Hydrogen & Fuel Cell Sector in China

Scope of Opportunity for Development

20 September 2018, London

Risk vs. Reward Matrix of Hydrogen & Fuel Cells technologies

Need for an energy carrier / storage for renewable power

- Two main technologies – batteries and hydrogen – can provide the required storage for renewables;
- While often portrayed as competitors, they are, in fact, complementary for different applications;
- In line with the above logic are our own investments in "Nikola Tesla" foundation.

Risks and challenges facing Hydrogen / Fuel Cells sector in China

- Need for more economically-viable methods to produce, store, and transport hydrogen;
- Need to expand hydrogen refilling infrastructure and applications;
- More targeted policy and regulatory frameworks for hydrogen-based technical solution must be developed.

Publicly announced "Demonstration city" pilot by the Government of China

- The project would address each of the concerns mentioned above in industry, transportation and power;
- The project meant to establish a replicable model of a hydrogen-powered city and demonstrate the technical and economic feasibility of various hydrogen-based clean technology solutions;
- If successful, the project would transform how the Chinese economy can develop financially and be environmentally sustainable.

China's advantages in developing Hydrogen and other Renewables relative to the rest of the World

- Many Chinese cities are building brand new infrastructure from scratch allowing for new technologies' uninhibited development, lending itself to, e.g. electric fleets and hydrogen fuelled fleets alike
- Specific to Hydrogen Fuel Cells, the high energy density of on-board hydrogen storage (about 10 times higher energy density compared to rechargeable batteries) makes hydrogen fuel cell ideally suited for powering large, heavy or "vertical" (e.g., flying) modes of transport
- Hydrogen is required not only for the energy transition and scaling up, but it will also power new digital business models (Please see next two pages)

Source: Hydrogen Council, September 2018

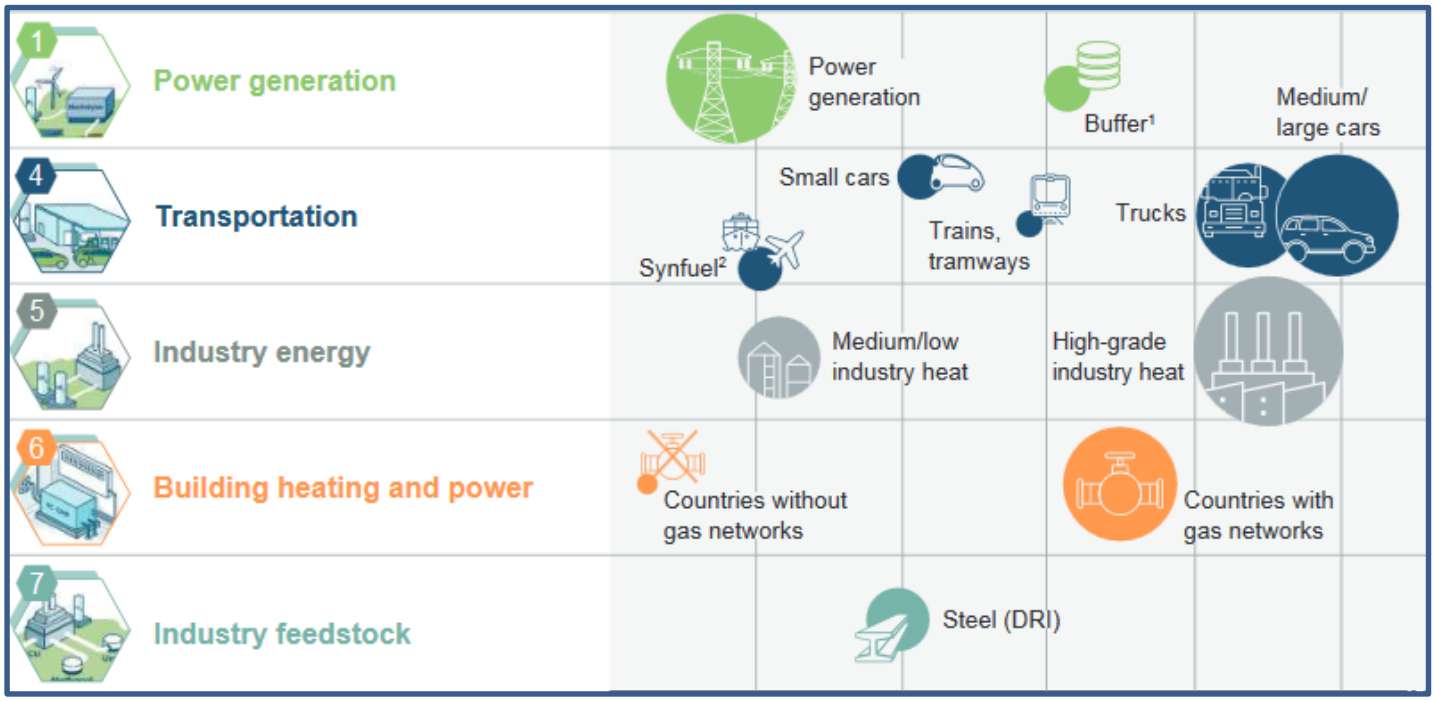
Hydrogen's seven key roles in the energy transition - 2050

