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Sustainable Mobility: Renewable Hydrogen in the Transport Sector

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The transportation sector is the second-largest source of CO_2 emissions, after electricity and heat generation, accounting for about 25 percent of global emissions.[1] However, it is also one of the most challenging to decarbonize due to its distributed nature and the advantages of fossil fuels in terms of high energy densities, ease of transportation, and storage. Moreover, the degree of difficulty in decarbonizing varies significantly across the sector, making the challenge even more daunting.

So far, emissions reduction strategies have focused on improving vehicle and system-wide efficiencies, mode switching, and electrification. The latter is proving relatively easy for smaller vehicles

1 IEA, "Data and statistics" https://www.iea.org/data-and-statistics/data-browser/?country=WORLD&fuel=CO2%20emissions&indicator=CO_2BySector, accessed May 2021.

that travel shorter distances and carry lighter loads. However, sector-wide decarbonization pathways will require a transition to low-carbon fuels and the deployment of enabling infrastructure to support innovation at scale.

Renewable hydrogen holds promise in sustainable mobility applications, whether by powering fuel-cell electric vehicles (FCEVs) like cars, trucks, and trains or as a feedstock for synthetic fuels for ships and airplanes. Fuel cells convert hydrogen-rich fuels into electricity through a chemical reaction. FCEVs use a fuel cell, rather than a battery, to power electric motors, and operate near-silently and produce no tailpipe emissions.

Hydrogen-powered vehicles offer key advantages, including shorter refueling times, longer ranges, and a lower material footprint compared to lithium battery-powered alternatives. However, high costs of ownership and a lack of enabling infrastructure are key challenges that must be addressed through policy support, technological innovation, and financial investment.

Hydrogen can complement existing efforts to electrify road and rail transportation and provide a scalable option for decarbonizing shipping and aviation. Figure 1 summarizes the mobility segments for which battery electric vehicles (BEVs), FCEVs, and vehicles running on bio- or hydrogen-based synthetic fuels are most applicable.

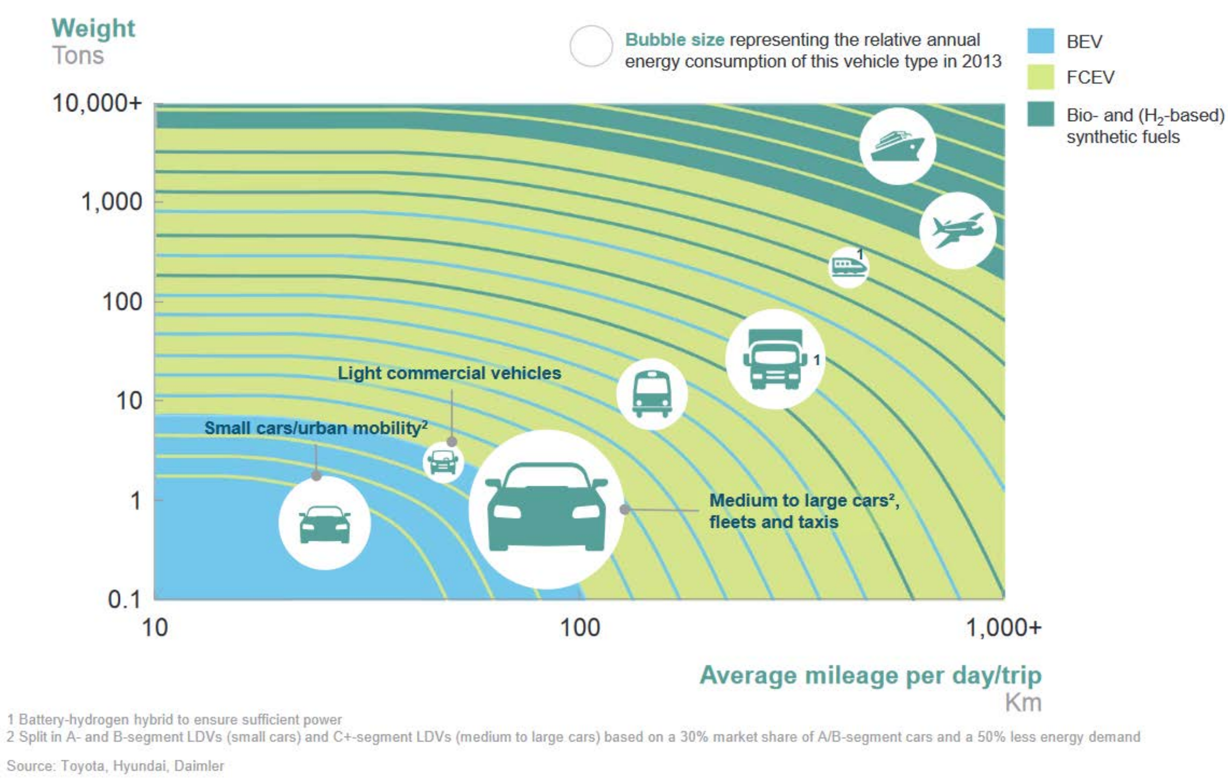

Figure 1. Hydrogen applications in the mobility sector. Source: Hydrogen Council (2017)

Road Transportation

Motor vehicles account for about 20% of global CO_2 emissions from energy and 75% of transportation-specific emissions.[2] Renewable hydrogen competitiveness will depend on overall costs of ownership and the availability of refueling infrastructure. Short refueling times, lower added weight for stored energy, and zero tailpipe emissions are key advantages. Fuel cells also show promise thanks to their lower material footprint compared to lithium batteries. Long-distance and heavy-duty vehicles offer the greatest potential, but investments are required to lower the delivered price of hydrogen. Captive fleets, such as taxis, buses, and trucks, can help overcome the challenges of low utilization of refueling stations and spearhead the adoption of hydrogen.

