The road to sustainability

Comparing EVs to hydrogen cars

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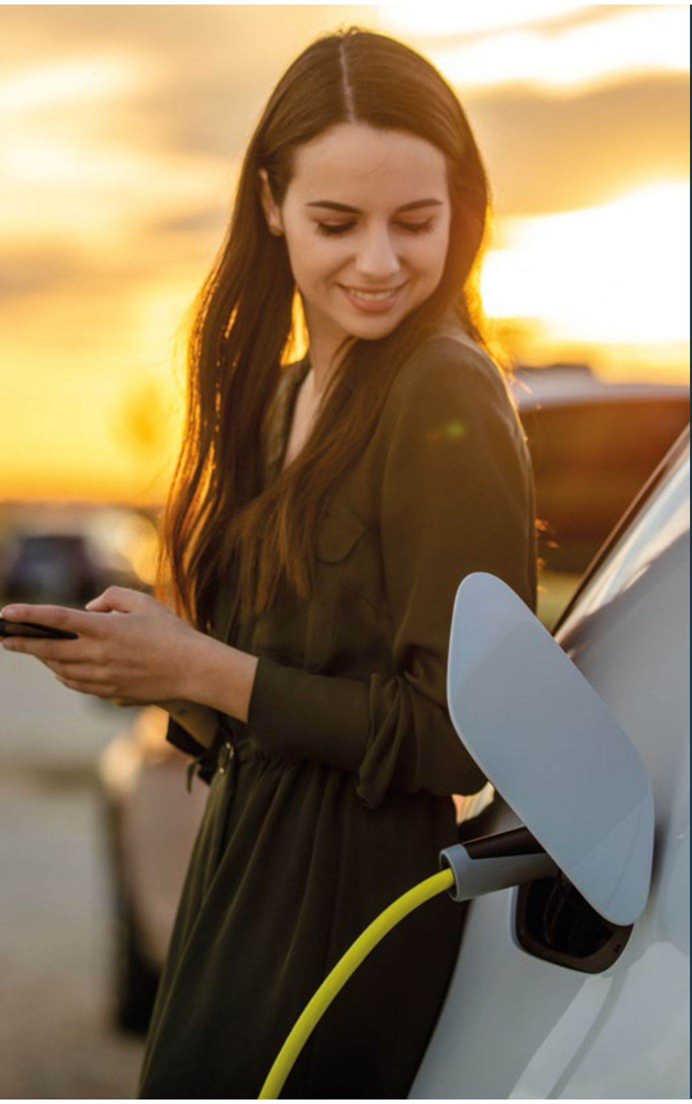
The road to sustainability: Comparing EVs to hydrogen cars

In line with the Paris Climate Agreement, the EU is implementing a ban on the sale of new internal combustion engine (ICE) vehicles by 2035*. Currently, battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) are the only powertrains that would still be allowed beyond that point.



Despite BEVs becoming increasingly more mainstream in Europe (12.1% of all car registrations in 2022 were BEVs)[1],this has not convinced all industry car manufacturers of its potential as the best way to reduce emissions from passenger cars. Car manufacturers like Toyota, Honda and Hyundai are partially investing in the development of FCEVs, cars powered using hydrogen. This paper seeks to compare the two and come with a final verdict on which we currently deem the best.

[1] https://www.acea.auto/fuel-pc/fuel-types-of-new-cars-battery-electric-12-1-hybrid-22-6-and-petrol-36-4-market-share-full-year-2022/