The world already produces and consumes more than 55 Mt of hydrogen annually in a wide range of industrial processes

Scaling-up: Hydrogen demand expected to increase 10-fold by 2050. Annual CO2 emissions could be reduced by 6 Gt in 2050

Most of the value creation in a hydrogen economy would occur in advanced industries. These industries create more employment and domestic value than the value chains of fossil fuels – directly, indirectly, and through implied effects.

The application of hydrogen at this scale would create a revenue potential of more than $2.5 trillion per year



1 – 3: Large scale integration of renewable energy and power generation; distributing energy across sectors and regions, and buffer to increase energy system's resilience
4: Decarbonizing transportation
5: Decarbonizing industrial energy use
6: Helping to decarbonize building heat and power
7: Providing a clean feedstock for industry

Source: Hydrogen Council, September 2018
Notes:
1 Percent of total annual growth in hydrogen and variable renewable power demand
2 For aviation and freight ships
3 Percent of total methanol, olefin, BTX production using olefins and captured carbon

Need for Hydrogen in new digital business models - 2030 outlook

1. Need for Hydrogen in fully autonomous, driverless taxis and shuttles

- Fully autonomous, driverless taxis and shuttles should hit the roads around 2020. Given their zero emissions requirements in many future urban centers and the need to drive long distances and remain always on, they can benefit from hydrogen's high energy density and fast refuelling;
- Since they operate in cities, the lower space requirements for hydrogen infrastructure allow for rapid and cost-effective scaling;
- By 2030, approximately 1.0 million to 1.5 million autonomous taxis and roughly 300,000 to 700,000 autonomous shuttles could be powered by hydrogen fuel cells (out of a total of about 20.5 million autonomous taxis and shuttles on the roads in 2030).

2. Need for hydrogen in digitally enabled freight chains

- Freight is fuelled by the booming e-commerce sector and most modes of commercial transport will eventually switch to autonomous technology;
- Hydrogen provides an ideal energy vector to fuel the whole freight chain – from forklifts, long-haul trucks, short-haul vans, and autonomous ships to last-mile parcel drones;
- By 2030, hydrogen and fuel cells could fuel approximately 3-4 million delivery trucks and vans globally.

3. Vertical take-off and landing (VTOL) taxis

- Set out to revolutionize urban transport, with companies planning to launch first operations already by 2020;
- VTOLs require a safe, clean, energy-dense, and fast-refueling energy storage, and hydrogen could allow high aircraft uptime, long ranges, and an efficient buildup of the start and land infrastructure;
- With some 20 to 40 % of electric VTOLs powered by fuel cells, between 4,000 and 8,000 hydrogen-powered VTOLs could fly in the skies by 2030.

4. Data centers

- Data centers already account for an energy demand close to that of France and forecasts predict this will double by 2030; Hydrogen could provide the power when solar and wind are not available, as well as efficient, responsive backup power.

