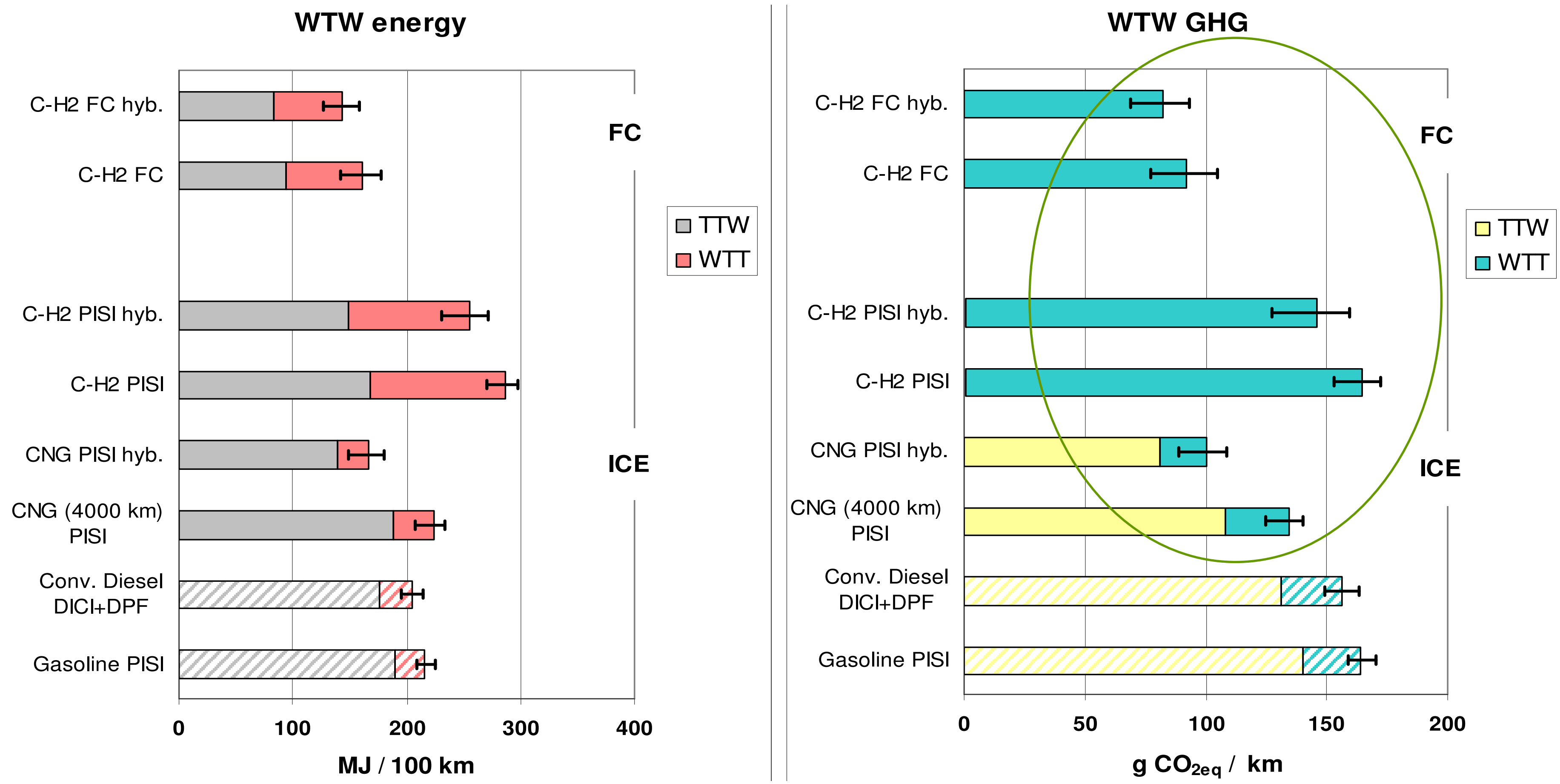


The conversion of biomass into bio-fuels is not energy-efficient

Ref: JEC study

WtW analysis: H_2 from NG - ICE and FC

2010+ vehicles

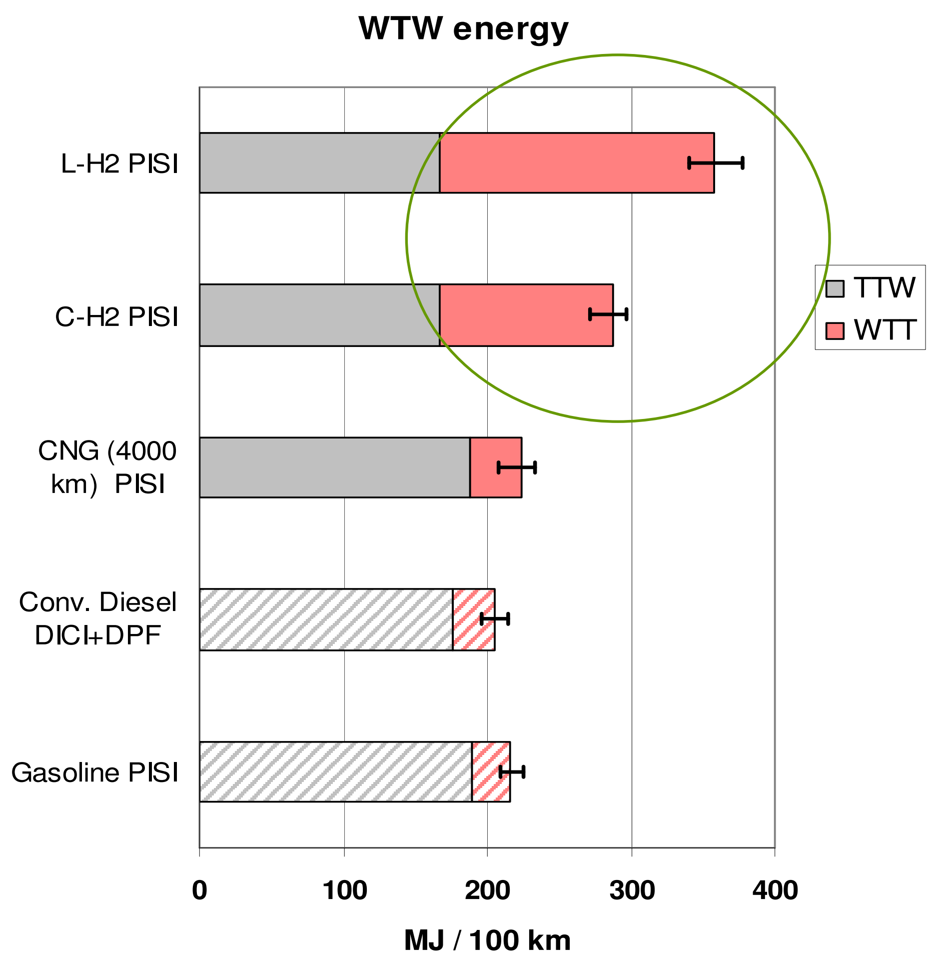


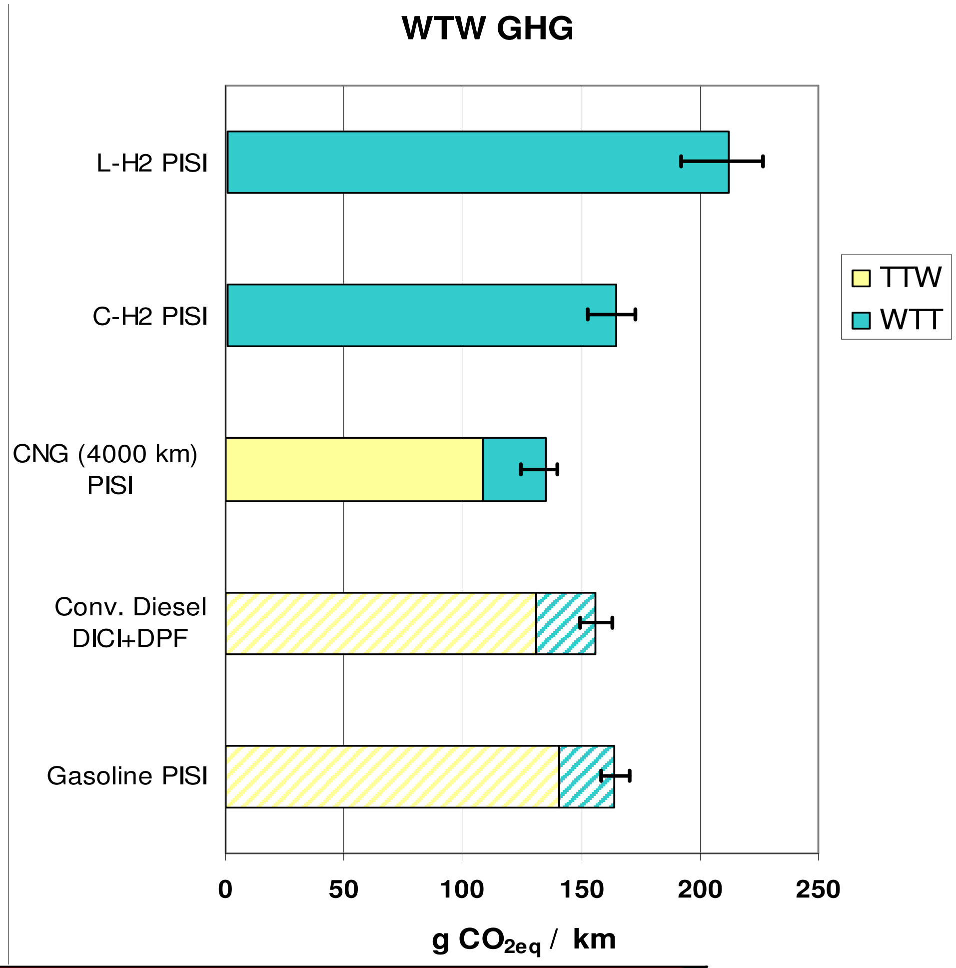
For H2 production from NG, GHG emission are only reduced with FCV

