World Hydrogen Energy Summit 2021
16-17 November 2021 - Virtual

Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

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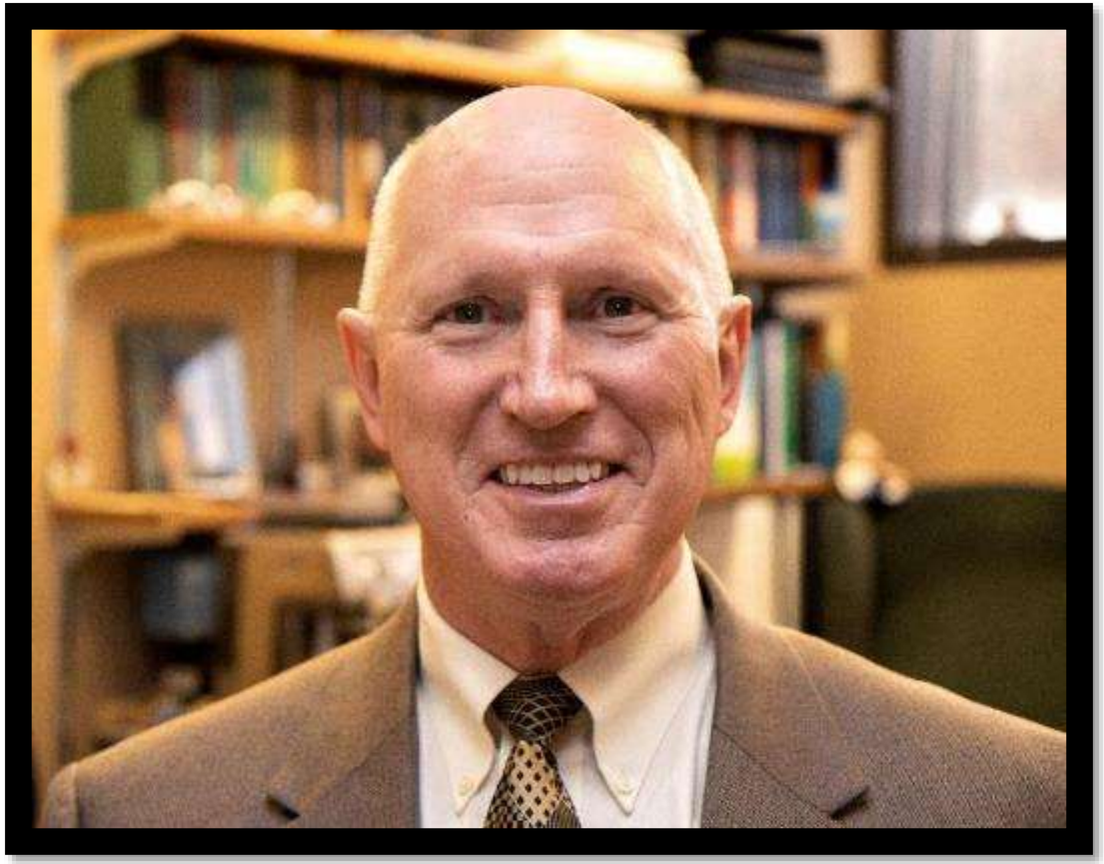
Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport



John W. Sheffield

I am a professor at Purdue University in West Lafayette, Indiana. I also serve as the President of the International Association for Hydrogen Energy and I am the Senior Associate Editor of the International Journal of Hydrogen Energy. I am excited to share with you some of my personal insights on …

Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

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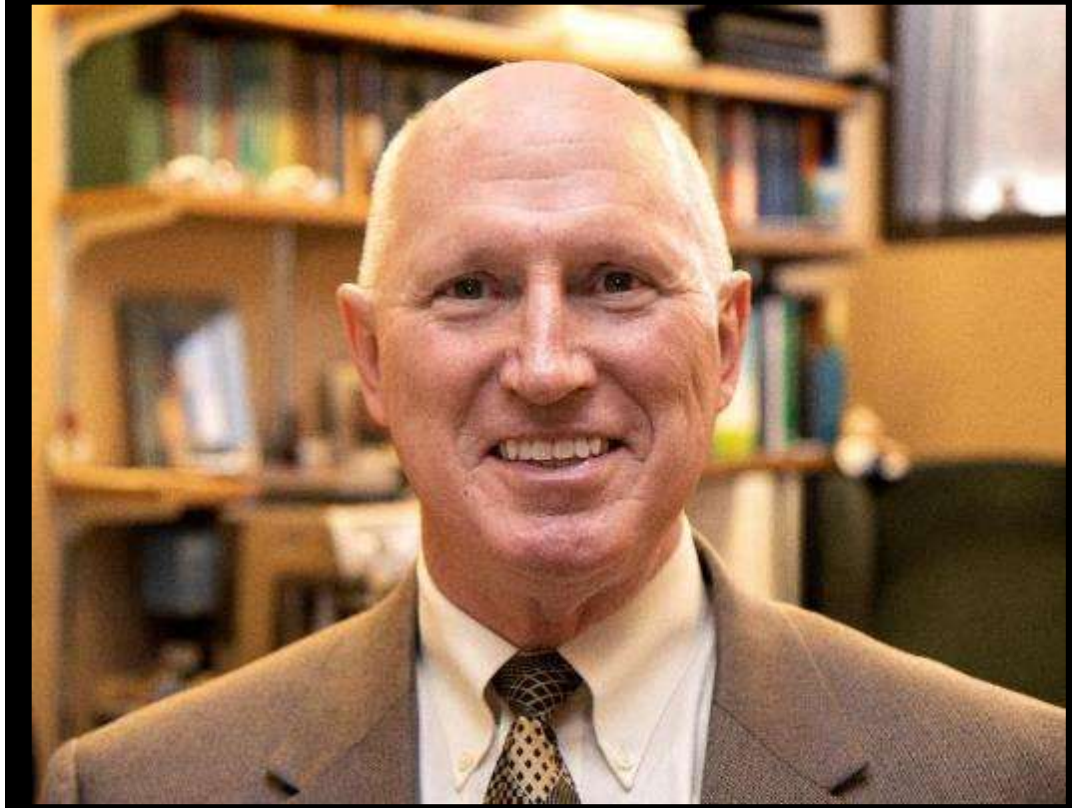
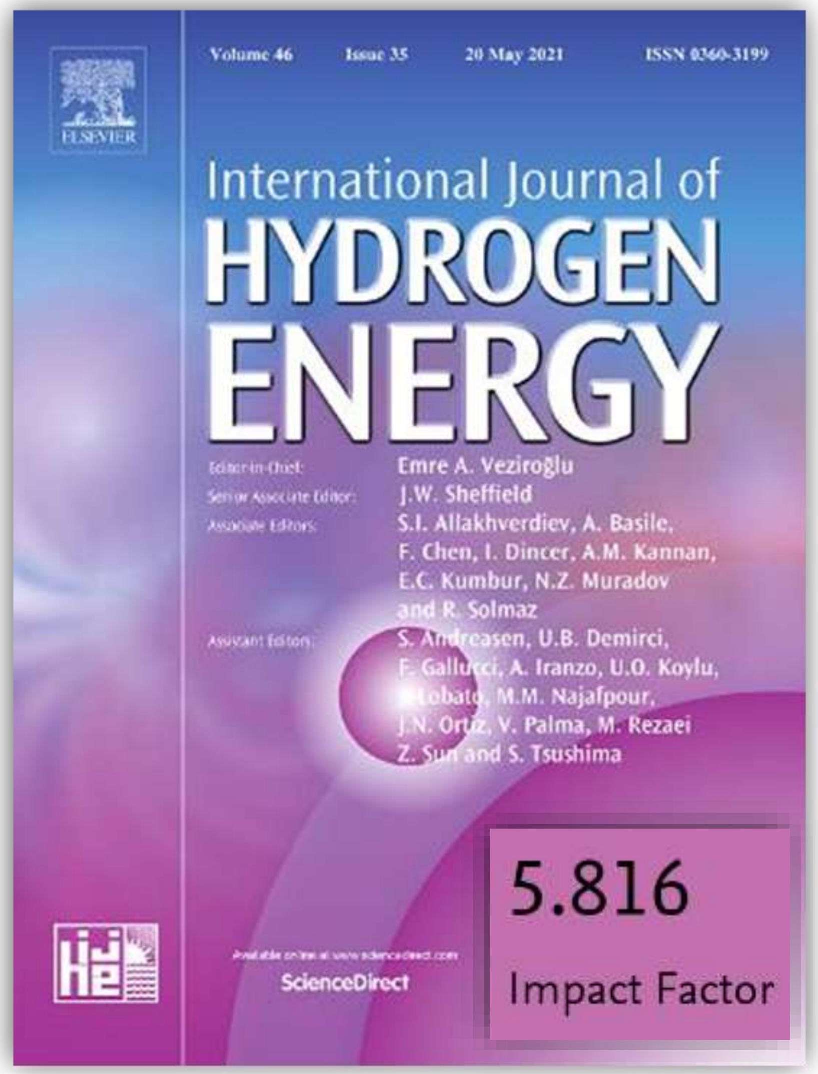


John W. Sheffield

My career in hydrogen energy began in 1976 when working for Pratt and Whitney Aircraft in West Palm Beach, Florida. Specifically, we were developing the technologies for high-power, continuous wave hydrogen fluoride and deuterium fluoride chemical lasers. Later my academic career started at the University of Miami, then California Institute of Technology, then Missouri University of Science and Technology and now at Purdue University.

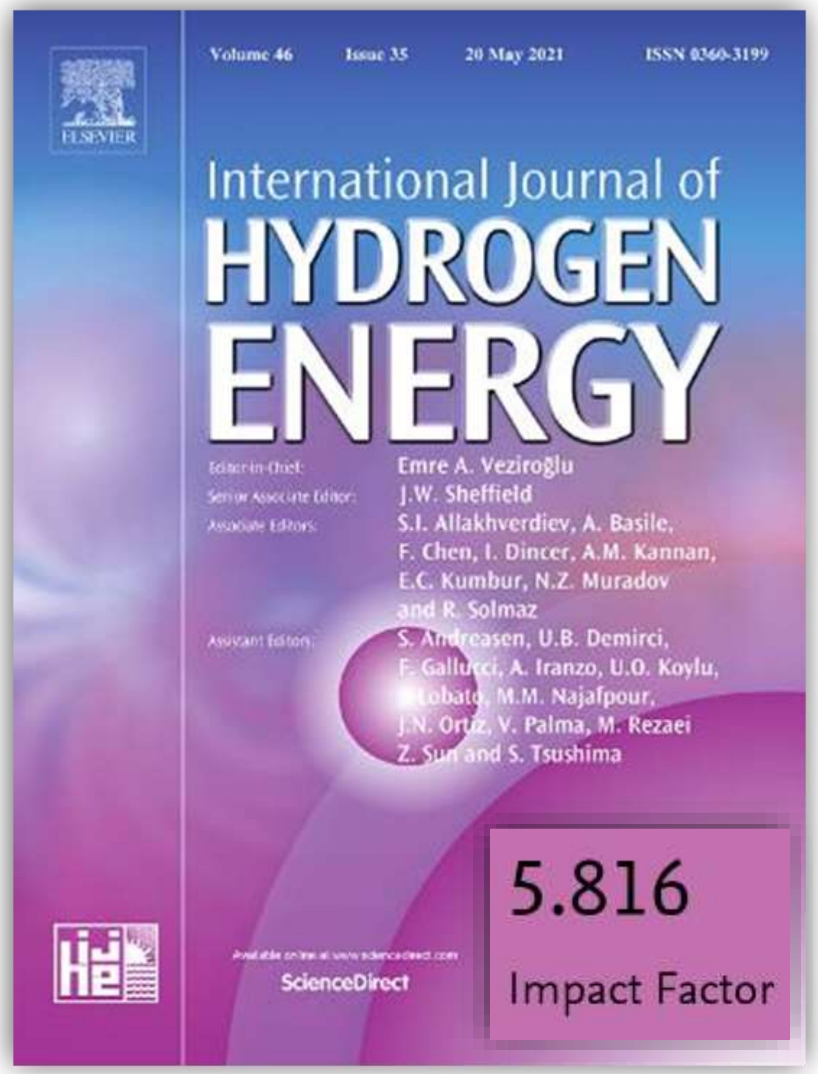
OUTLINE

- ***International Journal of Hydrogen Energy – The Metrics***
- *Future-Back Thinking*
- *Roadmap towards Zero Emissions*
- *Green Hydrogen Heavy-Duty Transport*



The **International Journal of Hydrogen Energy** is published by Elsevier and is our official journal of the **International Association for Hydrogen Energy** and was established in 1976. I joined two years later as the first Assistant Editor. Four years later it became monthly, biweekly in 2008, weekly in 2015.