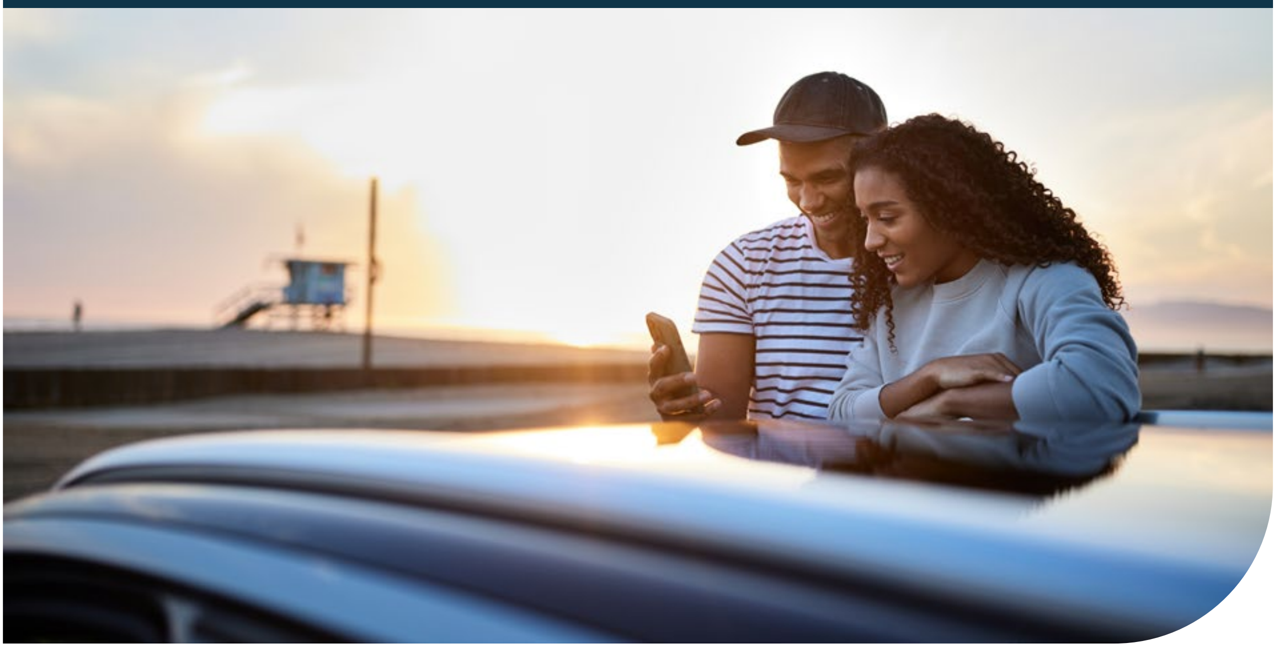
Why we need alternatives to petrol and diesel vehicles and by when

Based on the latest projections from Intergovernmental Panel on Climate Change (IPCC), we will hit the +1.5 degrees warming of the climate between 2030 and 2035 if emissions are not drastically diminished[2]. As agreed in 2015 during the Paris Climate agreement, governments will aim to avoid this by setting policies limiting emissions. As road transport emits about 10.5% of all emissions[3], it is increasingly subject to new legislation seeking to lower these emissions and avoid breaching the +1.5 degrees threshold. Currently BEVs and FCEVs are the only sustainable alternatives to petrol and diesel vehicles out in the market.

What are BEVs and FCEVs?

Battery electric vehicles are cars that are powered by electricity, stored in rechargeable battery packs.

Fuel cell electric vehicles are cars that are powered by electricity that uses hydrogen as the power source.