Ref: JEC study

WtW analysis: H_2 from NG - compr. vs. liquid

2010+ vehicles

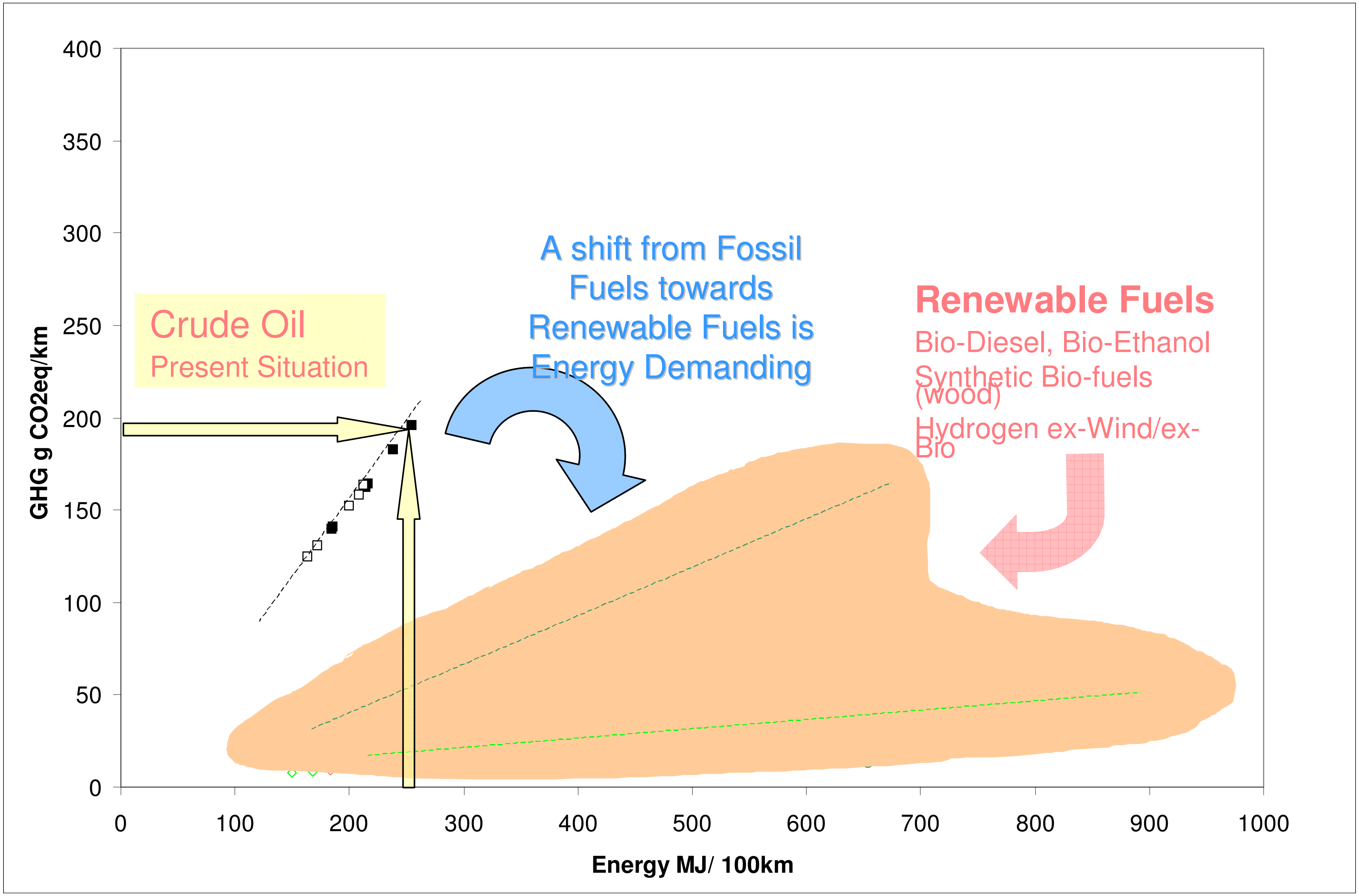




Liquid H_2 is less energy efficient than compressed H_2

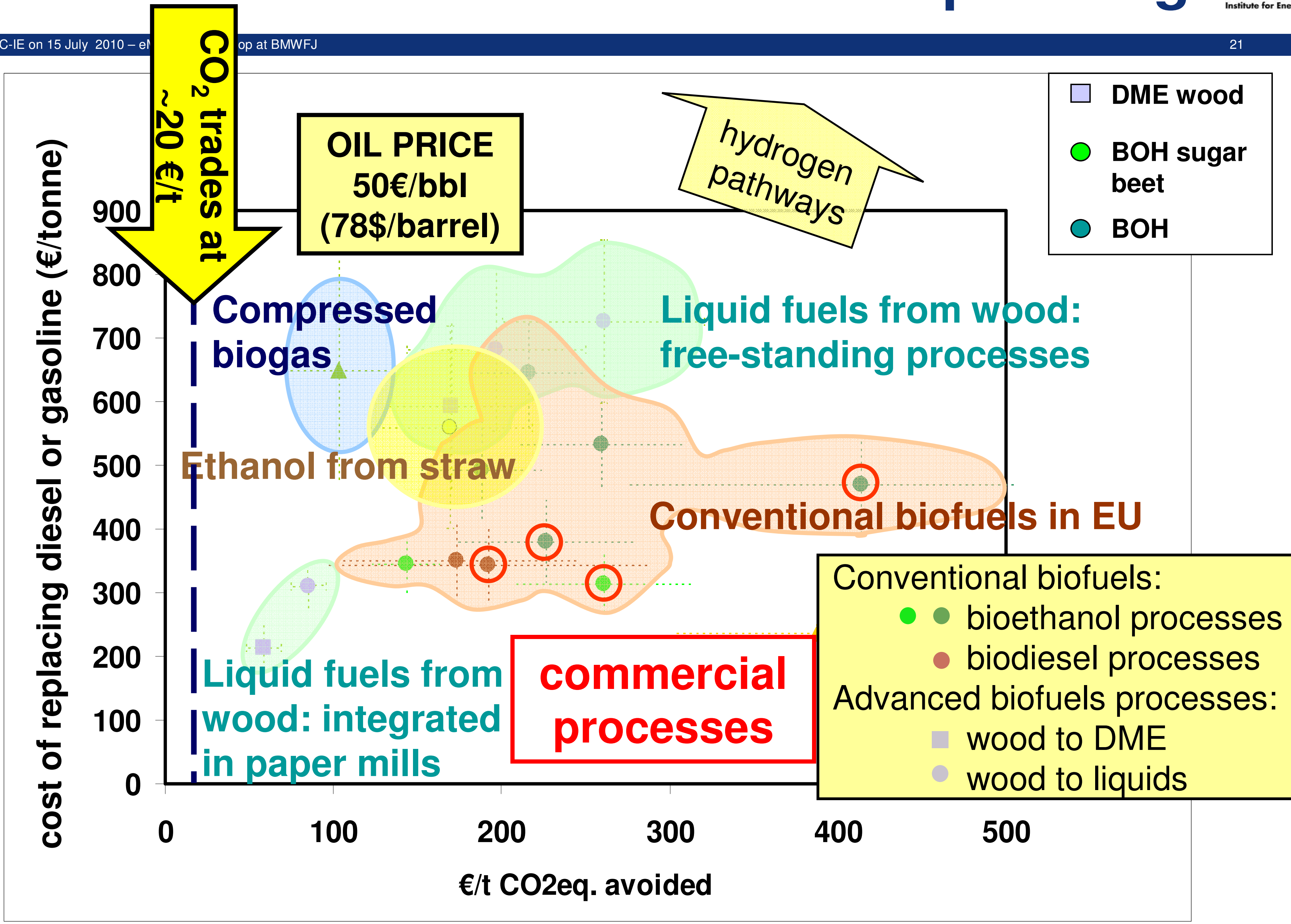
Ref: JEC study

The reduction of GHGE requires energy…



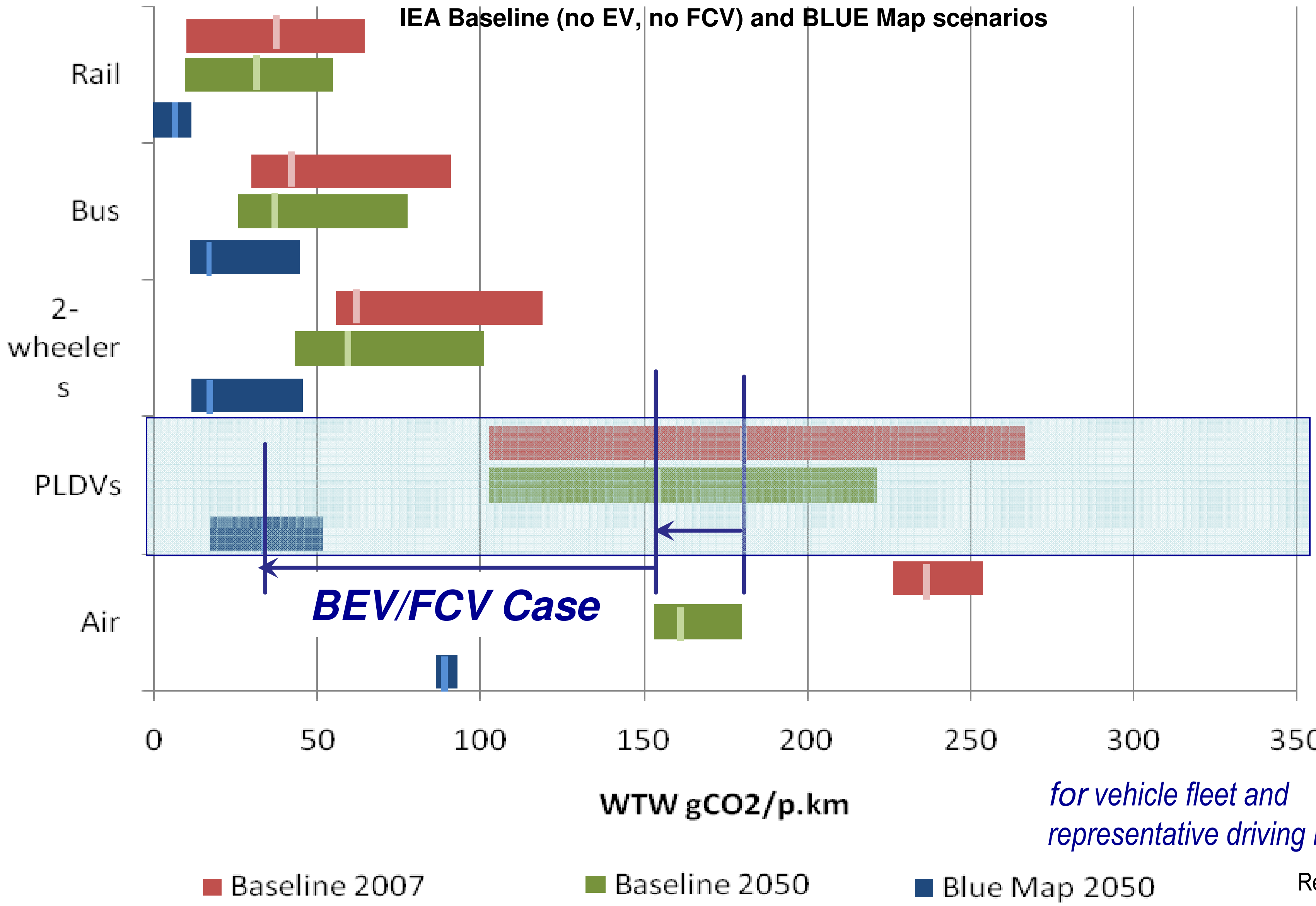
Ref: JEC study

… and comes with a 2-dimensional price tag



Deep GHG reductions call for BEVs & FCVs

GHG intensity of passenger transport in 2007 and 2050



for vehicle fleet and representative driving behaviour

Ref: IEA 2010 draft

BEV & FCV can compete with ICE/PHEV