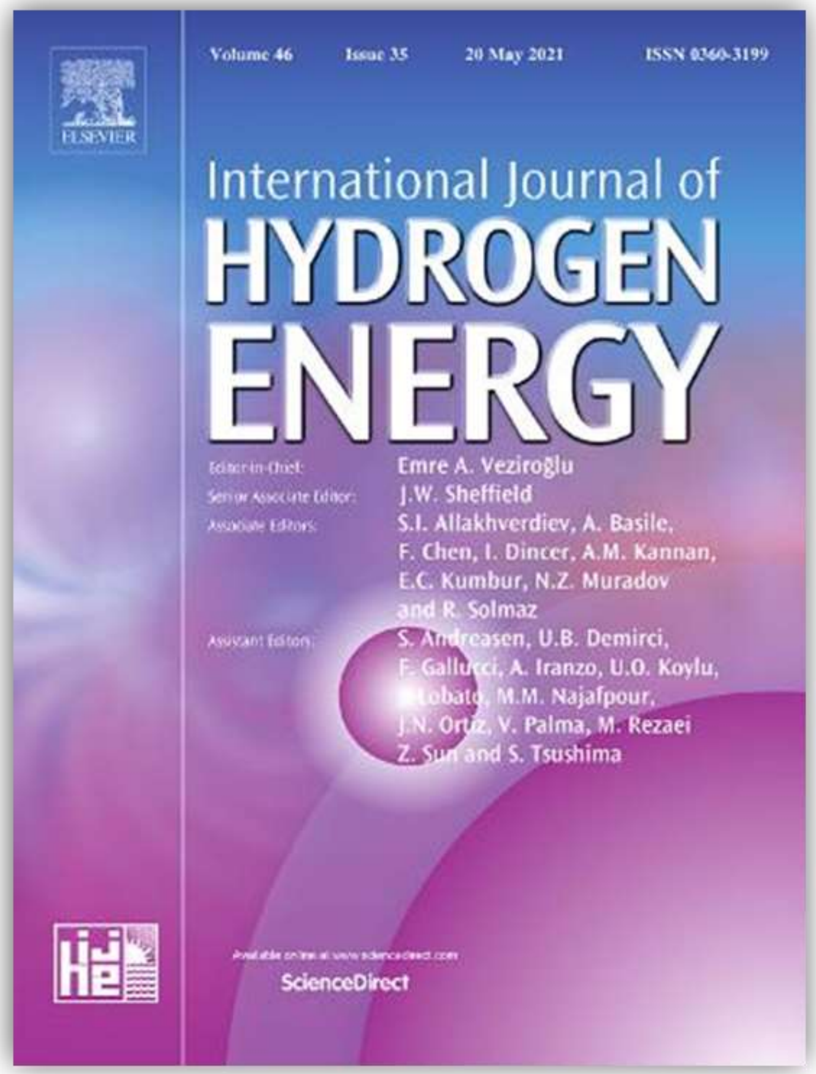
As of November 11, 2021, we have published 38,963 pages in 72 issues of Volume 46 in 2021.

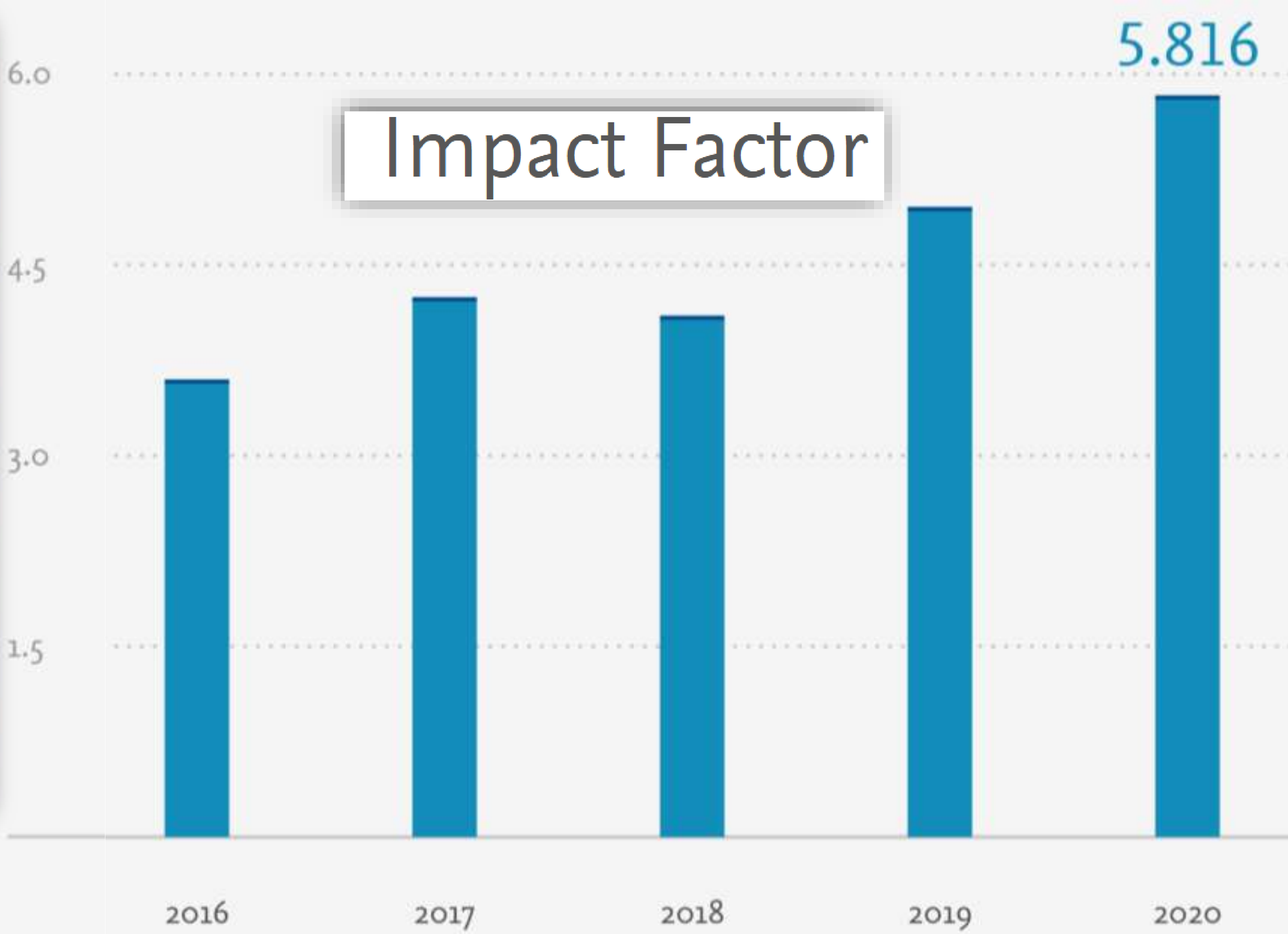


Journal metrics provide valuable insight into three aspects of the journal: IMPACT, SPEED and REACH.

These metrics help authors select the "best" journal for the publication of their research findings.

International Journal of Hydrogen Energy





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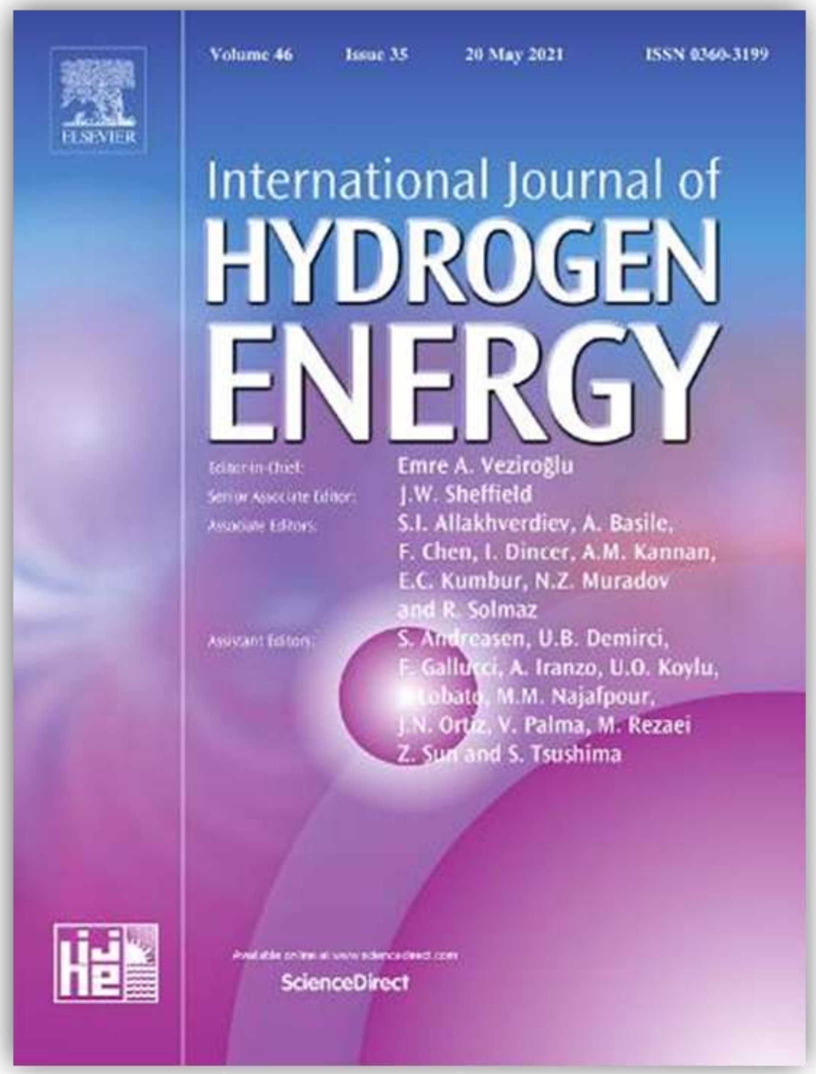

