



Engines, Energy and Environment Group



**Politecnico
di Torino**

Hydrogen as a fuel for internal combustion engines: potentials and challenges

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Is ICE a dead man walking ?



EU nations approve end to combustion engine sales by 2035

EURACTIV.com with AFP and Reuters

29 giu 2022 (updated: 30 giu 2022)

Advertisement



Agnès Pannier-Runacher, French energy minister, announced the deal after negotiations that
[Copyright: European Union]

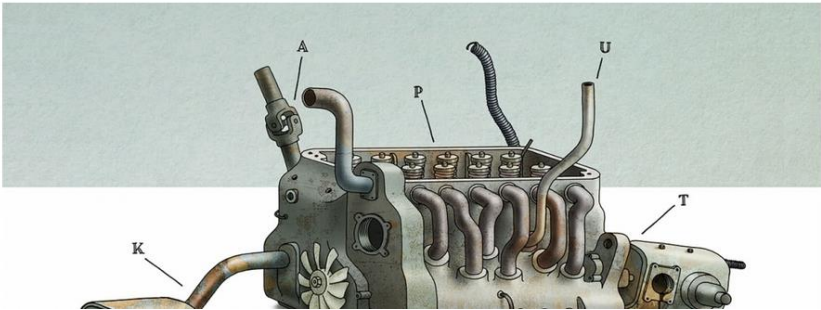


The Economist

Electric cars

The death of the internal combustion engine

It had a good run. But the end is in sight for the machine that changed the world



“Reports of my death have been greatly exaggerated”, Mark Twain, 1897



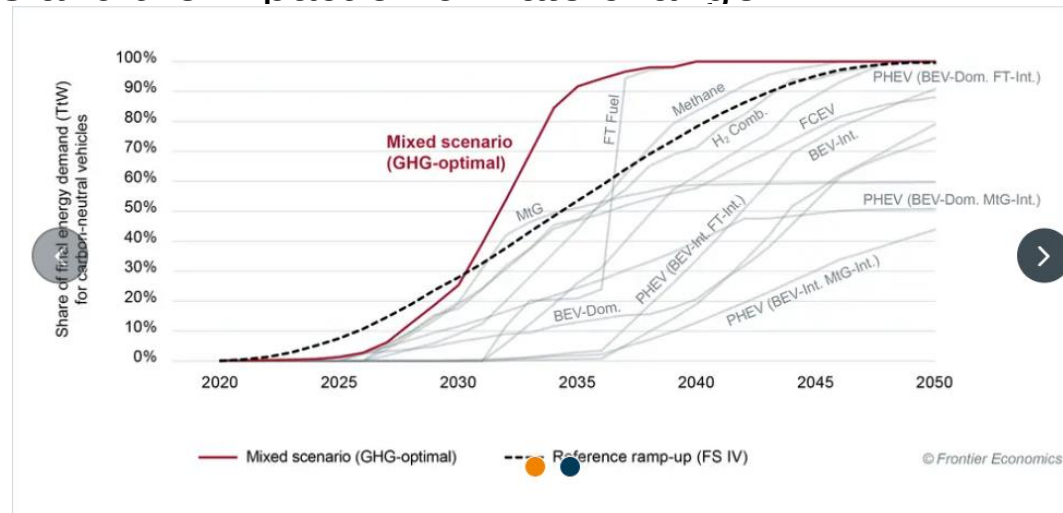
Why H₂ as a fuel for ICEs ?



In order to achieve the challenging GHG emission reduction targets for 2030-35, and the even more challenging carbon neutrality by 2050, there is not a “silver bullet” or a “one size fits all” solution, but all different options need to be investigated and exploited.

In this perspective, a recent study by FVW, a Germany-based worldwide innovation network, provided a comprehensive analysis of different powertrain technologies for the European transport sector. It concludes that:

“the speed of deploying GHG-neutral mobility solutions ... is much more important than the choice of technologies. The majority of GHG emissions are caused by the phase-out of the vehicle fleet, which is still operated with fossil energy carriers. Therefore, the faster a defossilized vehicle fleet can be introduced, the lower are the cumulative GHG emissions and the impact on climate change.”