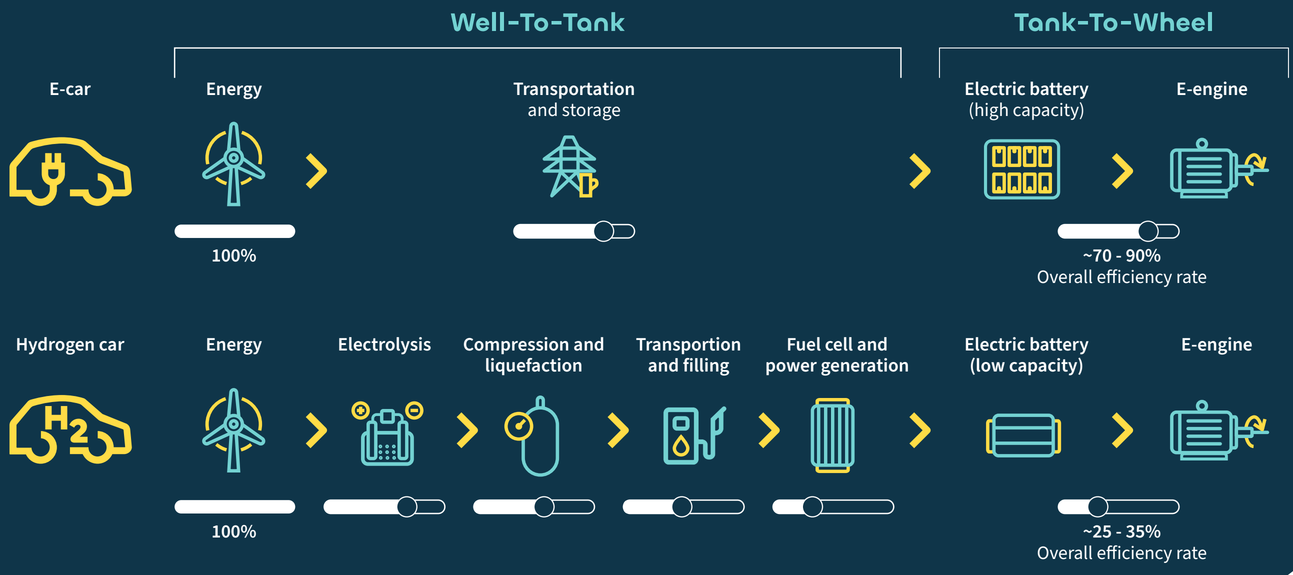
[2] https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf
[3] https://files.wri.org/d8/s3fs-public/2022-10/state-of-climate-action-2022.pdf?VersionId=sfihZTSIzbzenOLt565PlXldO2L5jTLg

Overall efficiency rates

The most common argument against green hydrogen is its overall efficiency rate as shown below:

Hydrogen and electric drive[4]

Efficiency rates in comparison using eco-friendly energy



This shows that the loss of energy for BEVs is between 10-30% and it is 65-75% for FCEVs. In other words, you could lose up to 3 kWh for every 1 kWh of energy used to power an FCEV. So, no matter how low the cost of green hydrogen will become, it will mean that the cost of charging a BEV could always be significantly lower than that.

The network challenge

Both BEV and FCEV need a network to make their use practical. Charging infrastructure for BEVs and hydrogen refuelling infrastructure for FCEVs. The **charging infrastructure** is rapidly being developed in Europe and is already considered mature in some markets[5]. For FCEVs, the number of **refuelling stations** is still in the single digits in most European countries, with a total of 245 in Europe. An overview of all hydrogen refuelling stations can be seen on **this map**. In comparison, the battery electric vehicle public charging network is about 500,000 already, as can be seen on **this map**.

[4] Volkswagen - https://www.chargepoint.com/blog/electricity-versus-hydrogen-4-reasons-electrification-right-choice-fleets
[5] https://www.leaseplan.com/en-ix/blog/sustainability/ev-readiness-2023/

The EU has agreed to build at least 1 hydrogen refuelling station every 200 km along the Trans-European Transport Network[6] (the most important connections linking major cities and nodes in Europe) from 2030 onwards. For electric vehicle charging stations however, from 2025 onwards, fast recharging stations of at least 150kW for cars and vans need to be installed every 60 km. Only rapid chargers from 150 kWh are counted so slower charging stations are not included in this count.

In short, the limited refuelling network for FCEVs will make mass adoption more difficult within the timeline before the climate reaches +1.5 degrees. While BEVs have the potential to meet mass adoption, looking at the current and planned charging network.