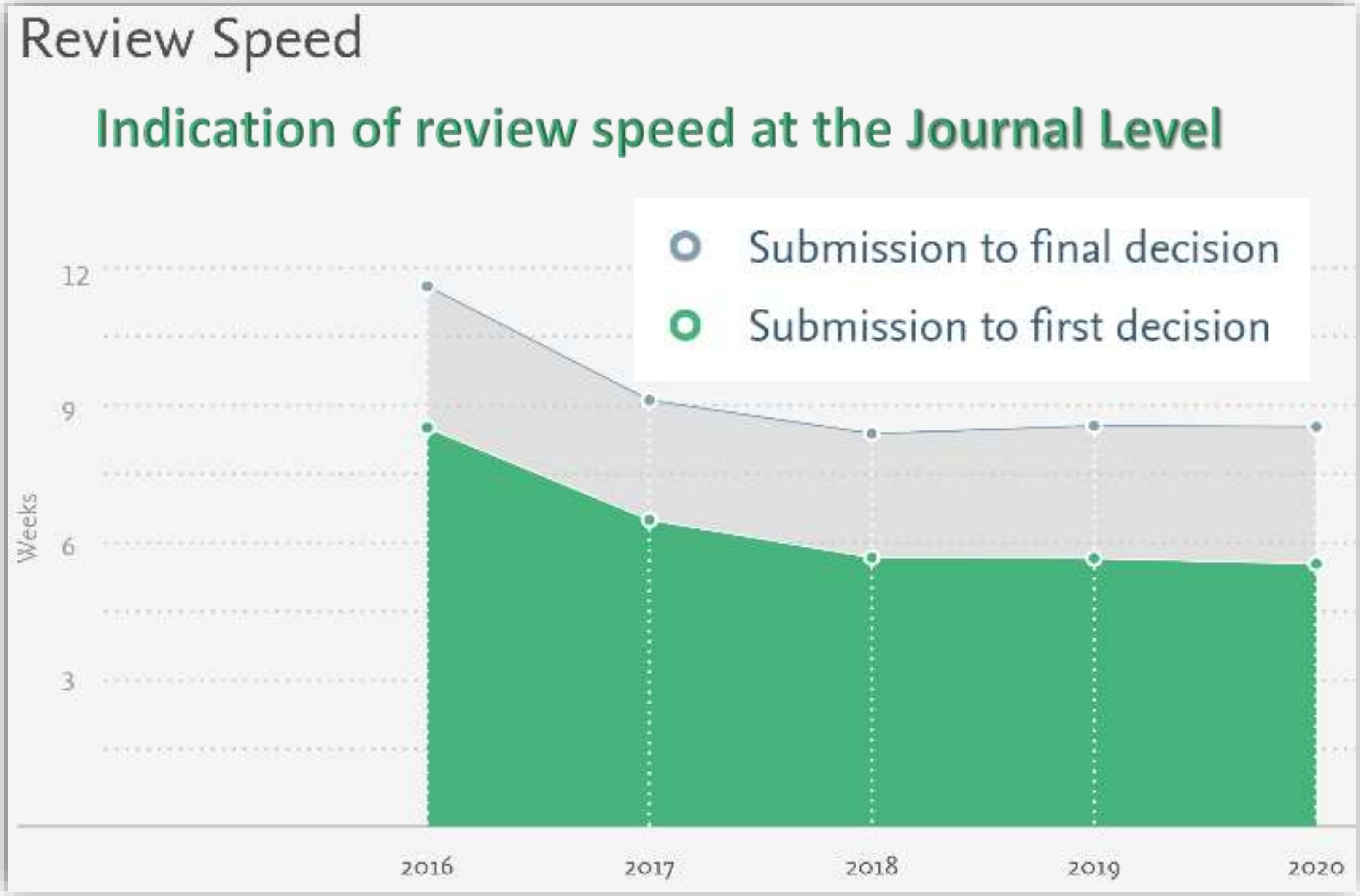

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REACH

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REACH

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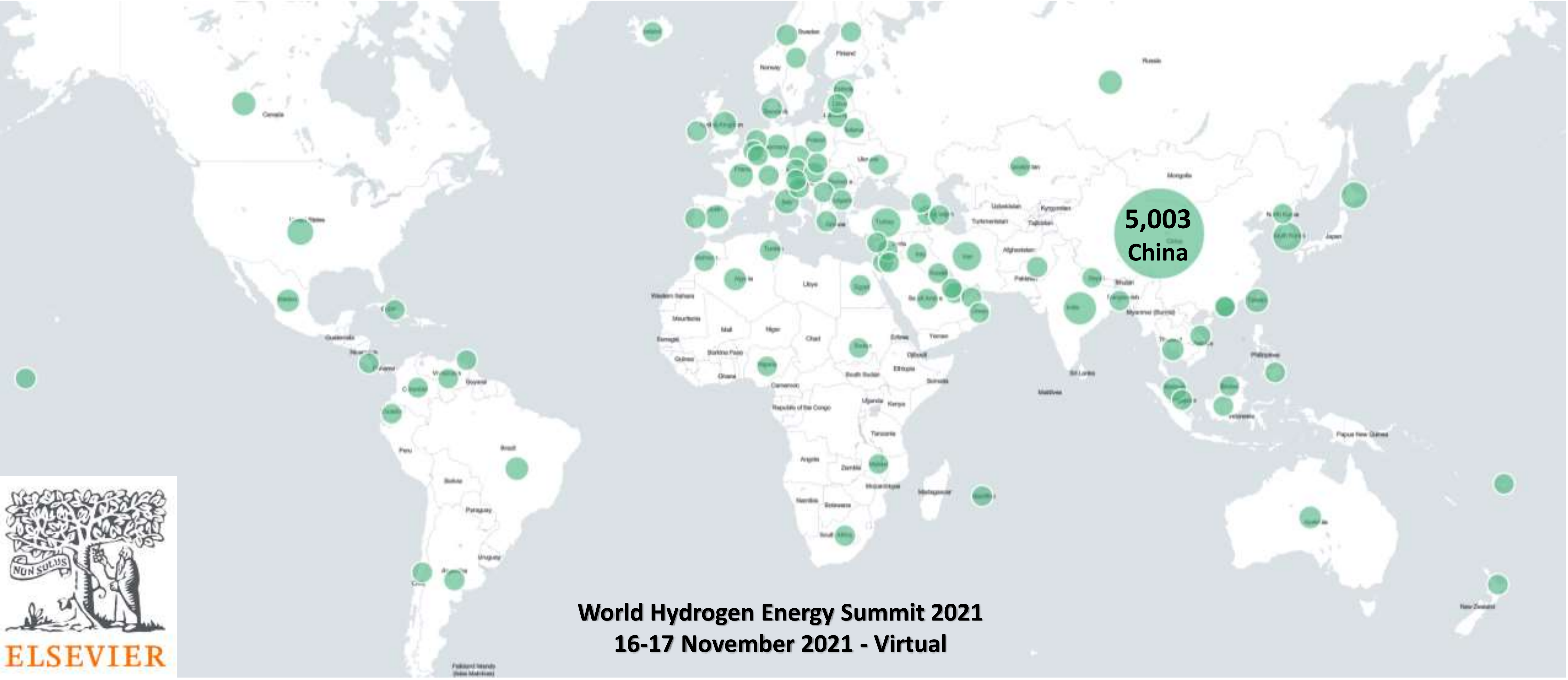

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OUTLINE

- *International Journal of Hydrogen Energy – The Metrics*
- ***Future-Back Thinking***
- *Roadmap towards Zero Emissions*
- *Green Hydrogen Heavy-Duty Transport*

What is Future-Back Thinking?

Future-back Thinking is an innovative approach to strategy development that empowers leaders to envision the *breakthrough opportunities* that drive long-term achievements and then implement the initiatives that are needed to meet the challenge. *Future-back Thinking* is sometimes called *Backcasting* as a planning method that starts by defining a desirable future and then works backwards to identify policies and programs that will connect that future to the present.

"If we want to achieve a certain goal,
what actions must be taken to get there?"

Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

Why use Future-Back Thinking?

Many organizations today however employ a *Present-Forward Thinking* which gives false hope to the thinking that existing business can be extended out in time indefinitely by simply making incremental improvements.

What is the Mindset Imperative

The world has changed, and our thinking must also change.

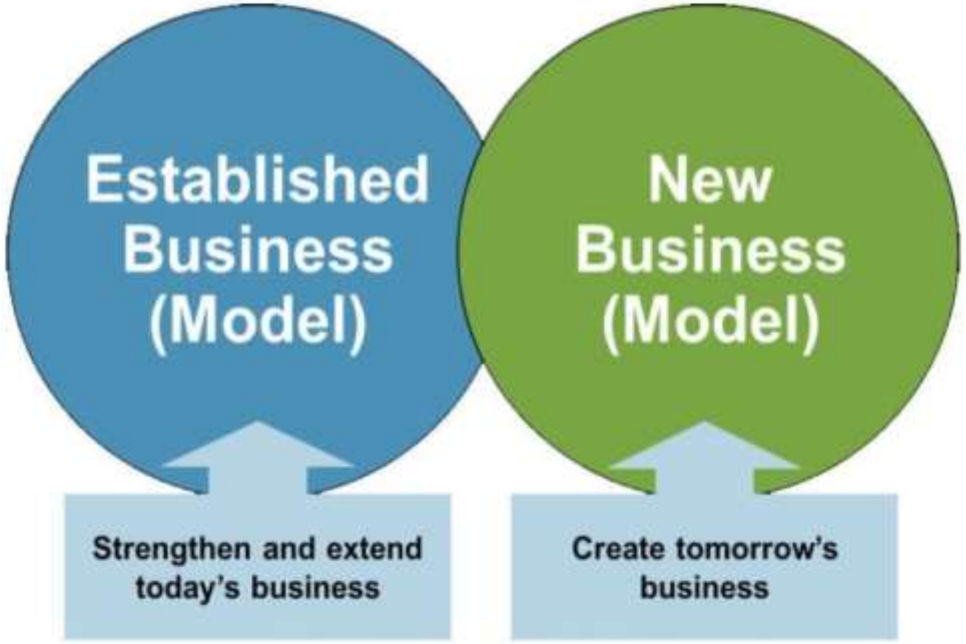
https://twitter.com/mark_w_johnson/status/1237824844219256836

Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

Future-Back Thinking for *Green Hydrogen*

To achieve *Net-Zero Emissions by 2050*, business and government leaders must truly work together using *Future-Back Thinking* as a '*dual transformation*' approach of extending the lifespan of the current core business while identifying and seizing the new-growth opportunities of tomorrow.

https://www.innosight.com/insight/a-future-back-approach-to-creating-your-growth-strategy/



AND not OR!

Imagine it´s 2050. **Green H_2** has transformed the way we work. Climate Change affects the way we live.

Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

We should consider using ***Future-Back Thinking*** for *Transformative Ambitions* for ***Green Hydrogen*** by making 'sustainable energy' irresistible for customers, while achieving systems change with partnerships that focus on meaningful action at scale, by using fuel cell and hydrogen technologies to create a step change within the renewable energy sector, hence helping you redefine what *value creation* means for your organization.

If necessary, you may need to ***reinvent*** your core business!

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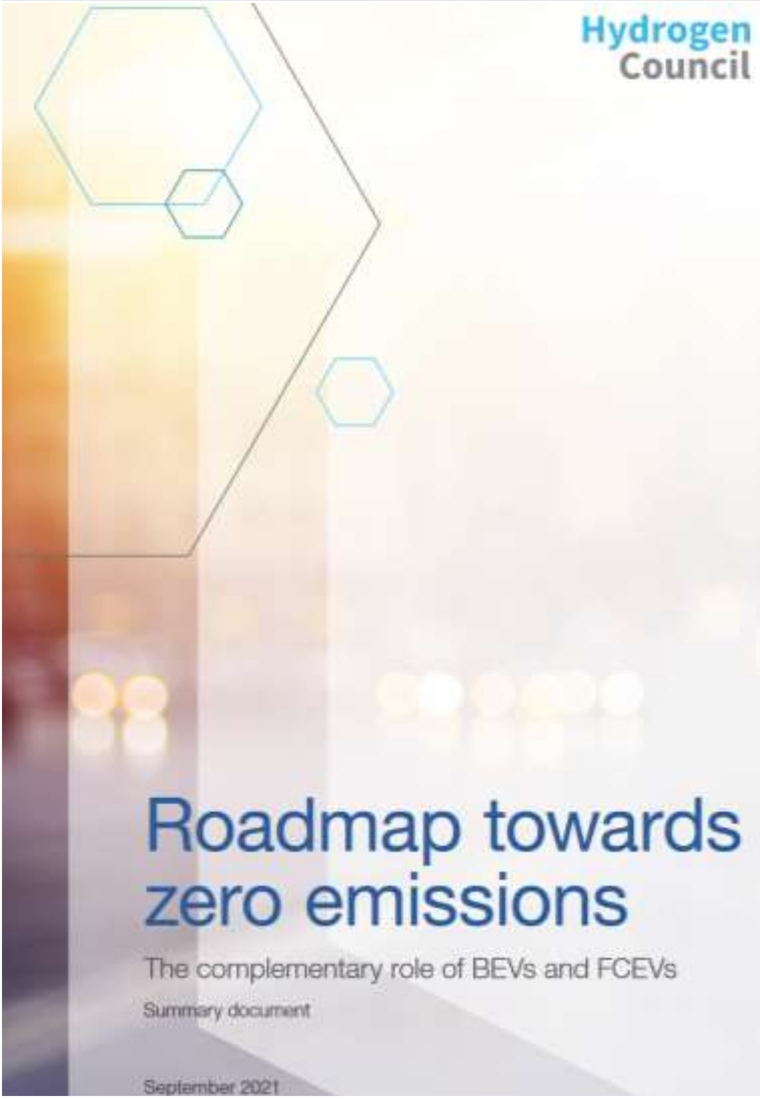
Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport



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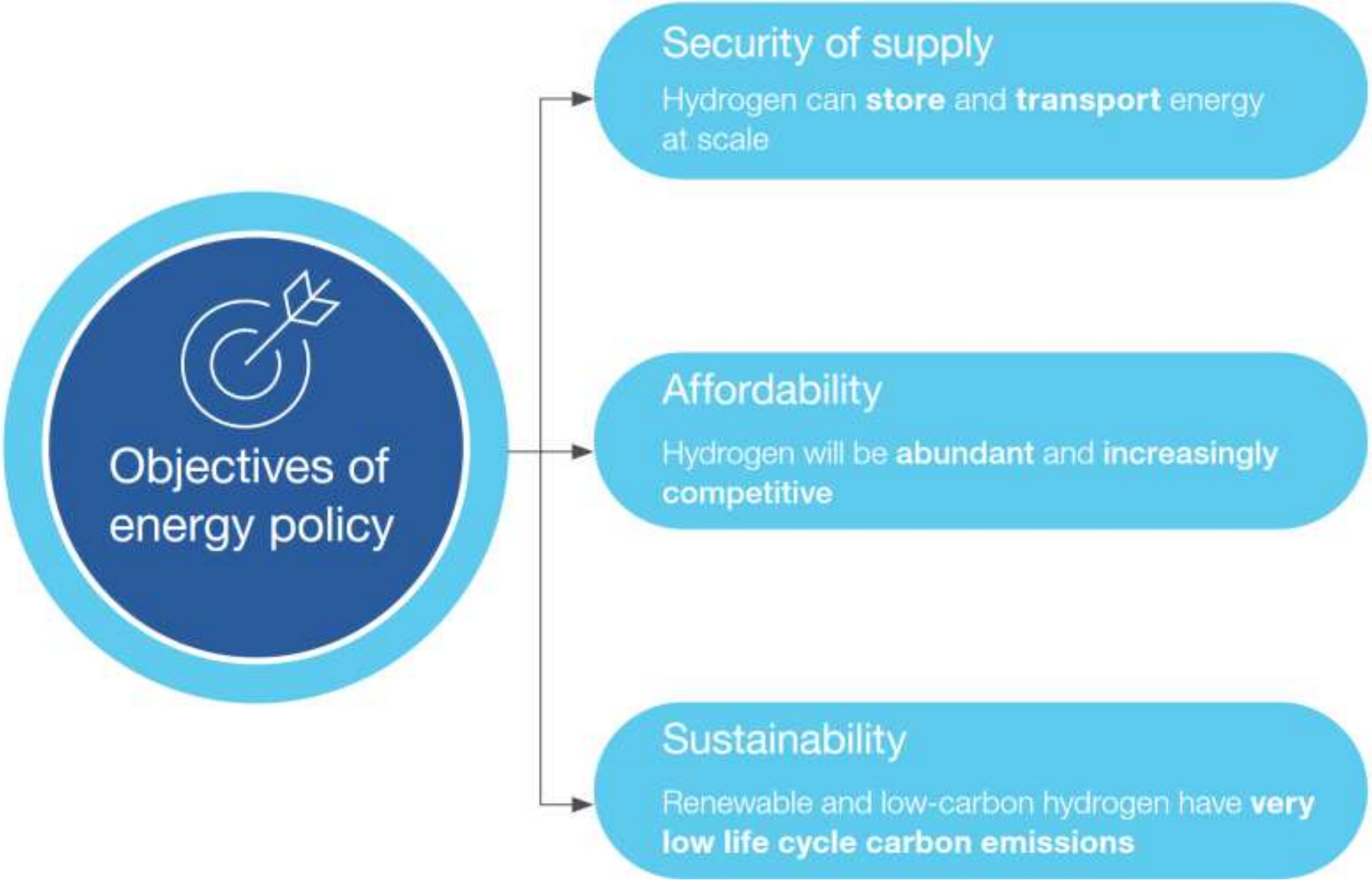
Hydrogen from renewable and low-carbon sources will be complementary to electricity in reaching all objectives of energy policy in the long term.



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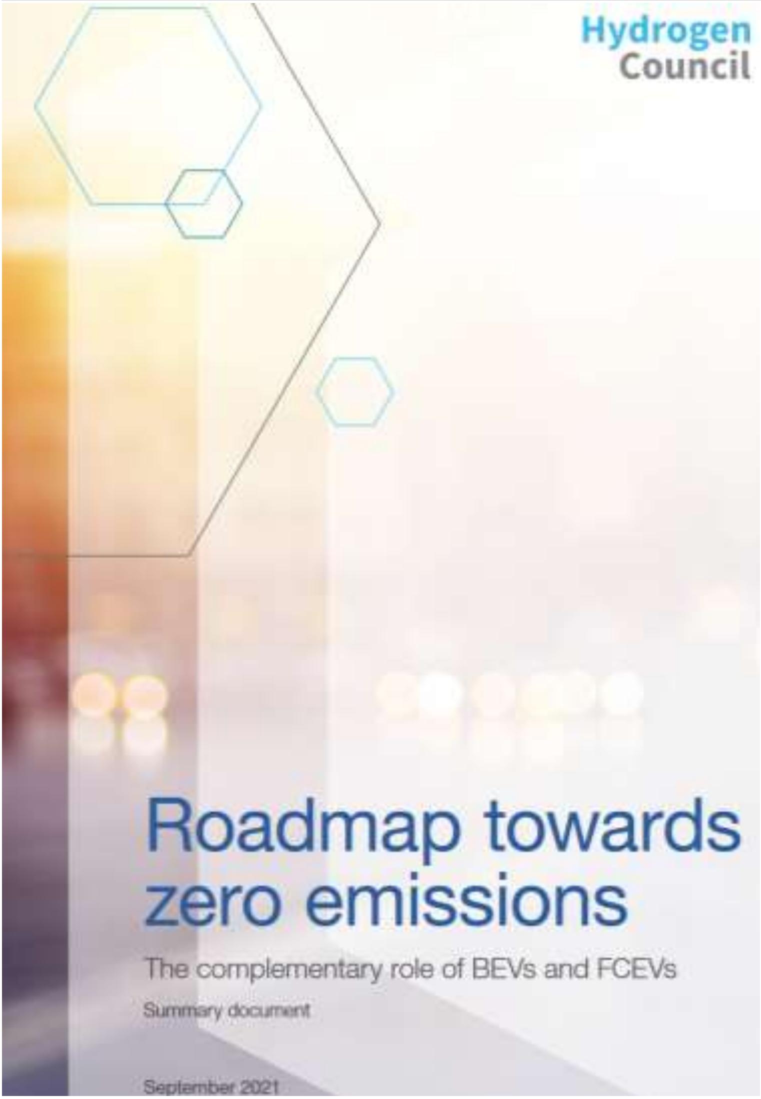
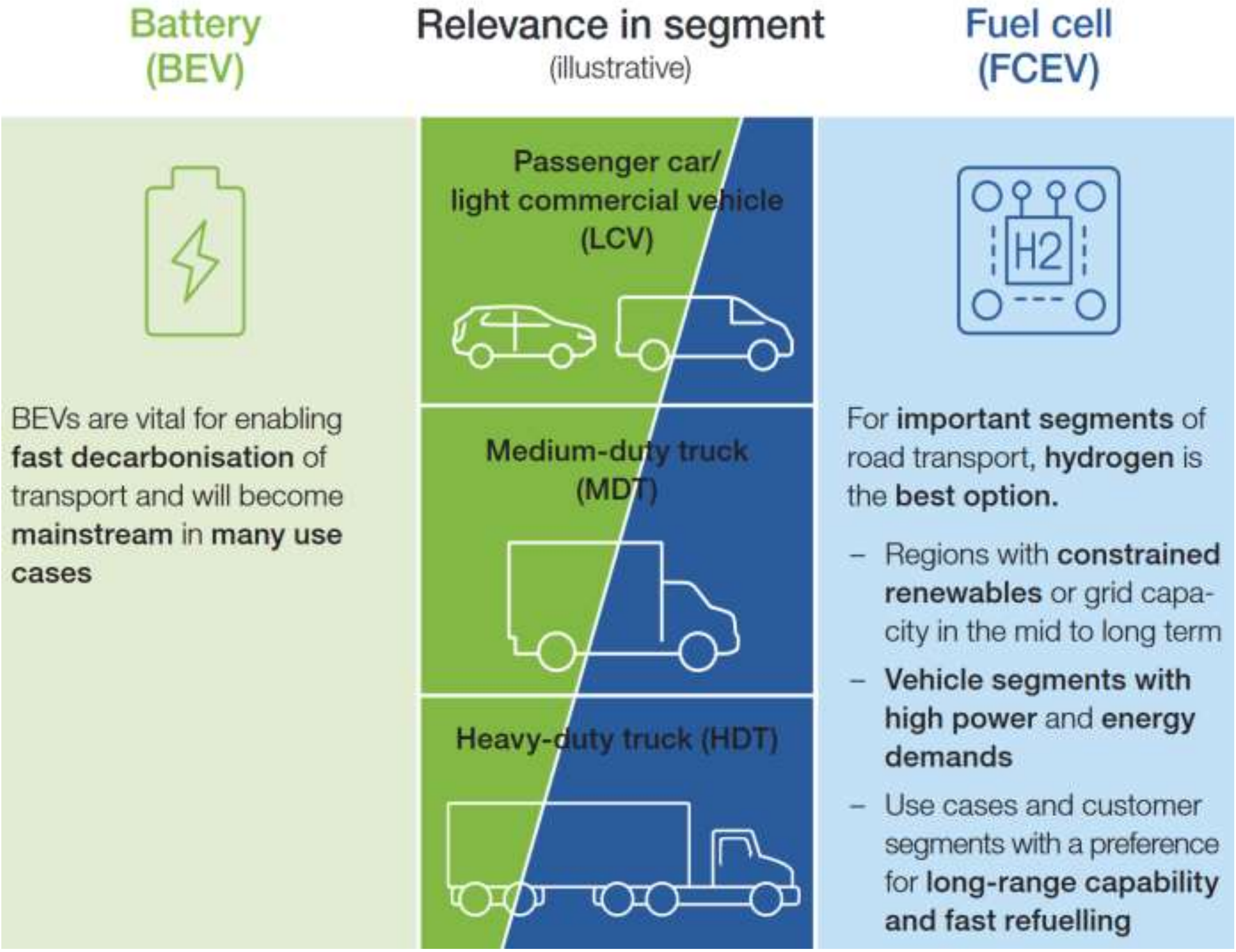


Hydrogen is well positioned for wherever large amounts of energy are needed, such as the heavy-duty trucks due to the higher energy storage density of the hydrogen fuel cell systems.