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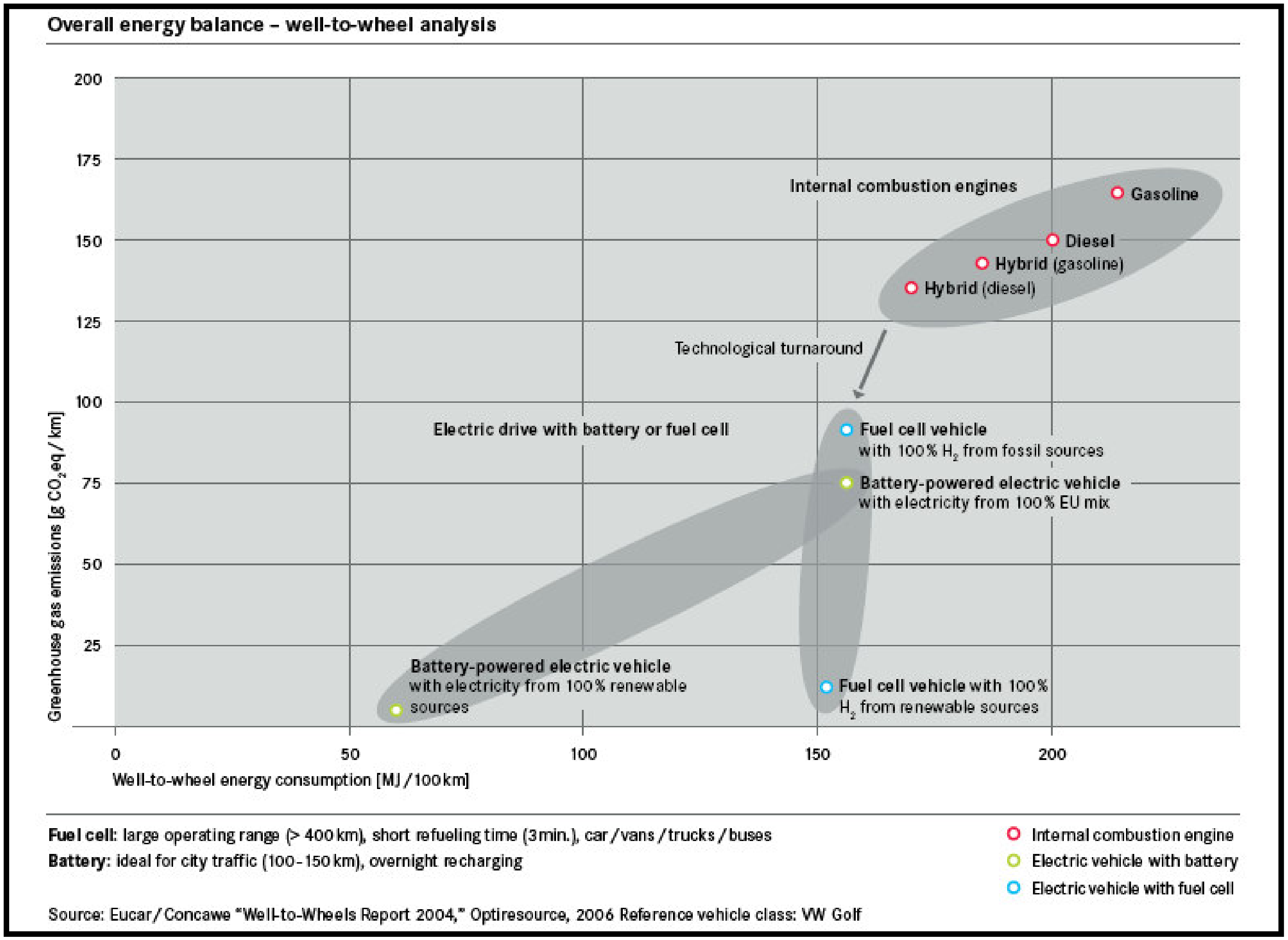
JRC-EUCAR-CONCAWE: Well-to-Wheel Analysis (WtW)

Extraction/ harvesting → Production/ Processing → Distribution → Tailpipe

Major update this year



Source: Daimler, 2009

BEV & FCV face technical issues…

Electricity and hydrogen can play a role in road transport >2020, but require near-term action

- Performance improvement and cost reduction, to reach levels similar to ICE
- Co-development of vehicles (incl. batteries, fuel cells) **AND** of recharging/refuelling infrastructure to avoid "chicken-and-egg" situation