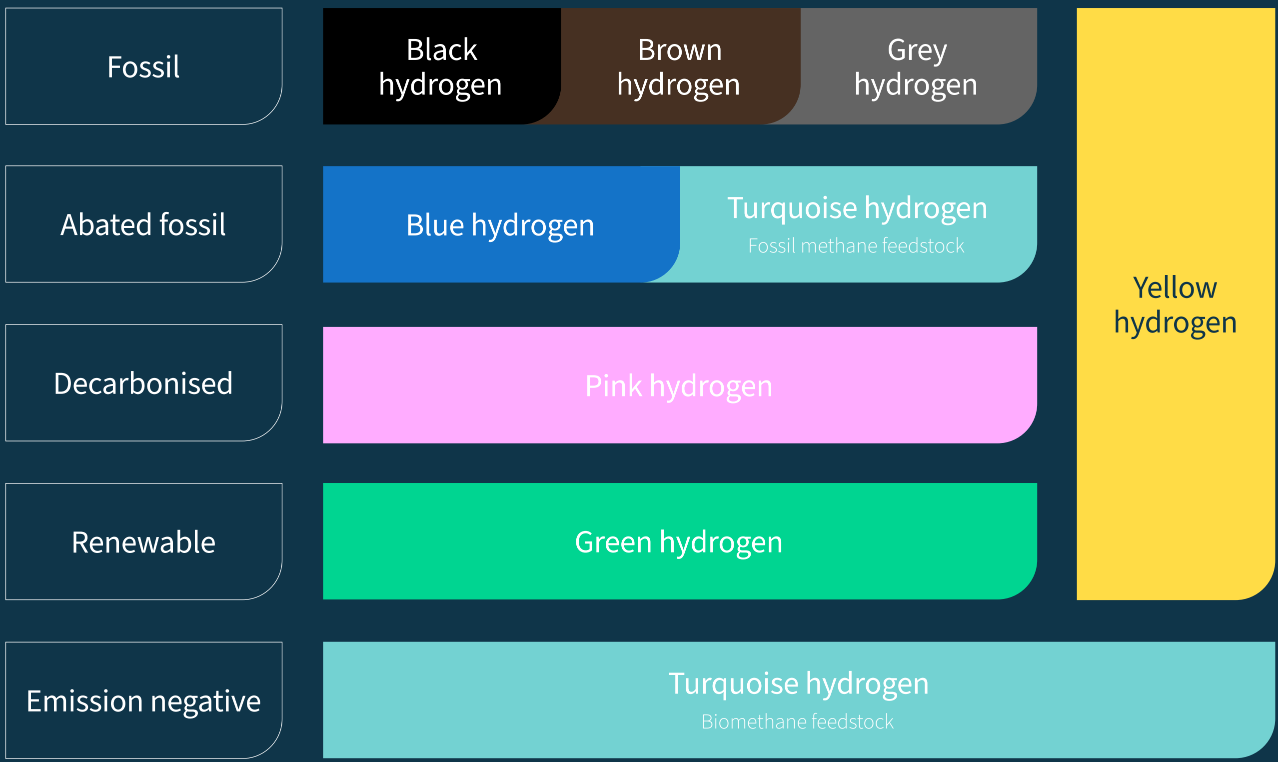
Sources of energy

There might be a role for FCEVs beyond 2035. But is it as sustainable as is claimed? If you only look at the tailpipe emissions, then just like BEVs, they do not emit any tailpipe emissions. Just water vapour and warm air come out of the tailpipe of an FCEV. But if you look at the source required to produce hydrogen, then the picture becomes murkier.

[6] https://europeansting.com/2023/03/29/european-green-deal-ambitious-new-law-agreed-to-deploy-sufficient-alternative-fuels-infrastructure/

The different energy sources used to produce hydrogen are often referred to as the hydrogen 'rainbow'[7]:

Hydrogen production coded by colour[8]



[7] https://www.boilerguide.co.uk/articles/hydrogen-rainbow
[8] https://fsr.eui.eu/hydrogen-in-the-energy-transition/

Currently, 99.6% of all hydrogen is either made through grey or brown hydrogen meaning it is produced using polluting processes. Only 0.4% comes from a lower/zero polluting energy source. The main reason for this is cost (which will be further explained in the cost of refuelling/ recharging chapter).