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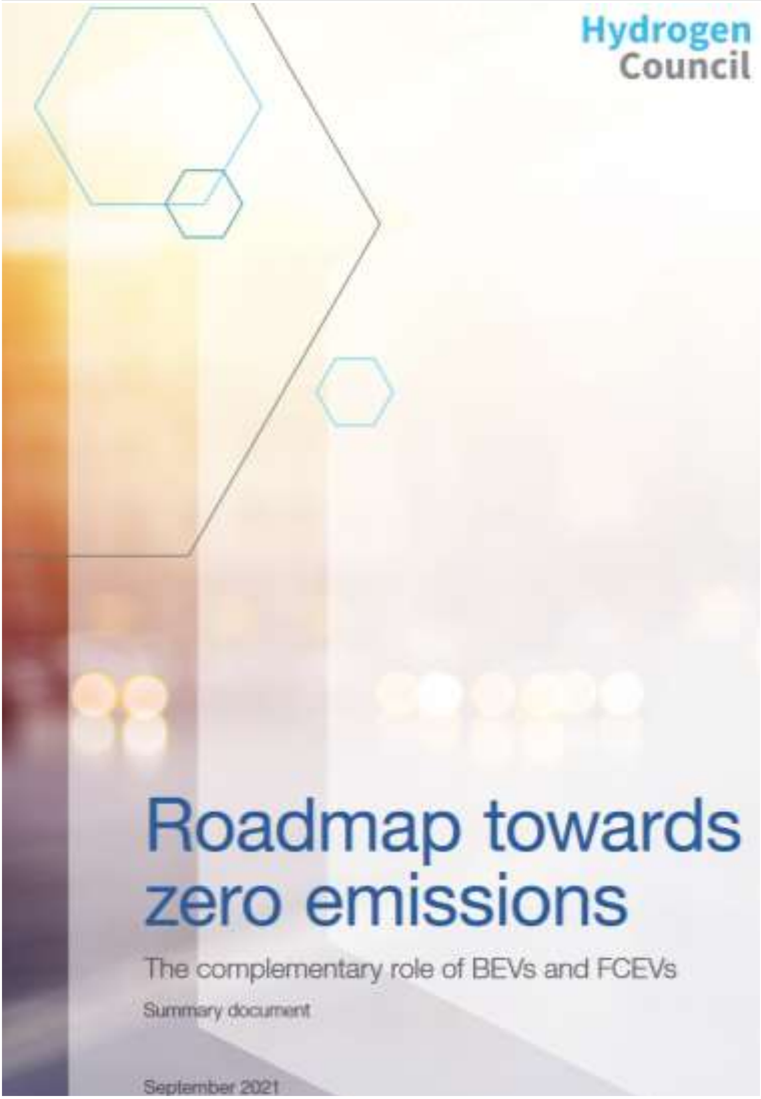

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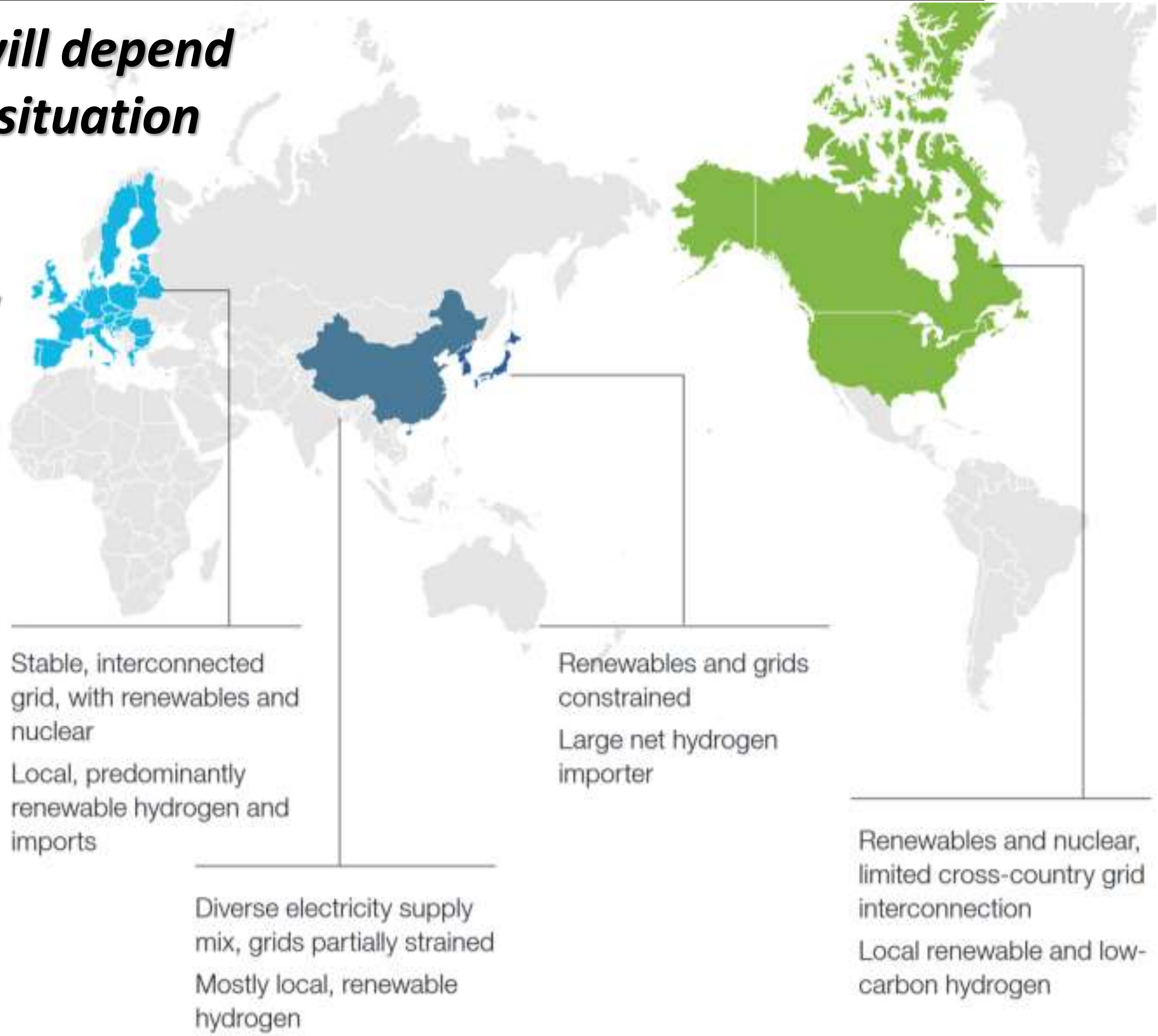
The exact role will depend on the regional situation

Europe is expected to have a highly seasonal electricity generation, that will need to be buffered over long Periods to time.



Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

12 Facts about the Complementary Role of BEVs and FCEVs

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Greener

1 Comparable systemic efficiency
In a systemic view, BEVs and FCEVs have comparable 'sun/wind-to-wheel' efficiencies

2 Similar CO_2 life cycle
BEVs and FCEVs are similarly beneficial in CO_2 life cycle assessment

3 Storage and import
Hydrogen can store local renewable energy across seasons and enable renewable energy import from optimal production locations

4 Resource demand reduction
Lower total resource demand due to recycled platinum and reduced nickel, cobalt, lithium mining

Faster

5 Independence from electricity mix
One path is not enough; faster decarbonisation can be combined with a low-carbon energy system independent from the electricity mix

6 Additional capacity
Transition towards decarbonised transport just kicking off, BEV and FCEV must jointly accelerate

7 Building momentum
Greater momentum on hydrogen than is visible on the road

8 Convenience and flexibility
Convenience and flexibility are key customer needs, which FCEVs can meet with long range and fast refuelling

9 Situational benefits
Optimal choice is not black and white and varies by location and use

Cheaper

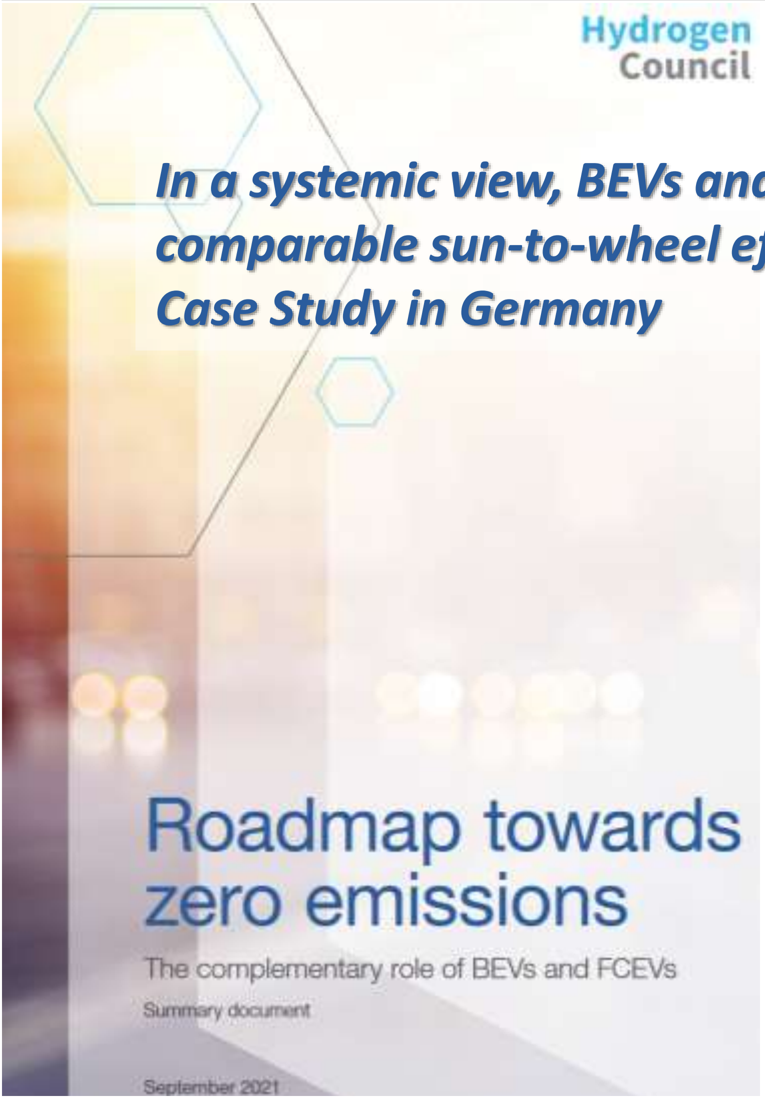
10 Hydrogen is the cheapest option in some segments
Getting from A to B with hydrogen will be the cheapest option in many road transport segments in this decade

11 Infrastructures complement each other
Two infrastructures are cheaper than one: hydrogen supply can reduce peak loads and thus reduce necessary grid upgrades

12 De-risking
Hedging bets with two pathways de-risks the most significant transition in the automotive industry's history

Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

In a systemic view, BEVs and FCEVs have comparable sun-to-wheel efficiencies: Case Study in Germany



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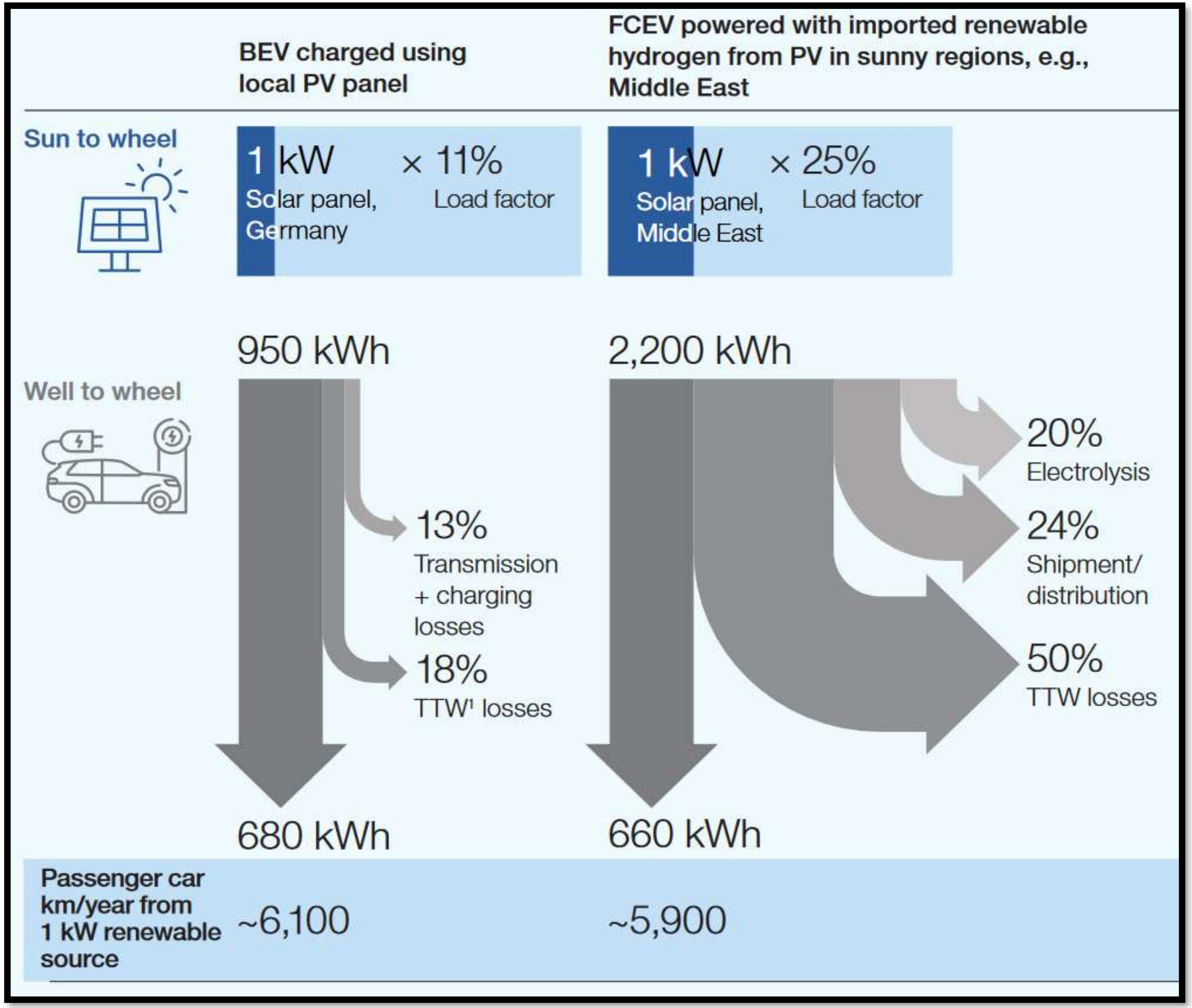