Rail

Rail is one of the most energy-efficient and clean transport modes. Trains carry 9% of global motorized passengers and 7% of freight but account for only 3% of energy demand and 1% of CO_2 emissions for the overall transportation sector.[3] Renewable hydrogen-powered trains could be most competitive in rail freight and rural/regional lines where long distances and low network utilization do not justify the high costs associated with track electrification. Hydrogen trains also hold promise due to flexible bi-mode operations, allowing them to run on electrified and conventional lines alike. However, innovation in compressing and storing hydrogen will be needed to improve economics and scalability.

Shipping

Despite being one of the most efficient forms of freight transport, shipping remains a challenge for decarbonization efforts. The sector accounts for about 3% of global and 11% of transportation related CO_2 emissions and has an industry goal of reducing emissions by 50% by 2050 from 2008 levels.[4] Renewable hydrogen and ammonia can overcome the limitations of battery ships. However, high costs compared to fossil fuels, the challenge of cargo volume loss due to fuel storage (in terms of energy content parity, while batteries require 64 times more volume than marine diesel oil, hydrogen

2 IEA (2019), "Transport sector CO_2 emissions by mode in the Sustainable Development Scenario, 2000-2030" https://www.iea.org/data-and-statistics/charts/transport-sector-co2-emissions-by-mode-in-the-sustainable-development-scenario-2000-2030, accessed May 2021.

3 Ibid.

4 International Maritime Organization (2018), "UN body adopts climate change strategy for shipping" https://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx, accessed May 2021.

and ammonia only require 8 and 3 times more, respectively[5]), and the deployment of global refueling networks need to be addressed.

Aviation

In 2019, aviation accounted for around 3% of global energy-related CO_2 emissions and 12% of transportation sector emissions.[6] Compared to road transportation, this seemingly small number should not be dismissed, though, since the overall contribution to global warming is significantly higher due to emissions other than CO_2, like nitrogen oxides and soot. Although the pandemic has caused the most extensive retrenchment in aviation history, it also provides a unique opportunity for the sector to restructure itself towards a low-carbon future. Drop-in synthetic liquid fuels provide an attractive decarbonization option at the expense of higher energy consumption and potentially higher costs. Direct hydrogen use also shows promise, but the sector will need to borrow technologies developed for the automotive and space industries and apply them to commercial aircraft operations while achieving similar or better safety targets. Due to the very long aircraft development and certification lead times, these challenges demand urgent answers from both industry leaders and policymakers.

5 ETH Zurich (2019), "Towards Net-Zero: Innovating for a Carbon-Free Future of Shipping in the North and Baltic Sea" https://fe8dce75-4c2a-415b-bfe4-e52bf945c03f.filesusr.com/ugd/0a94a7_0980799ebca344158b897f9040872d36.pdf, accessed May 2021.

6 Air Transport Action Group, https://www.atag.org/, accessed June 2021.

Conclusions

Before renewable hydrogen can truly become a game-changer in the transportation sector, significant barriers, mainly related to storage, infrastructure, and costs, will need to be addressed.

From an innovation perspective, it will be crucial to reduce costs and improve performance. Technological challenges around weight and hydrogen storage need solutions, particularly in the maritime and aviation sectors.

From a policy perspective, renewable hydrogen adoption at scale will require governments to:

- Establish a role for hydrogen in long-term domestic and international energy strategies, considering geopolitical and market implications.
- Implement policy support in the form of low-carbon targets and carbon pricing measures to stimulate commercial demand for clean hydrogen.
- Address investment risks, especially for first movers, such as targeted and time-limited loans and guarantees.
- Focus on new hydrogen applications, clean hydrogen supply, and infrastructure projects.
- Support research and development efforts and public-private partnerships to accelerate innovation cycles.
- Harmonize standards and eliminate unnecessary regulatory barriers while developing certification systems and regulations for carbon-free hydrogen supply.

To date, technological factors, economic considerations, and consumer choices have hindered the adoption of hydrogen at scale in the transportation sector. New geopolitical forces such as the challenges of sustainable development and climate change are reshaping the playing field. Stakeholders around the world must decide their role in the transition to a decarbonized transportation sector.

*This policy brief is the third in the **Mission Hydrogen** series, a collaboration with the Italian Institute for International Political Studies (ISPI) on the future of hydrogen leading to the G20.*

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