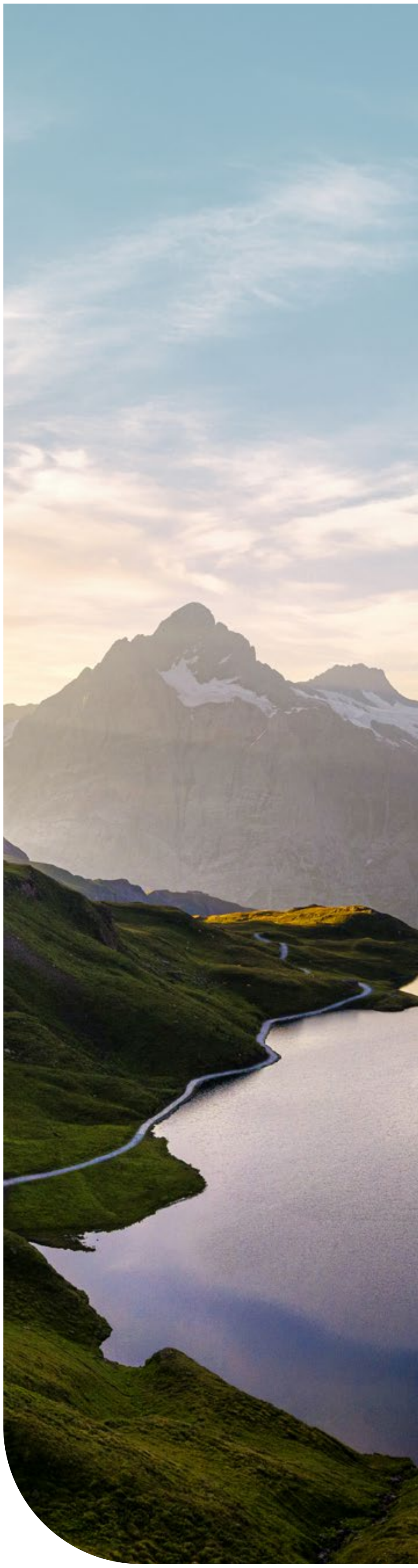
Currently, electricity generation from renewable sources in Europe is almost 40%[9], so it is fair to say that on average 40% of all BEV required energy currently comes from a renewable source. Thus, the current energy used for BEVs compared to that of hydrogen is greener by a factor of 100. While 40% is still a long way off from 100%, the advantage BEVs have over FCEVs is that they will automatically take advantage of the renewable energy targets set by the European Union. The goal of the EU to is to have at least 55% of all its energy from renewable sources by 2030, which seems within reach sooner rather than later. The Ukraine war and subsequent energy crisis in 2022 is expected to accelerate the uptake of renewable energy as it has made energy independence top of mind in Europe's parliaments[10].

FCEVs: the hydrogen leakage problem

There is another potential environmental impact with hydrogen: the risk of hydrogen leakage during production or transportation (often named as the main advantage over electricity generation). In short, hydrogen leakage results in methane staying longer in the atmosphere[11]. A recent study in Nature[12] estimates that if more than 9% of the green hydrogen leaks somewhere before being consumed, it will cancel out the environmental impact indirectly through the extended presence of methane in the atmosphere. This negative effect stills requires more research and on the current level of leakage more research is also necessary. A study by Columbia University estimates the current rate to be 2.7% but this could be up to 5.6% by 2050 due to the widespread adoption of hydrogen use cases with a high risk of leakage[13]. That means that today already 30% of the green promise of hydrogen evaporates (2.7%/9%) and this could be as high as 60% (5.6%/9%) in the future. Hydrogen leaking comes from the fact that hydrogen is a very small atom and is therefore difficult to contain over longer periods of time.

[9] https://www.energymonitor.ai/tech/renewables/europe-renewables-in-2022-in-five-charts-and-what-to-expect-in-2023/#:~:text=In%20the%20EU%2C%20renewables%20are,to%20the%20grid%20in%202022
[10] https://www.iea.org/news/renewable-power-s-growth-is-being-turbocharged-as-countries-seek-to-strengthen-energy-security
[11] https://www.energypolicy.columbia.edu/publications/hydrogen-leakage-potential-risk-hydrogen-economy/
[12] https://environment.princeton.edu/news/switching-to-hydrogen-fuel-could-prolong-the-methane-problem/
[13] https://energypolicy.columbia.edu/publications/hydrogen-leakage-potential-risk-hydrogen-economy/#:~:text=The%20leakage%20rate%20stands%20between,%242%2Fkg-H2).