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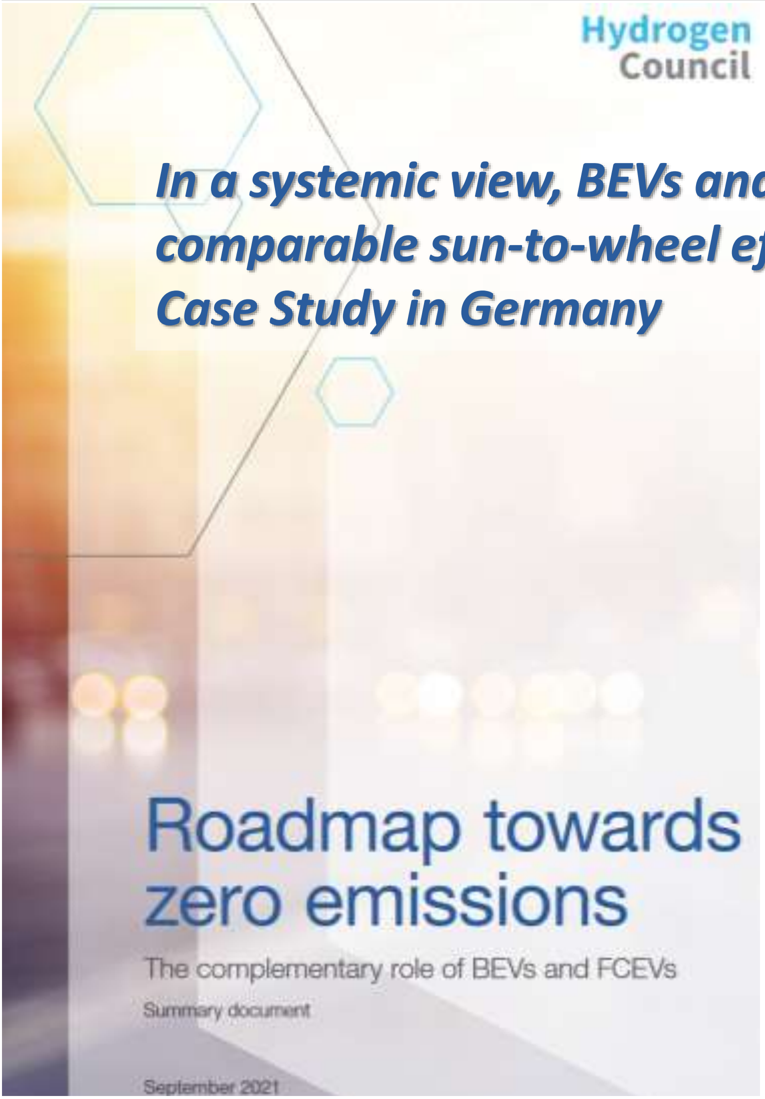
In a systemic view, BEVs and FCEVs have comparable sun-to-wheel efficiencies: Case Study in Germany



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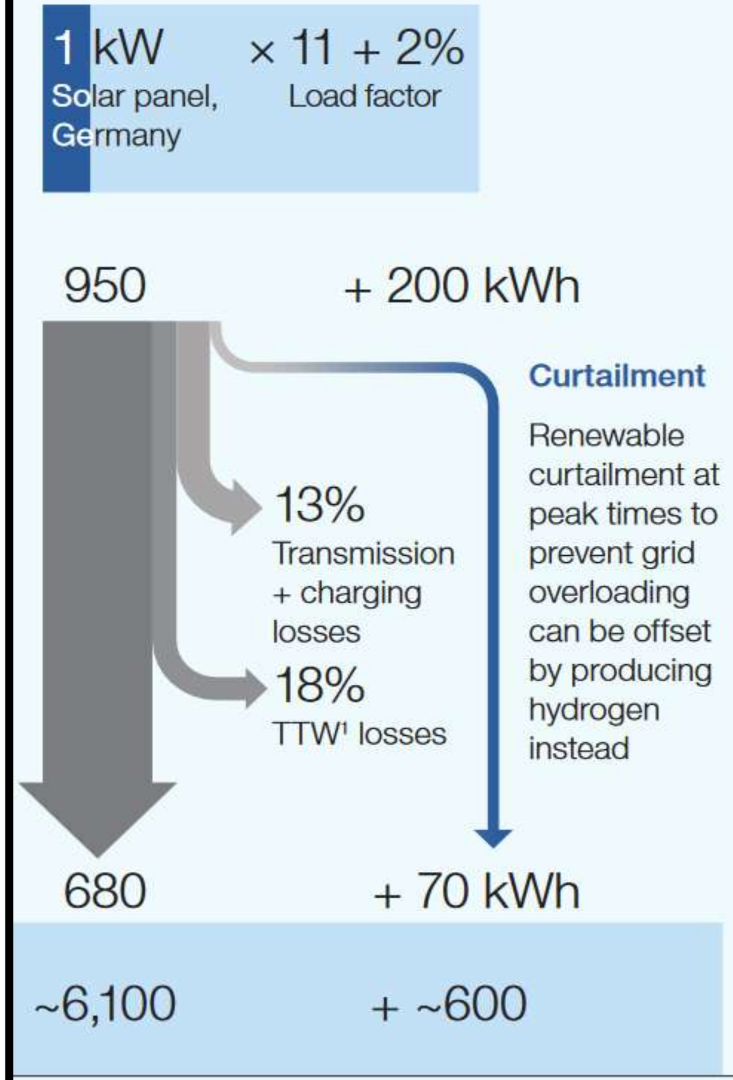
BEV charged using local PV panel; peak supplies renewable hydrogen for FCEV fuelling



- Easy **storage and long-distance shipment** of hydrogen from **optimal regions**
- Renewables can be used more effectively
- **Increased total amount of energy available** from same renewable installation
- Local hydrogen generation not subject to **demand fluctuation or grid constraints,** thus avoiding curtailment

1 TTW losses; 4% battery, 7% power electronics, 4% motor drive electronics, 4% gearbox; FCEV stack 39%; FCEV BoP 10%; FCEV additional recuperation -10%

Note: There are additional effects along the life cycle that can bring further energy balance benefits to FCEV

Assumptions: 11.2 kWh/100 km WLTP consumption at the wheel (Tesla Model 3 standard range); 20% curtailment losses forecasted for a steady-state German renewable electricity scenario

Source: Expert interviews; Kim et al. (2020); Nedstack (2019); Lohse-Busch (2019); NREL; Büchi et al. (2005); Eberle & Helmolt (2012); Sun (2010); Besselink et al. (2010); Hydrogen Council Cost Roadmap

Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

Hydrogen will be available to store local renewable energy across seasons and to import renewable energy from optimal production locations.

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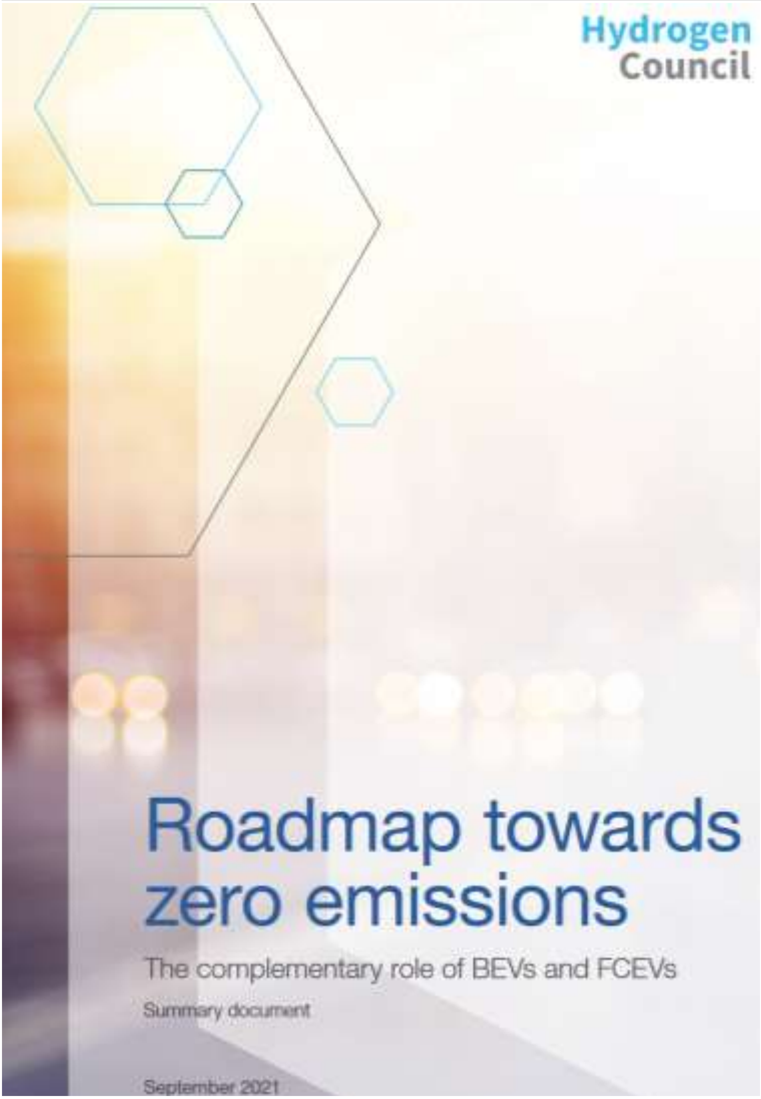

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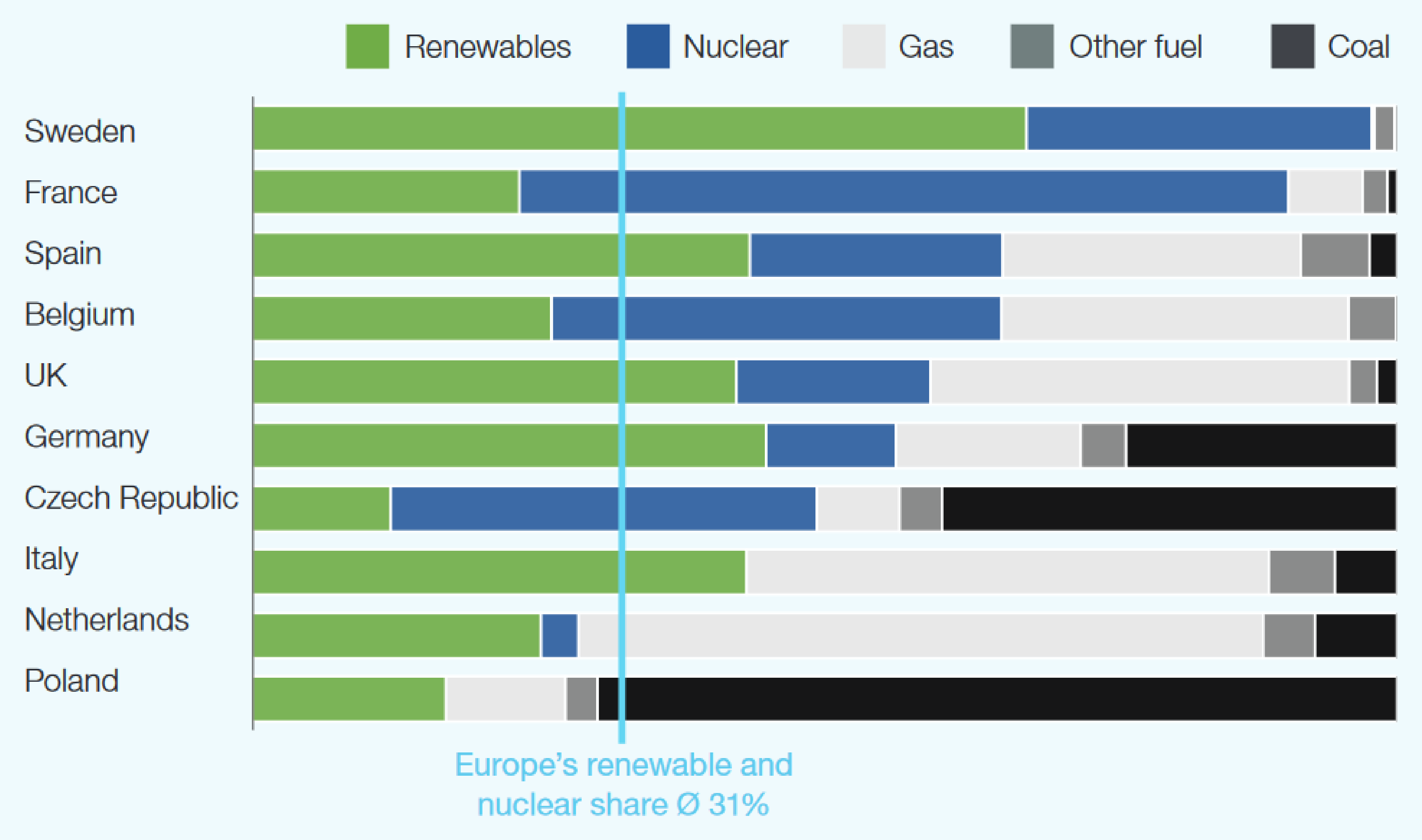
ONE PATHWAY IS NOT ENOUGH!