Potential technical show-stoppers:

Batteries Electric Vehicles, Plug-in Hybrid Electric Vehicles:

- Battery performance (energy density, power density, cyclic degradation, ..)

Fuel Cells Vehicles:

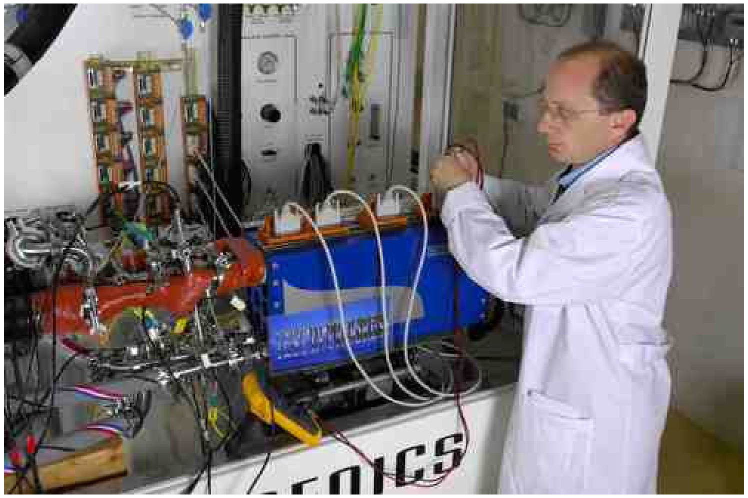
- On-board hydrogen storage
- H2 production and distribution technologies, refuelling (safety aspects)
- Fuel cell performance (degradation, …)

For all:

- Clean energy sources (RES, nuclear, CCS)
- Smart grid

Addressed by:

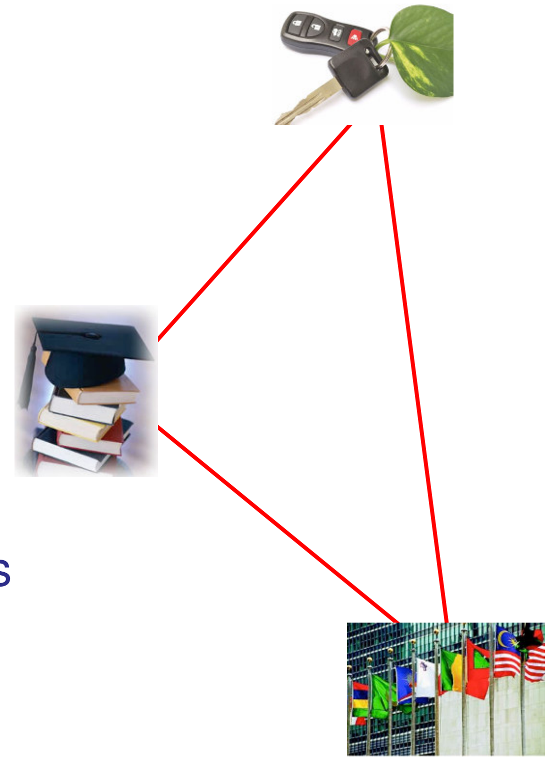
- step-up in research and demonstration to achieve performance at acceptable cost