BEVs: the battery problem



Now, we also need to address the environmental impact of batteries. While the development of more sustainable batteries is rapidly evolving, the current dominant battery technology (lithium-ion batteries) does still have a significant environmental impact. **Transport & Environment** estimates the impact of current batteries developed in China (the most common country of origin today) to be 7.9 tonnes of CO_2 assuming standard supply chain emissions. However, they estimate this can become as low as 1.9 tonnes of CO_2 by 2030 assuming a low impact supply chain and when the battery would be developed in Sweden (currently several battery factories are being built there).

Then there is the topic of the social implications of batteries: some metals (primarily cobalt) used in the batteries are sourced from countries where working conditions can be quite poor. Stories of child labour and forced labour have made cobalt into a controversial resource. The most common lithium-ion chemistry battery is the lithium-nickel-manganese-cobalt-oxide (NMC) battery which can have up to 20KG of cobalt per 100kWh battery[14]. The good news is that there are four main groups of alternative battery technologies currently being developed which either limit the use of cobalt significantly or don't require it at all. One of these technologies is the iron-based battery (LFP), already used by Tesla in half of its vehicles as of Q1 2022[15]. While it has a lower energy density and thus less range, it does not require cobalt or nickel (another expensive resource). Another benefit is that Tesla was able to double the number of charging cycles compared to lithium-ion batteries, before having to be replaced. For more information on all these four low/zero cobalt battery technologies, please visit **International Energy Forum**. An additional benefit to eliminating cobalt is that these batteries will also be cheaper, making BEVs even more competitive as batteries are the most expensive component.

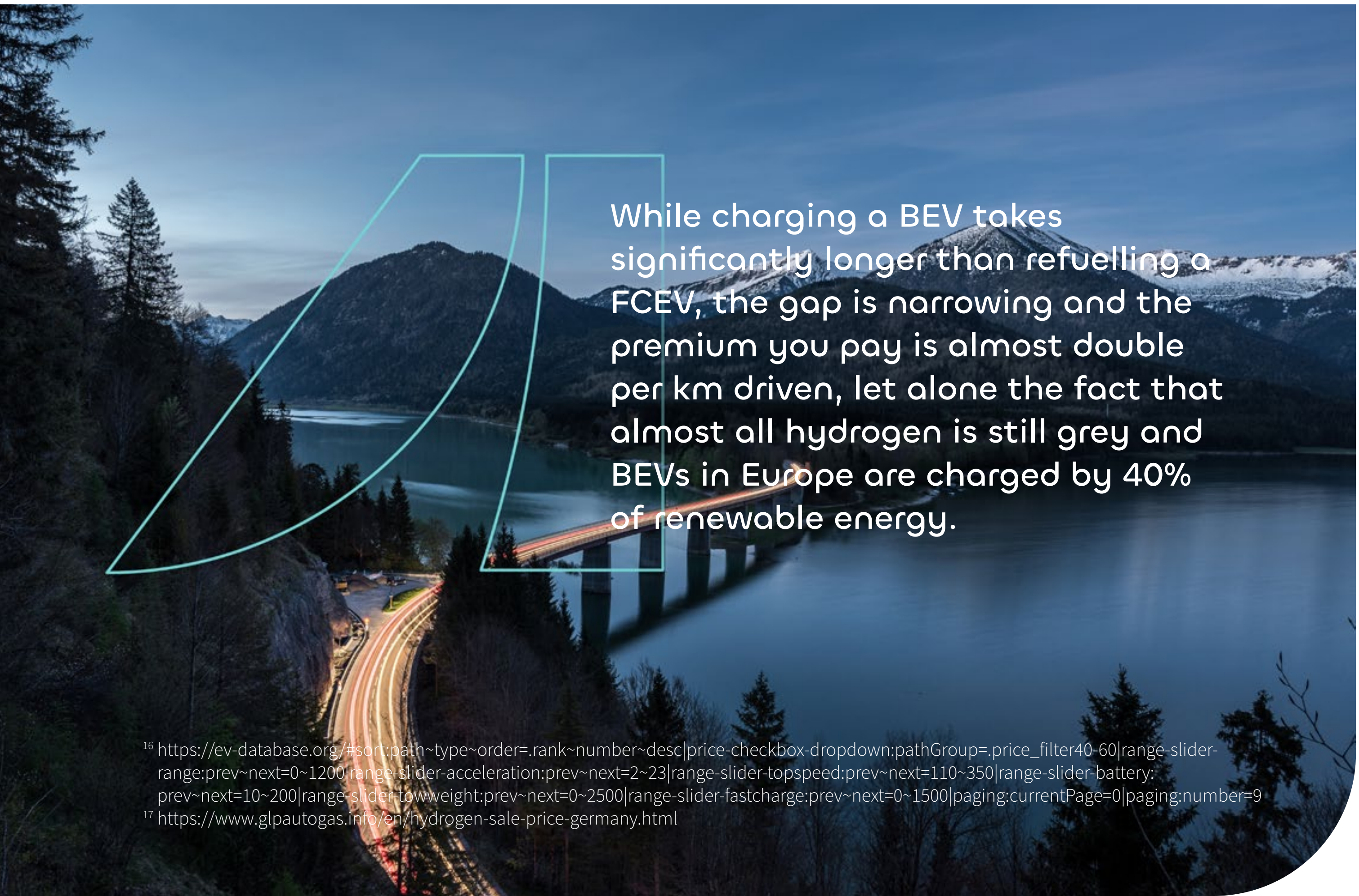
[14] https://www.energy.gov/eere/vehicles/articles/reducing-reliance-cobalt-lithium-ion-batteries
[15] https://electrek.co/2022/04/22/tesla-using-cobalt-free-lfp-batteries-in-half-new-cars-produced/