Grid electricity by source in top 10 European countries (2020)



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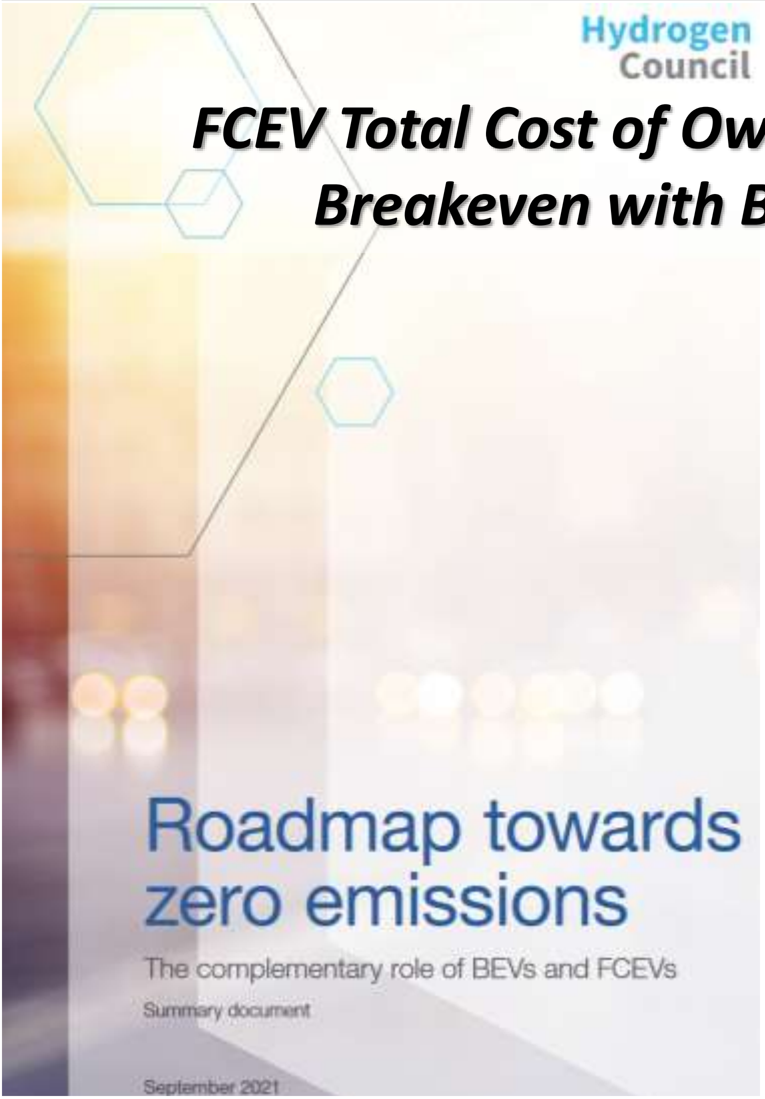
FCEV Total Cost of Ownership Breakeven with BEV



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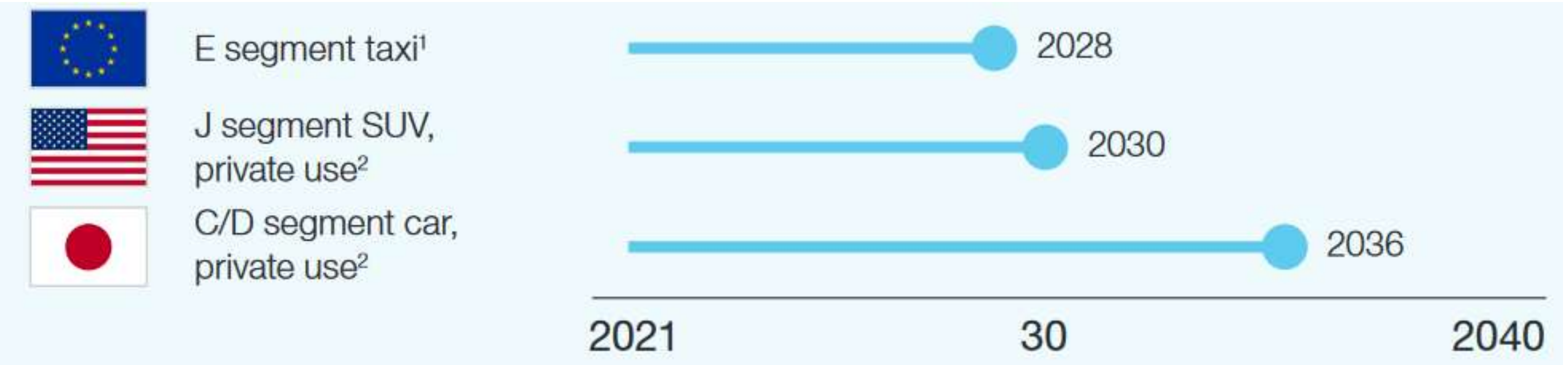

1 Annual mileage taxi: Germany 56,000 km, includes stack replacement assumption for FCEV taxi

2 Annual mileage private car: Japan 8,000 km, US 17,000 km

Key drivers for cost development

Fuel cell system
Steep learning rate from increased manufacturing volumes – costs may fall to <USD 80/kW (stack and BoP)

Fuel costs
Average hydrogen price at refuelling station dispenser expected to go from ~USD 10/kg today to ~USD 4.8/kg by 2030

Battery system
Decrease in battery cost per kWh (USD 144 to 77/kWh, already down from USD 1,160/kWh in 2010)

Grid and charger infrastructure
Technical improvements of chargers as well as production at scale are lowering the cost of chargers, while infrastructure costs are rising

Other components, e.g. tank, power electronics, also contribute to price decreases of either technology to a lesser degree

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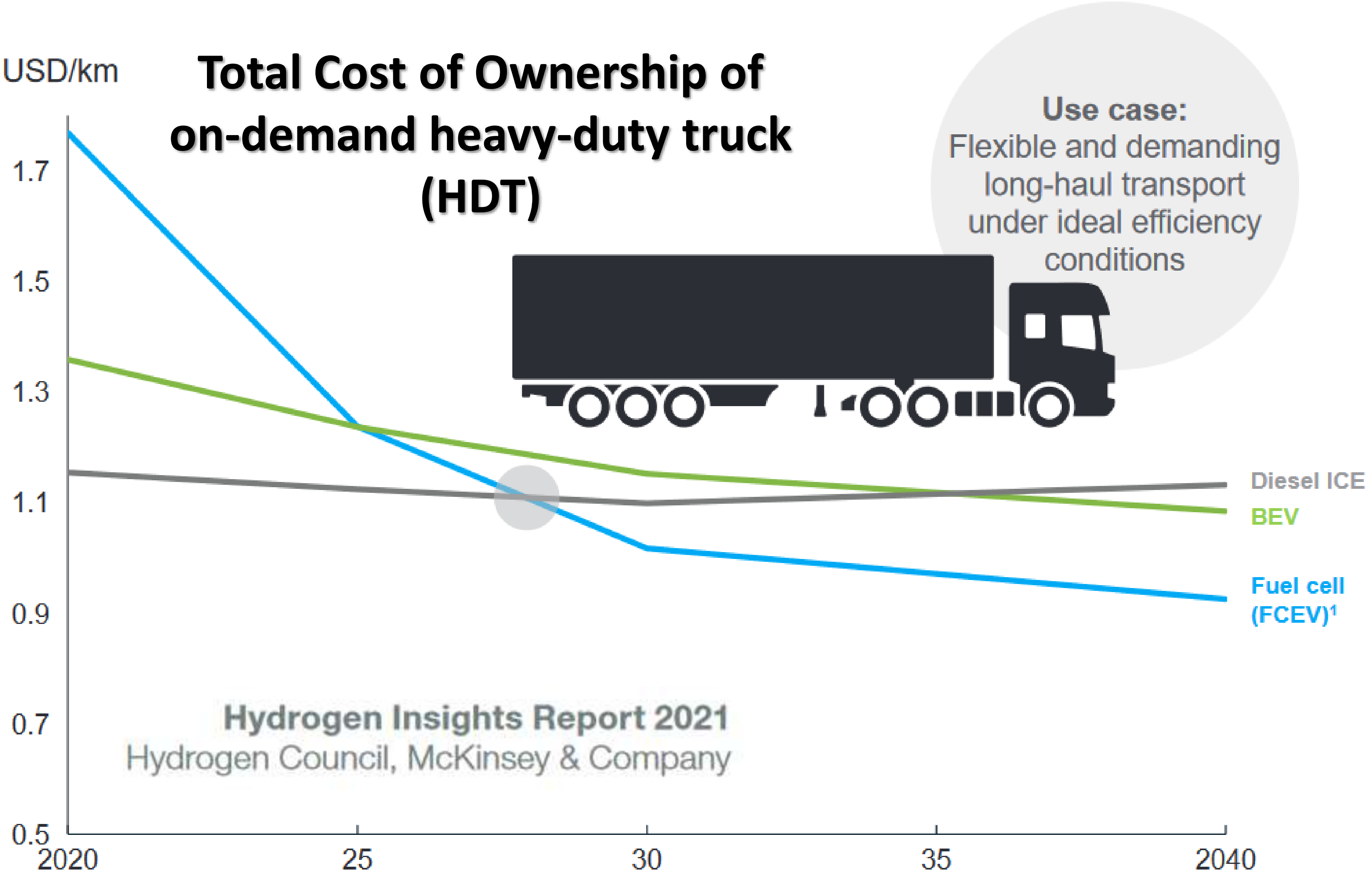
Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

We expect the on-demand HDT FCEV to become the cheapest option in terms of TCO by 2030.