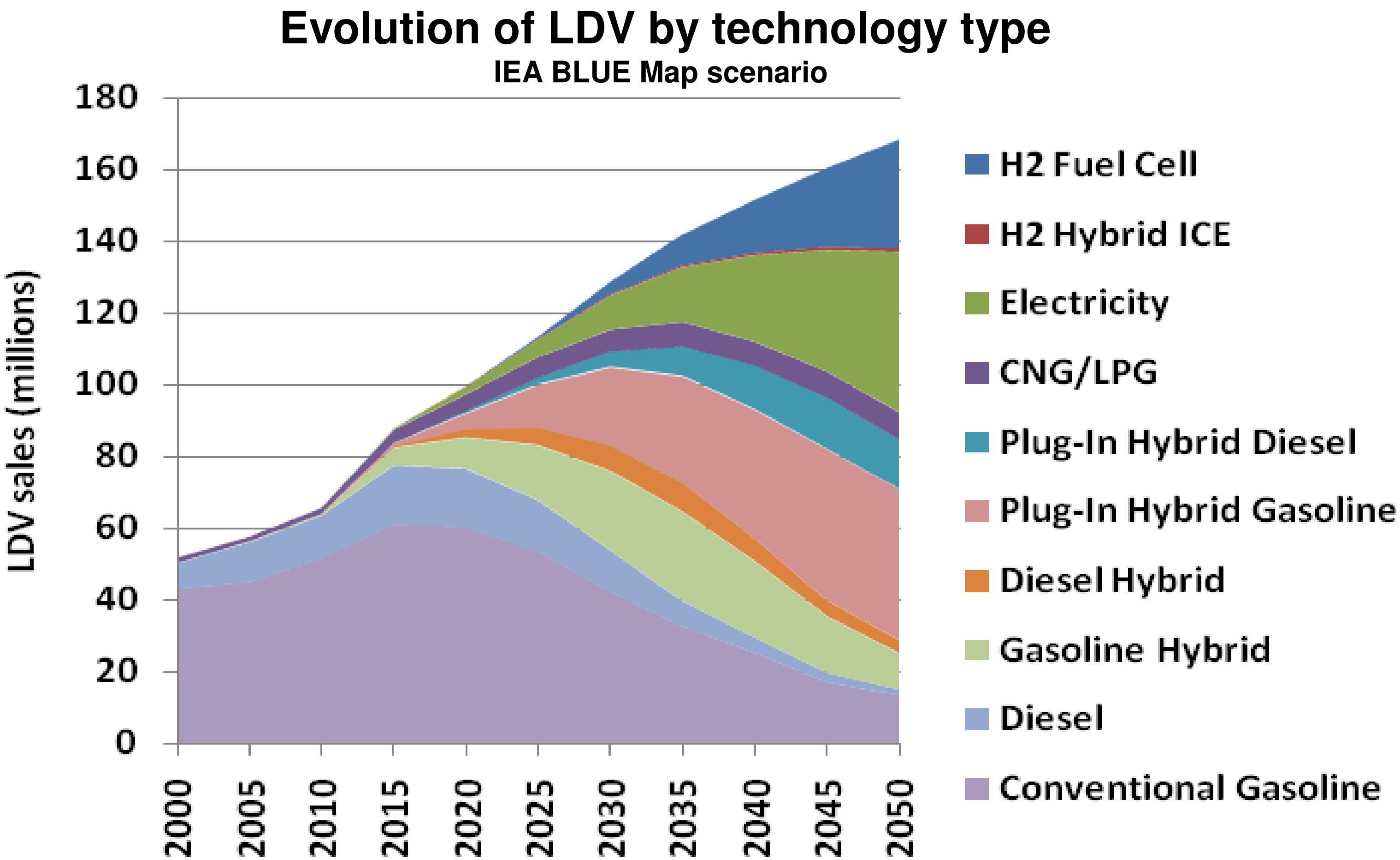
… and market challenges

Non-technical show stoppers:

- Customer acceptance (costs, performance in terms of range and recharging time, safety perception of H_2, **but also cleaner energy sources**)
- Valley of death between demonstration and full market roll-out
- Chicken-and-egg: vehicle versus refuelling/recharging infrastructure
- Lack of skills
- Absence of / lack of harmonisation of standards and regulations
- Verification of sustainability
- Raw material security
    - Noble metal group elements as catalysts
    - Rare Earth metals in batteries and electric motors



The IEA envisions an EV paradigm shift

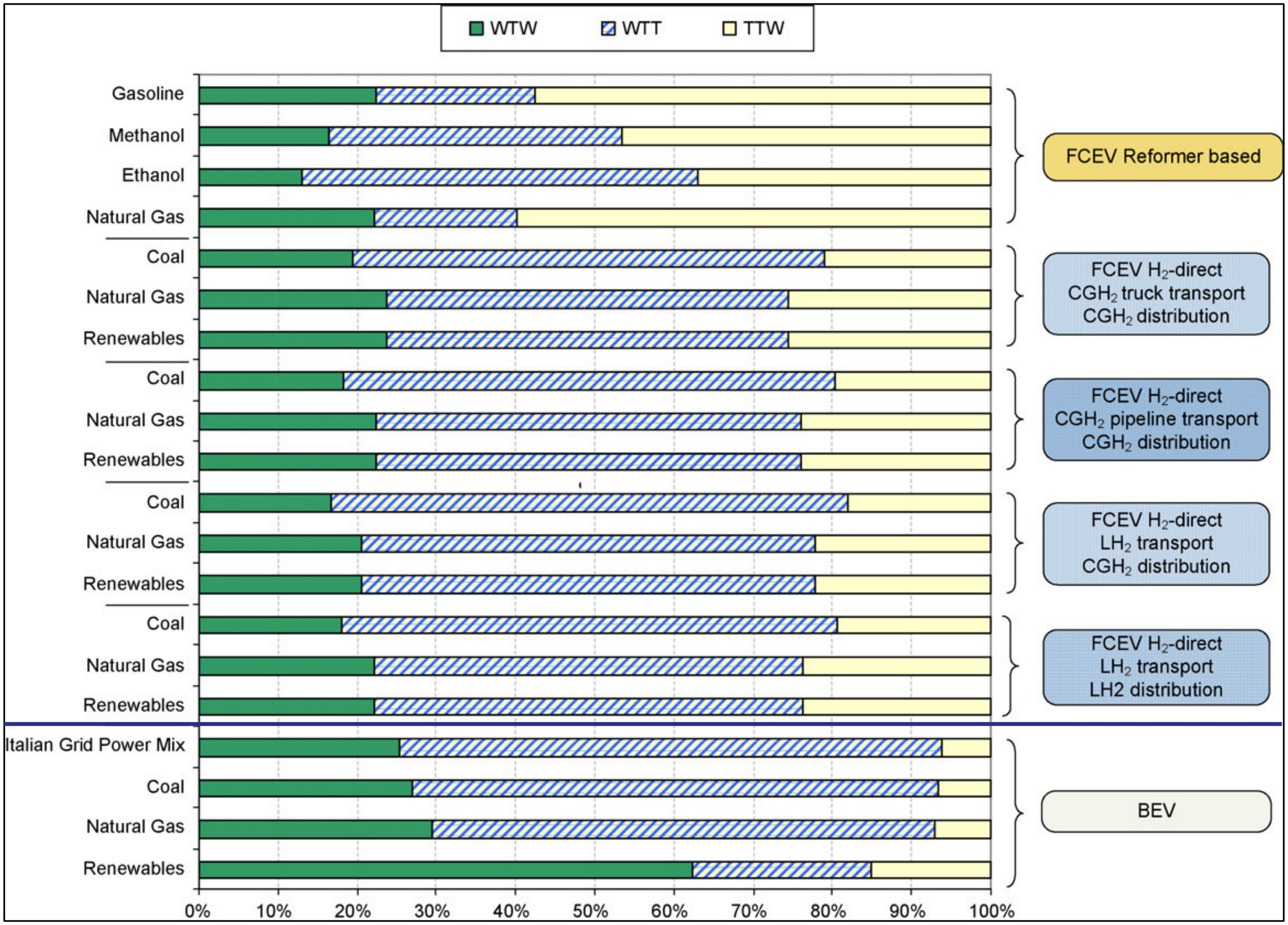


- **ICE, including hybrids, decline after 2030**
- **PHEV, BEV and FCV will reach ~80% of sales in 2050**

Ref: IEA 2010 draft

The FAQ: BEV vs. FCV or BEV and FCV?

WtW efficiency, WtT and TtW losses for BEV and FCV



For "nominal" conditions: BEV seems superior to FCV (lower WtT losses)

But

A realistic simulation of drive cycles is needed

Ref. Campanari IJHE, 2009 (battery = Li-ion)