Source: «Transformation of mobility to the GHG-neutral post-fossil age », FVW Report, 2022, Project Coordinator Dr.-Ing. Ulrich Kramer (Ford-Werke GmbH)

Why H₂ as a fuel for ICEs ?



□ H₂-ICE for Commercial & Heavy Duty at similar cost of Diesel engines (<< of Fuel Cell or Battery)



□ H₂-ICE considered as “zero-emission vehicle”



□ No compromise in driving range, payload and reliability

□ Retrofitting of existing vehicle & engine architectures



□ Reuse of existing footprints & skills, with positive LCA (production & recycle) quick time to market



□ Improve/keep sound experience of existing engines

□ Capability to operate at Heavy Duty conditions for prolonged time & in harsh environment

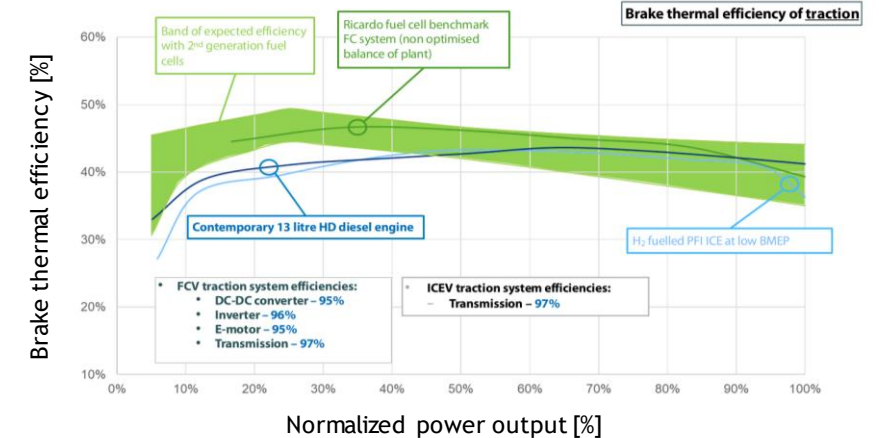


□ Quick refueling time (like for actual engines)



□ Reduced recharging footprint & no grid peak load vs BEV

□ Few H₂ stations sufficient for hub based specific fleets



Variations across categories

	Bio/synfuel	Hydrogen internal combustion engines (H ₂ -ICE)	Hydrogen (H ₂) fuel cell	Battery electric
Emissions				
CO ₂ intensity	CO ₂ intensity depends on source of biomass/carbon	Zero/minimal CO ₂ if using green/blue H ₂	Zero/minimal CO ₂ if using green/blue H ₂	CO ₂ intensity depends on grid mix; zero CO ₂ if using renewable power
Air quality	NO _x and particulate-matter emissions similar to diesel	No significant NO _x emissions with SCR ² aftertreatment	Zero emissions	Zero emissions
Total cost of ownership				
Efficiency (well-to-wheel)	~20%	~30% for renewable H ₂ production	~35% for renewable H ₂ production	75–85%+ depending on transmission and charging losses
Powertrain capital expenditure	Same as today's combustion engines	H ₂ engine with similar capex as diesel ICE, but H ₂ tank required	High capex for fuel cells and batteries, but more scalable than BEV ³	High capex if large batteries required (medium for smaller/lighter segments)
Constraints (space/payload)	Same size and weight as today's combustion engines	Engine with same size as today, but H ₂ tank needed	More space needed than combustion engine for fuel cell and H ₂ tank	Higher weight than combustion engine; payload constraints subject to use case
Uptime/refueling	<15 minutes, depending on tank size	<15–30 minutes, depending on tank size	<15–30 minutes, depending on tank size	3+ hours, depending on ability for fast charging
Infrastructure costs	Can use existing infrastructure	H ₂ distribution and refueling infrastructure required	H ₂ distribution and refueling infrastructure required	Charging infrastructure and grid upgrades required

[1] Ricardo Webinar - “Development of Heavy-Duty Hydrogen Powertrains for 2025+”, Nov 24th, 2020