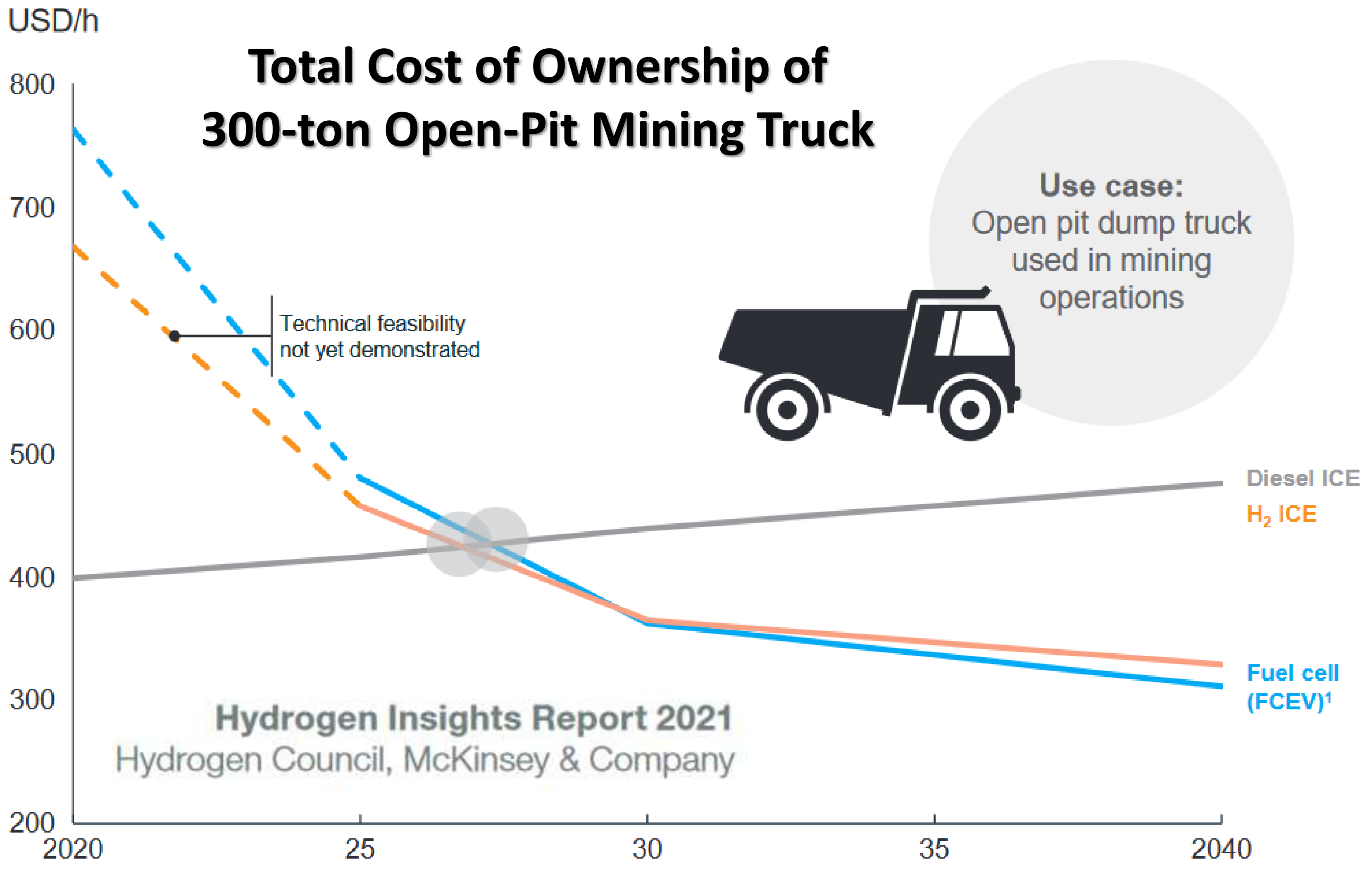
It should achieve break-even with battery-electric vehicles (BEVs) by around 2025, and with internal combustion engine (ICE) HDTs by 2028.



Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

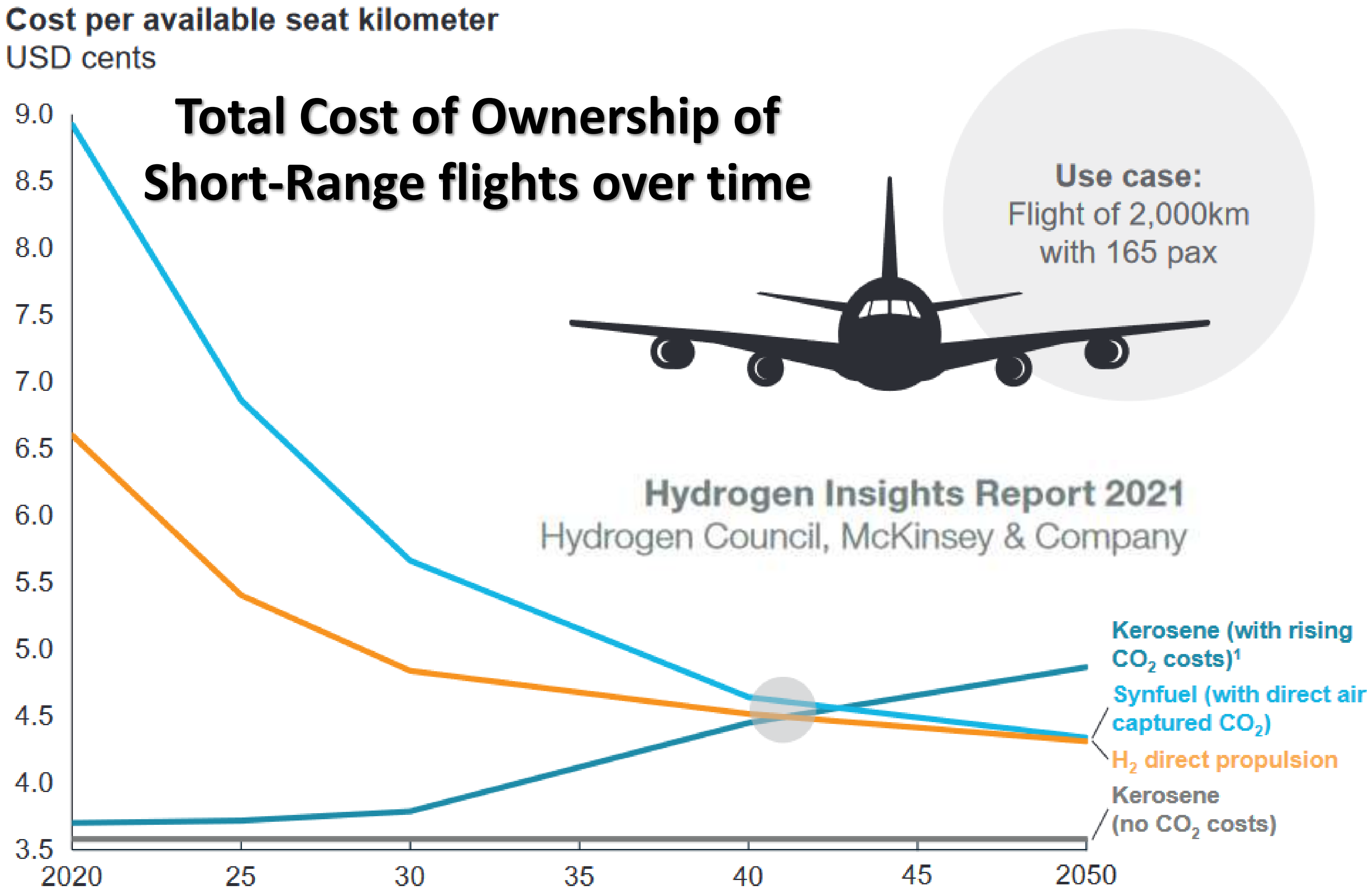
We expect that both H_2 ICE vehicles and FCEVs should breakeven with conventional diesel trucks before 2028.

For the FCEV truck, around 20% of the TCO change result from declining fuel cell powertrain costs, and another 60% because of the lower hydrogen production cost.



Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

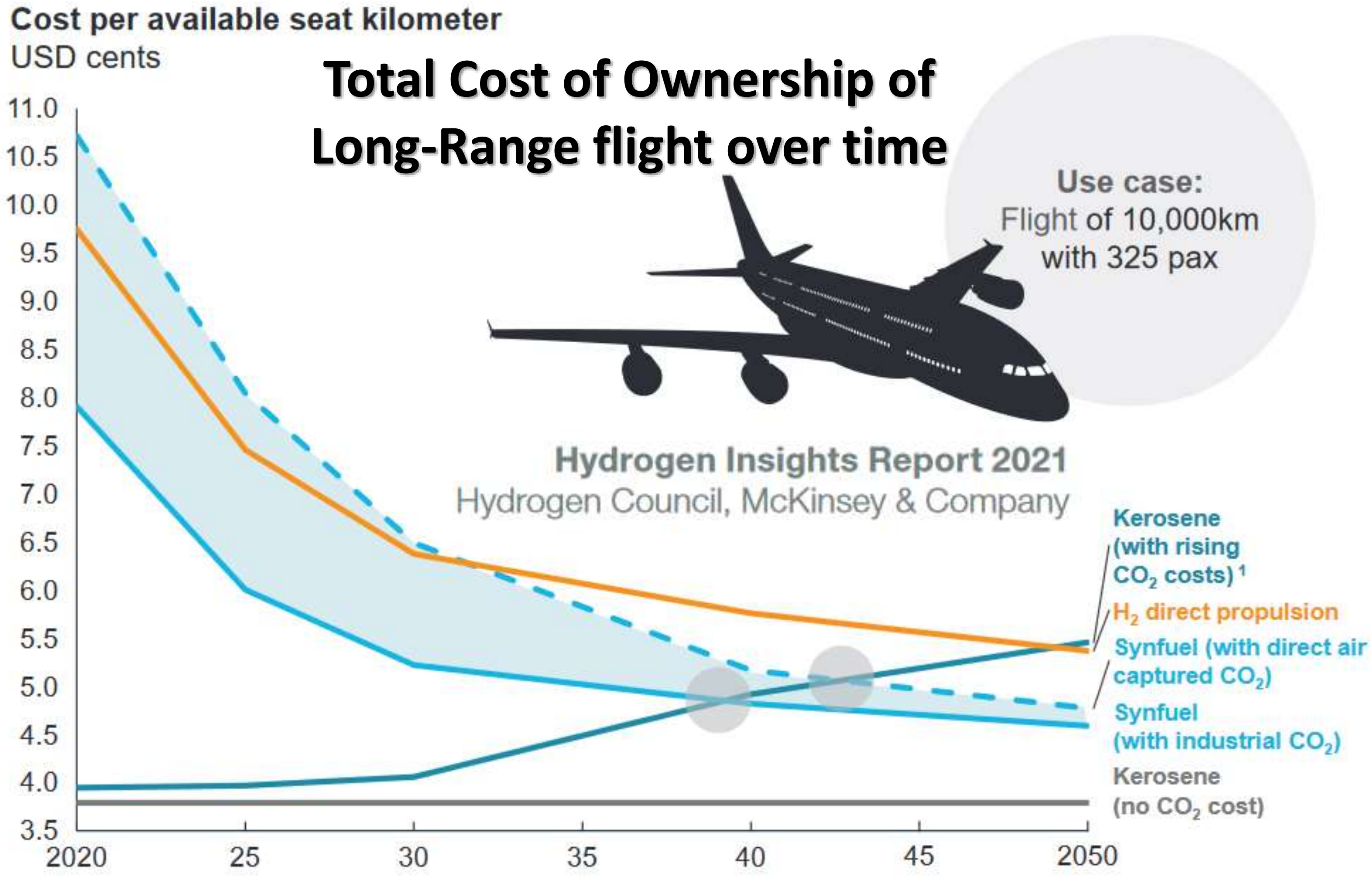
Hydrogen is a more competitive decarbonization alternative for "Short-Range" flights than synfuel as it outperforms synfuels in both costs and climate impact. Switching from kerosene to hydrogen implies a cost of about USD 100/t of CO_2 eq. If this additional cost were allocated entirely to the end consumer, it could increase the price of an airplane ticket by 30-35% in 2030.



1. CO_2 cost growing from approx. 30 USD/t CO_2e in 2020 to 50 USD/t CO_2e in 2030, 200 USD/t CO_2e in 2040 and 300 USD/t CO_2e in 2050

Future-Back Thinking for Breakthrough Growth in Green Hydrogen Heavy-Duty Transport

For the Long-Range flight segment synfuel is the most cost-competitive viable decarbonization option, as the required tank size would rule out hydrogen for distances of more than 10,000 km. While synfuel in the near future is still expensive, the costs of synfuel should drop significantly (by over 50% between 2020 and 2040), driven by the decreasing prices of hydrogen and CO_2.



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Bridging Continents by H_2

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23rd World Hydrogen Energy Conference

Onsite and Online

June 26-30, 2022 Istanbul Congress Center, Istanbul, Turkey

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