Current offer of models

While both powertrains are likely to see several technological breakthroughs in the future, it is BEVs that are already produced at scale and with prices to become competitive with ICE vehicles, a clear sign of the powertrain's maturity. For FCEVs, this is not yet the case. Currently only two commercially available models exist (the Toyota Mirai and Hyundai Nexo) but both are still expensive: about €70,000 each in Germany. For BEVs, in the price category €30,000-40,000 alone (also taking German pricing), there are 40+ models as of June 2023[16].
In total, there are over 200+ models available, and this number is expanding rapidly.

Cost of refuelling/charging

While there are many bold projections of the production cost of hydrogen dropping to as low as €1, - per kg*, these assume a lot of breakthroughs which have yet to materialise. And this is only the production cost. For a retail price, the transportation, storage and margins of producers, traders, and retailers need to be considered. For context, production cost of grey hydrogen is now estimated at €3-4 per kg, while being €13.85 per kg at the pump in Germany as of June 2023[17]. Assuming 100 km per kg of hydrogen, we get about €0.14 per km. Given that green hydrogen is more expensive for the foreseeable future this price per km is unlikely to become any lower.



While charging a BEV takes significantly longer than refuelling a FCEV, the gap is narrowing and the premium you pay is almost double per km driven, let alone the fact that almost all hydrogen is still grey and BEVs in Europe are charged by 40% of renewable energy.

[16] https://ev-database.org/#sort:path~type~order=.rank~number~desc|price-checkbox-dropdown:pathGroup=.price_filter40-60|range-slider-range:prev~next=0~1200|range-slider-acceleration:prev~next=2~23|range-slider-topspeed:prev~next=110~350|range-slider-battery:prev~next=10~200|range-slider-towweight:prev~next=0~2500|range-slider-fastcharge:prev~next=0~1500|paging:currentPage=0|paging:number=9
[17] https://www.glpautogas.info/en/hydrogen-sale-price-germany.html

Charging a BEV will always take more time, even at the fastest chargers. The actual time varies depending on many different factors: the battery size, the power capacity of the charger, the speed at which the battery can be charged and weather conditions, to name but a few. In general, a conservative average of current models available is about 30 mins to get to 80% charged, recent models are already halving this and some of the emerging battery technologies are promising even faster charging speeds. Looking at the financial aspect, BEVs will always be more affordable than FCEVs (as mentioned above, due to overall efficiency loss for powering an FCEV). But when comparing prices of refuelling an FCEV vs charging a BEV, it is fair to take rapid charging rates which are considerably more expensive than destination charging and home charging. In Germany (as of June 2023) the current Tesla supercharger rate is €0.42 per kWh[18].
If we then assume an average efficiency of 20 kWh per 100 km[19], we get a price per km of about €0.08 per km.