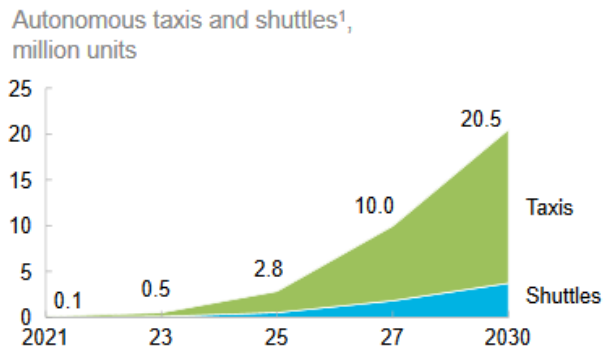
In the four use cases described, the potential for hydrogen could amount to about 5-7 million t of annual hydrogen demand, for a total of some 5.5 million to 6.5 million fuel cells in use by 2030.

Source: Hydrogen Council, September 2018

APPENDIX A

Autonomous taxis and shuttles

Autonomous taxis are becoming a reality



Growth in autonomous taxis and shuttles

- Investments in autonomous driving in the past 5 years have exceeded 15 billion USD.
- As of today, level 4 autonomous cars have driven over 16 million test kilometers on the road, and the technology has undergone many more millions of test kilometers in simulators.
- Over 10 automakers are planning to launch level 4 autonomous cars by 2020, and level 5 cars by 2025. By 2030, we believe more than 20 million autonomous taxis and shuttles could be on the road, transporting passengers in the city of the future

Prerequisites to achieve full potential

- Autonomous taxis and shuttles require high uptime. Fast refuelling is another critical factor, undermining the applicability of batteries.
- Limited parking availability in dense urban areas cannot handle large numbers of taxis refuelling for 30 minutes or more, and driving to dedicated refuelling/recharging areas outside of cities would limit uptime.
- AVs need a high energy density fuel that provides enough power for the onboard computing technology for level 5 autonomy. The energy source must also enable shuttle operations with larger and heavier vehicles, which will increasingly replace urban buses.

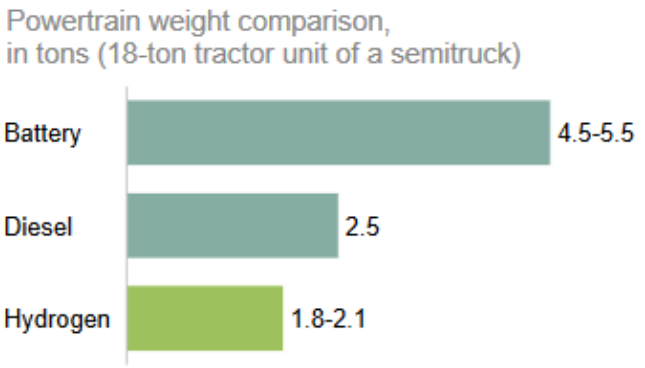
Three key benefits of Hydrogen for AVs

- First, its high energy density helps when powering larger and heavier shuttles and meeting the computing requirements for level 5 autonomy without any compromises on payload or range. Due to faster refueling times, comparable hydrogen stations would occupy about 15 times less the space than battery chargers, which need more charging points due to the extended charging time.
- Second, hydrogen ensures high uptime by offering Long ranges and fast refuelling times.
- And third, the refuelling infrastructure needs little space in dense urban areas.

Source: Hydrogen Council, September 2018.

Digitally enabled freight chains

Hydrogen as an energy vector for long-haul trucks requires less weight for the powertrain



Hydrogen tanks have
10 times
the energy density (by weight) than batteries[1]

1 0.2 kWh/ kilogram for rechargeable batteries used in battery electric vehicles (BEV) compared to 2.2 kWh/kilogram for onboard hydrogen storage for light-duty fuel cell vehicles (FCEV); Source: U.S. DOE Office of Energy Efficiency and Renewable Energy, MCFM

SOURCE: DOE; Nikola Motors; Bloomberg; Manager Magazin; Sustainable Transportation Lab

Delivery truck growth rates

- By 2030, approximately 3.0 million to 4.0 million short- and long-haul hydrogen delivery trucks could be on the road. These include medium- and heavy-duty trucks for long-haul deliveries, with a baseline of about 22 million vehicles globally in 2030.
- Assuming a hydrogen adoption rate of about 1 % of sales in 2030, it could lead to an estimated 80,000 medium- and heavy-duty hydrogen-fueled trucks.
- Another potential segment involves short-haul delivery vans for last-mile trucking. In 2030, the global fleet baseline for these vehicles could number roughly 155 million units.