Both the comparison of WtW consumption…

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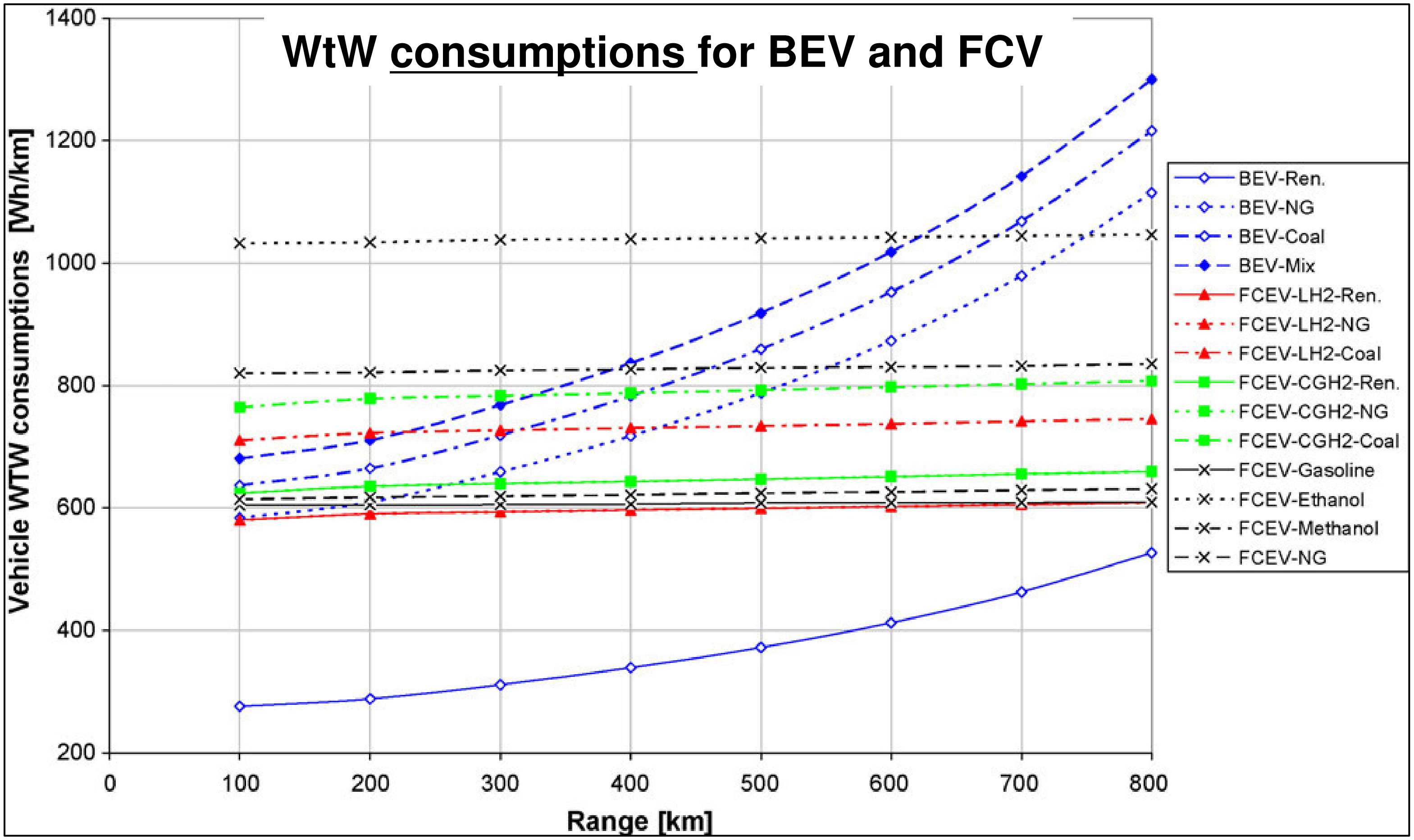

- **WtW energy consumption of BEV seriously affected by driving range**
  ⇒ BEV competitive for ranges below 300-400 km
- **BEV from electricity mix: highest consumption of all (Italian mix as reference)**

Ref. Campanari IJHE, 2009

… and GHGE favour FCV at greater ranges

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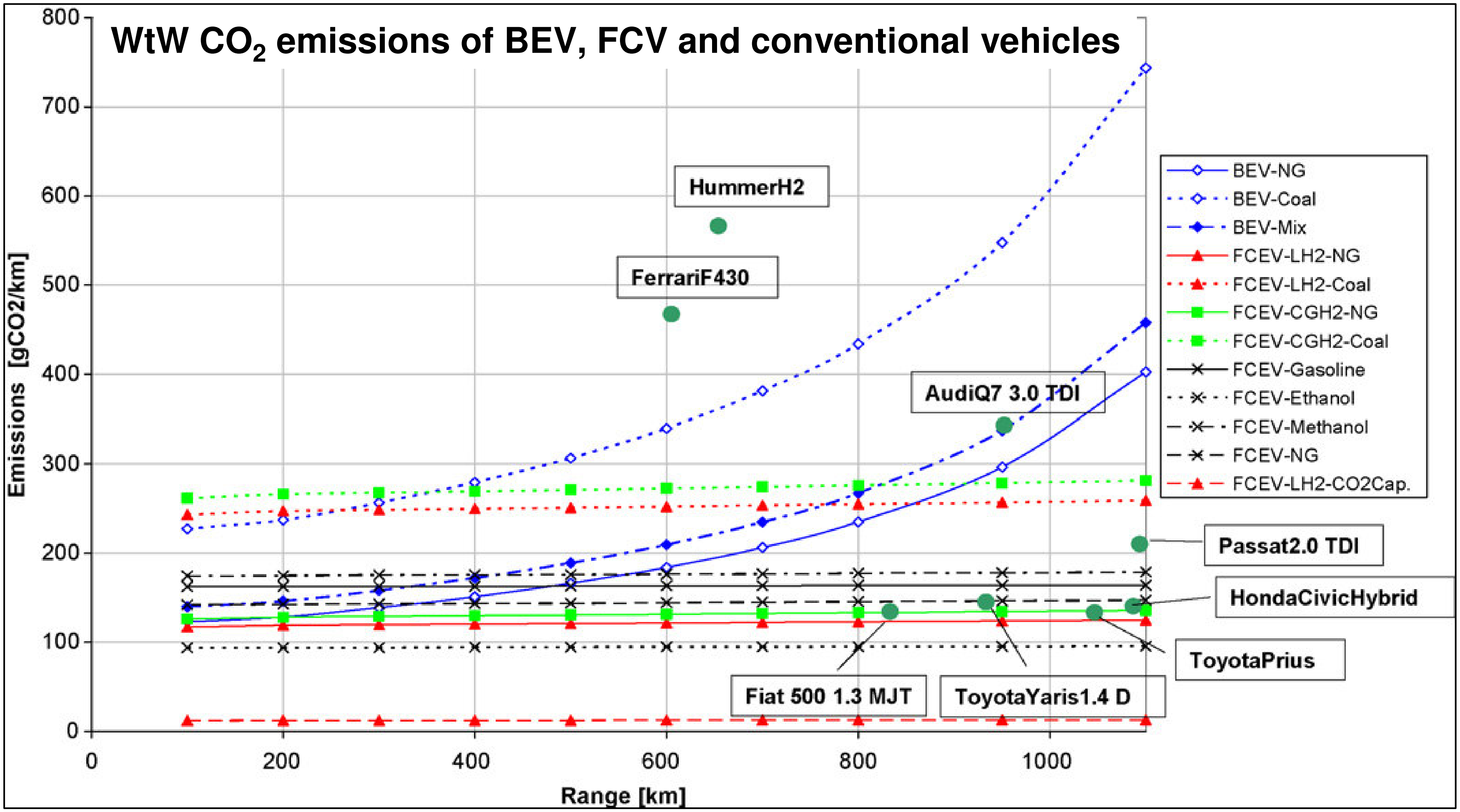
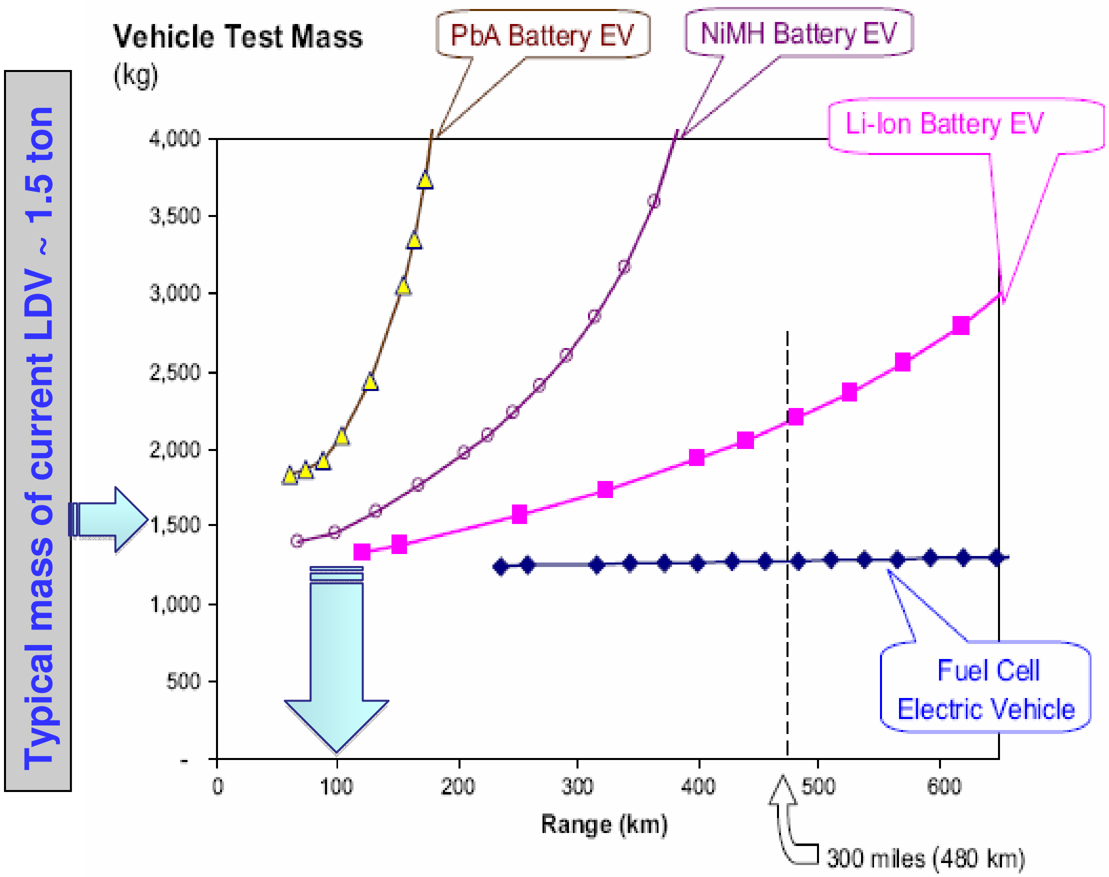