[2] adapted from Bernd Heid, Christopher Martens, and Anna Orthofer, “How hydrogen combustion engines can contribute to zero emissions”, McKinsey & Company 2021

Academia Meets Industry for a New Generation of H2 ICE

Politecnico di Torino & Dumarey



WCXTV

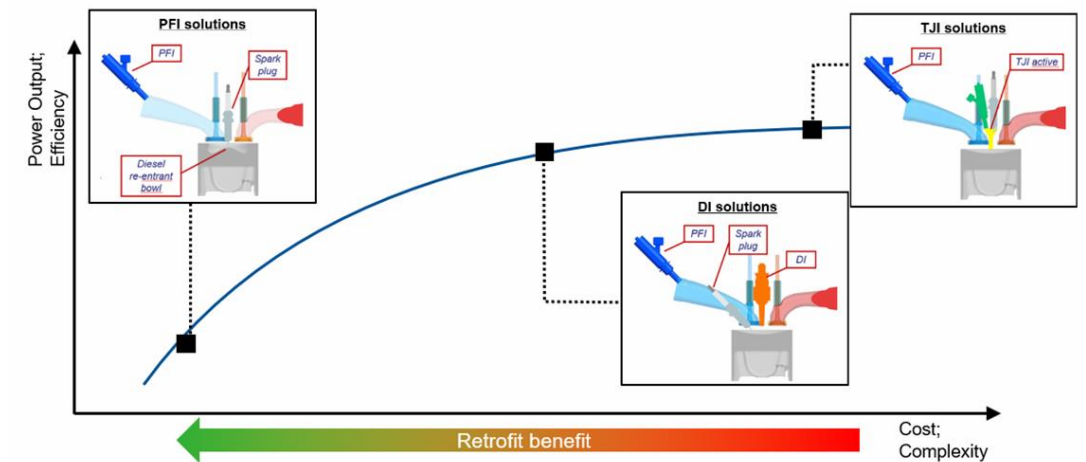
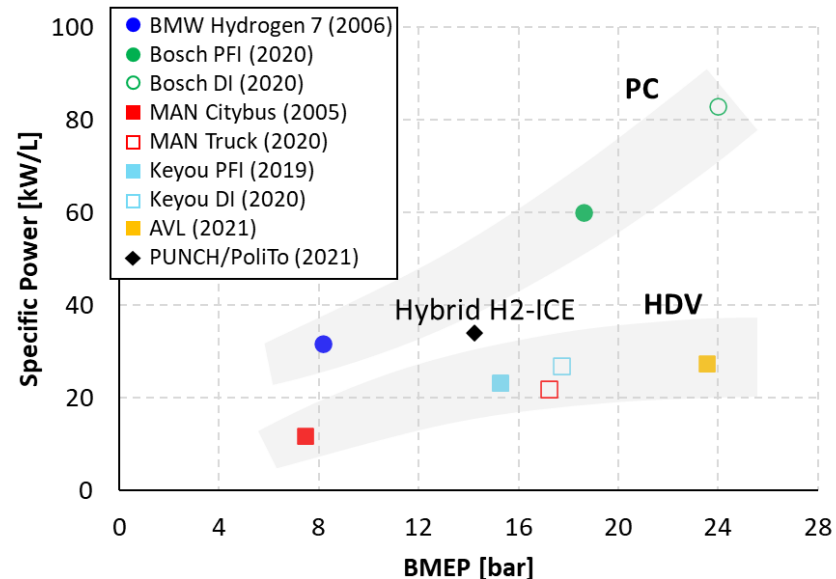
Conclusions



In conclusions, **highly efficient, near zero emissions** hydrogen fuelled internal combustion engines are technically **feasible**. **BTE up to 45%** with premixed combustion and low pressure injection systems appear to be realistic targets, with possible further improvements moving to high pressure direct injection.

NOx emissions appear to be **manageable**, thanks to the combination of low engine out levels obtained through ultralean combustion, and dedicated aftertreatment.

Hydrogen fuelled internal combustion engines, especially in HEVs, can be a valuable option to achieve the **decarbonization of the road transport sector**, along, rather than in competition with, Fuel Cells and BEVs.





Thanks for your kind attention!

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