Subsidies

Given the lack of economies of scale for FCEVs, it is still heavily dependent on subsidies for the development of the vehicles, the refuelling network and hydrogen itself. While it is true that BEVs have gone through a similar phase, the trend in mature EV countries[20] is one of removing the incentives such as the introduction of weight-based taxation for BEVs in Norway.
This removal of the training wheels is another sign that the European BEV market is maturing, however governments should be careful about removing incentives too soon as BEV adoption may stall.
When looking at the total cost of ownership (TCO) comparison from the EV Readiness Index 2023[21] between BEVs and ICE vehicles, BEVs are cost competitive in 14 countries. For FCEV vehicles this is still a long way of in any market primarily due to the high cost of hydrogen and the high purchasing price of the models available.

[18] https://www.electrive.com/2023/05/11/tesla-cuts-prices-at-its-superchargers-in-europe/#:~:text=Tesla%20has%20significantly%20reduced%20the,the%20prices%20for%20Tesla%20drivers.
[19] https://ev-database.org/cheatsheet/energy-consumption-electric-car
[20] https://www.leaseplan.com/en-ix/blog/sustainability/ev-readiness-2023/
[21] https://www.leaseplan.com/en-ix/blog/sustainability/ev-readiness-2023/

Verdict

At the time of writing, BEVs beat FCEVs on all aspects except for the time it takes to charge, which is already becoming less of an argument with upcoming battery technologies. True: the production of batteries still needs to be improved to avoid significant environmental and social impacts, but this is also in the pipeline for the new generation of batteries.

Comparison in Europe	Battery electric vehicles	Hydrogen vehicles
# of charging/refuelling stations	500,000	245
Share of energy sustainable	40%	0.4%
Estimated % of green potential compromised due to leakage	0%	30%
Total CO_2 emissions from battery production	7.9 tonnes	0 tonnes
Overall efficiency rate	70-90%	25-35%
Number of models available	200+	2
Energy price per km in Germany	€0.08*	€0.1385* (grey hydrogen)
Time to charge/refuel	+/-30 mins (10-80% avg)	5 mins
Cost competitive with ICE in EU countries	14	0

**Assuming German hydrogen cost of €13.85 per kg and 1kg per 100km efficiency. For BEVs, assuming 20 kWh per 100km for BEVs and using Tesla fast charger prices per June 2023: €0.42 per KWh.*

Most managers of large fleets are more hesitant to adopt hydrogen cars for these reasons. BloombergNEF supports this view with their Clean Hydrogen Ladder[22], where they put hydrogen passenger cars right at the bottom of the ladder because of its lack of competitiveness.

Perhaps FCEV technology could be more practical for medium and heavy commercial vehicles (also a bit higher up the Clean Hydrogen Ladder). Although currently, demand seems to be lacking. In a recent subsidy round for zero-emission trucks in the Netherlands, 1,600 applications were filed within 24 hours while only 400 spots were available. While applicants had the choice for a subsidy for either a BEV truck or hydrogen truck, all 1,600 were filed for BEV trucks[23].

The transition to zero-emission vehicles is crucial for company fleets and the automotive industry at large in the pursuit of sustainability and climate mitigation. While both battery electric cars and hydrogen fuel cell vehicles offer promising eco-friendly alternatives, the current edge firmly belongs to battery electric vehicles. At Ayvens we work with clients on their fleet sustainability goals and in the transition to more sustainable fleets.

[22] https://www.linkedin.com/pulse/hydrogen-ladder-version-50-michael-liebreich/
[23] https://www.hydrogeninsight.com/transport/nobody-wanted-a-hydrogen-vehicle-all-1-600-requests-for-dutch-zero-emission-truck-subsidies-were-for-battery-electric-models/2-1-1434803?zephr_sso_ott=hzEGGp

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