- BEV WtW GHGE seriously affected by driving range (similar to energy consumption)
- Some commercial vehicles outperform BEV
- For today's typical driving ranges only FCV is feasible

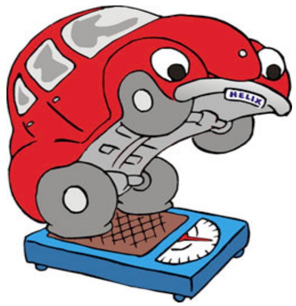
Ref. Campanari IJHE, 2009

BEVs suffer from low energy density…



- **Higher mass for BEV than for current ICE gives rise to higher energy consumption and, with current electricity mix also to higher GHG emissions, despite higher efficiency.**
- **This does not apply for FCV – even when H2 is produced by reforming natural gas.**

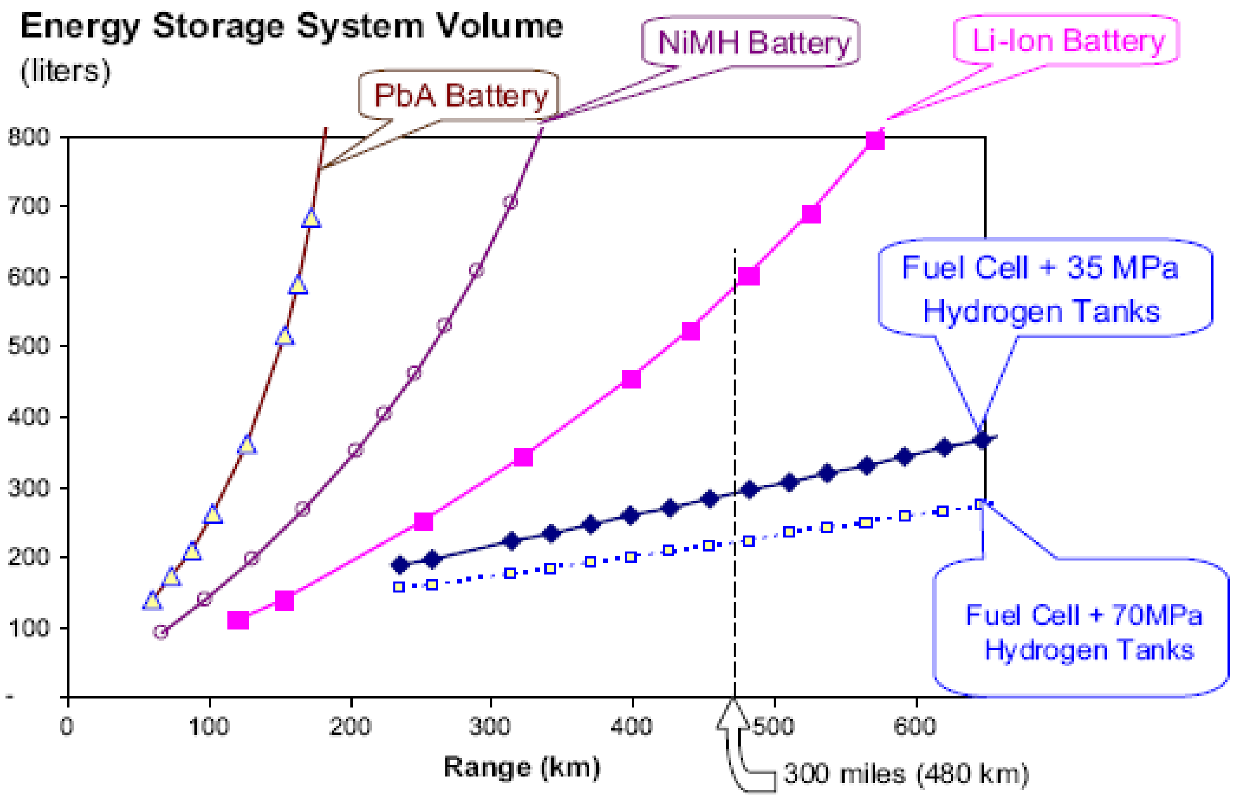
- **"Acceptable" range for LDV only possible with Li-ion batteries**
- **BEV only competitive for ranges < 100km**



Ref. Thomas, IJHE, 2009

… both gravimetric and volumetric

Volume of H2 storage + FC system and of batteries as function of vehicle range



FCV feature 50% less loss of useful space than BEV with Li-ion batteries

Ref. Thomas, IJHE, 2009

BEV vs. FCV: The user perspective

Fuelling time

- FCV: average H_2 fuelling times for >16000 refuellings of 140 FCV: 3.3 minutes (NREL)
- BEV: charge time depends on
  - recharging rates: avoid overheating and maintain voltage balance
  - driving range
  - power rating of dispensing equipment
- For acceptable (but not yet achievable) ranges: tens of hours – or alternative concepts: change of battery pack, necessitating different business model

Vehicle cost

- At present slight advantage BEV

Fuel cost per km

(= fuel price per unit of energy (€/MJ) * fuel efficiency TtW (MJ/km) = €/km)

- BEV superior only when off-peak charging possible

Fuelling infrastructure cost (before full deployment)

- Lower up-front investments for BEV

Conclusion: There is no BEV vs. FCV…

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Technology measures are definitely required to achieve needed CO_2 emission reduction from road transport:

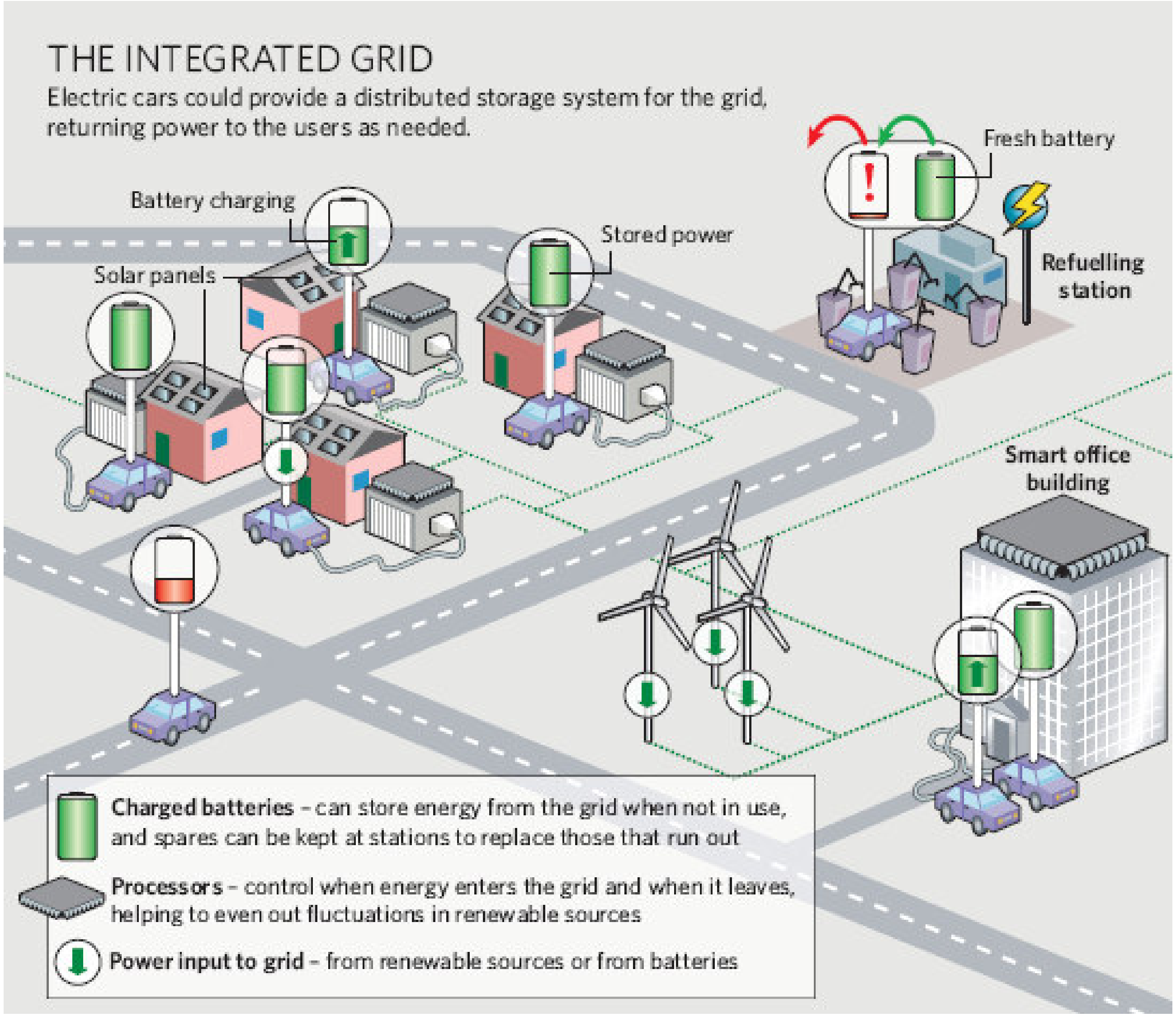
- Implement a.s.a.p. all possible efficiency improvement measures
- Eliminate ICE from many, if not most LDV in the long term:
    - Make transition to all-electric (BEV, FCV) over next few decades
    - HEV, 2nd generation biofuels and PHEV in the near term

… both electrons and protons are required!

- Clean transport is not possible without clean power!!
  - Transport must be considered in transitioning to low (zero)-C energy system of which it will constitute a non-negligible demand part – transport technology policy is de facto a major element in energy technology policy (SET-Plan)
  - Decarbonising power generation represents an even more urgent challenge than electric vehicle technologies because of the time it takes to implement
  - Impact on grid in terms of needed capacity, but also flexibility to be seriously considered
- FCEV represent a range and refuelling advantage over BEV. As of now, batteries are competitive in PHEV and BEV for niches/fleets. Both will benefit from developments in electric drive trains.
- Necessary transition to zero-C road transport technologies has a positive impact on
  - Local pollution and noise, particularly in urban environment, with health and cultural conservation benefits
  - Security of energy supply

The focus of the electron R&D is on the grid…

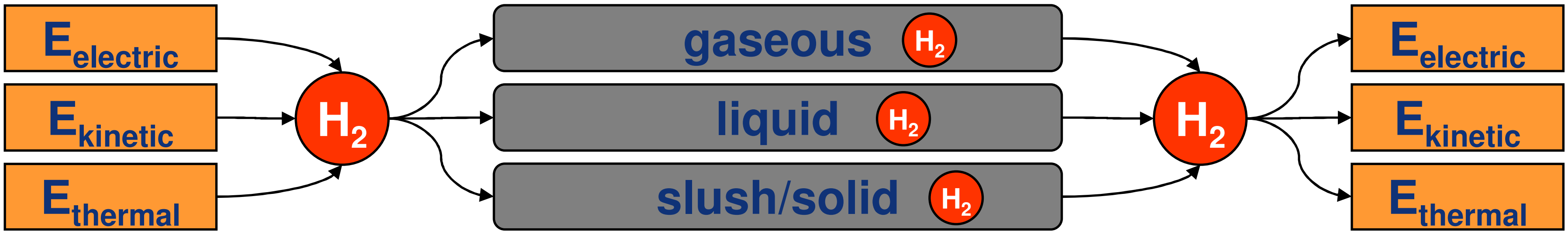
Electric vehicles provide opportunity for grid balancing

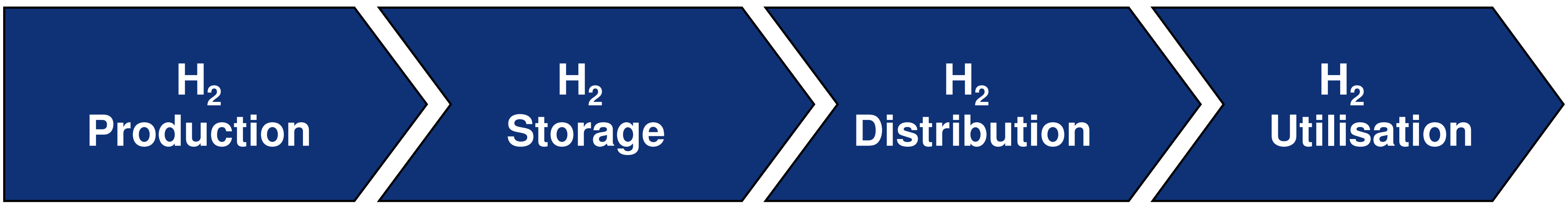


Grid balancing can facilitate increased usage of intermittent renewable resources.

Source: Tollefson (in Nature 2008)

... and the proton R&D focus on the value chain





- Electrolysis
- Reforming
- Thermal

?

- Chemical
- Combustion
- Fuel Cell

The JRC-IE conducts R&D on H_2 storage…

High-pressure gas tank testing facility GasTeF

N_2 liquid storage

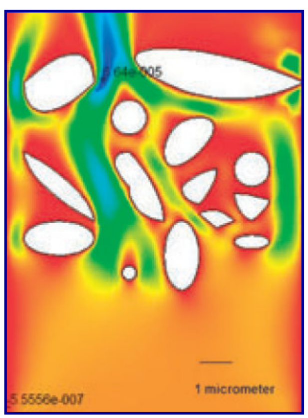
H_2 and CH_4 storage

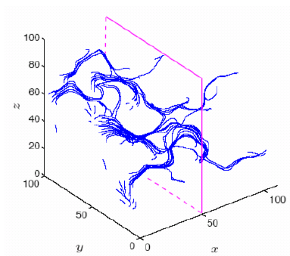
Compressor and tank testing "bunker":
- 1 m thick composite walls
- 3 meters sand
- 40 tons sliding door
- 225 m^3 interior filled with N_2 during tests

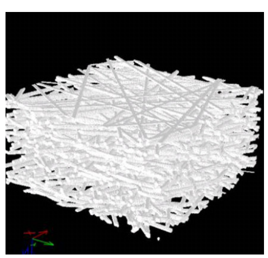
…validates and verifies FC technologies…

Environmental and vibration testing of FC systems and their performance

efficiency, engine and evaporative emission testing







ISO TC 197, IEC TC 105
UN-ECE WP 29

… and performs complete systems tests…

Vehicle Emissions LAboratory (VELA)

- **The laboratory, equipped with the most advanced facilities and instrumentation, allows the physical/chemical and toxicological characterization of the emissions from all types of transport fleet.**
- **Its measurements support assessments in:**
  - Energy Efficiency in Transport
  - Tank-to-wheel analyses and vehicle and emission inventories modeling
  - Several support activities for vehicle related regulations and standards (incl. testing)

… to turn the Decarbonisation vision into reality