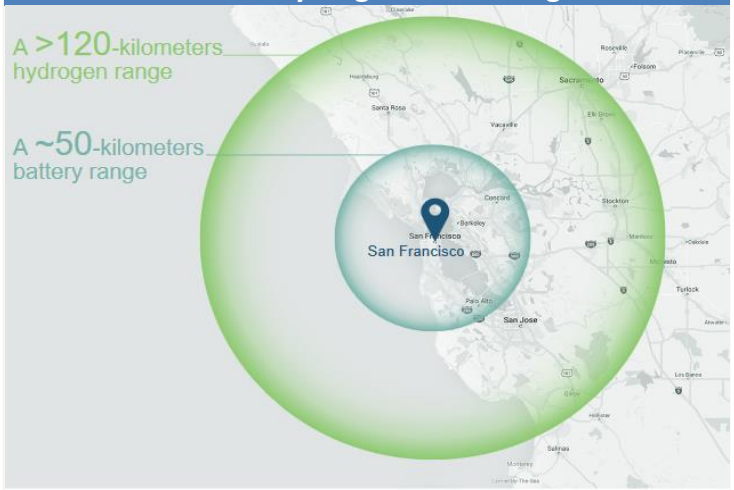
Freight handling machinery growth rates

- 50,000 hydrogen forklifts by 2030, derived from a total fleet of approximately 8.5 million vehicles and a hydrogen adoption rate of about 4 percent of sales.
- 17 Hydrogen fuel cells could also power some 130,000 to 260,000 delivery drones for last-mile deliveries. This estimate takes into account an estimated 290 billion packages in 2030, with about 10 % express parcels, of which 10 percent are drone deliveries.
- The hydrogen-powered drone estimate is a result of our scenario, which assumes a total of roughly
- 3,000 annual deliveries per drone and a hydrogen adoption rate of about 20 to 40 percent.

Source: Hydrogen Council, September 2018.

VTOL taxis

San Francisco – hydrogen allows longer routs



Economic value of VTOLs

- VTOL taxis support on-demand aviation services, which offer rapid, zero-emission passenger transport. The economic value of this technology is particularly high in congested urban areas like Los Angeles, where residents spend over 100 hours per year stuck in traffic jams.
- Furthermore, VTOLs can make commuting to major cities from the suburbs more convenient, reducing the need to live close to the city center. While still in the pilot phase, estimates claim over 20,000 VTOLs will be flying by 2030.
- More than 80 companies are currently working on the technology.

Benefits of Hydrogen

- One, its high energy density helps in powering vertical transport and computing requirements as future generations of VTOLs become autonomous.
- Two, due to its high energy density, hydrogen provides high uptime, which can maximize flying times and thus offset the high initial investment needed for developing and setting up an entirely new industry. High uptime also converts to longer-range capabilities, opening additional routes not servable with battery VTOLs.
- Three, it allows for quick refuelling without the risk of powertrain lifetime reductions as seen for batteries.

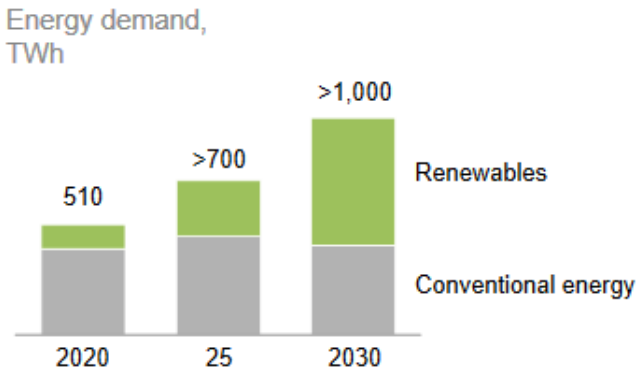
Reduction in onboard energy storage

- Higher energy density also decreases the weight of onboard energy storage. Calculating the weight requirements for a battery powertrain capable of completing five flights between San Francisco and Palo Alto, which corresponds to a total of 240 km, leads to an estimated powertrain above 800 kg.
- Hence, savings from the powertrain could reach several hundred kg, which could be used to either achieve higher uptime and longer ranges or transport more passengers, leading to increased revenue. A hydrogen share of 20 to 40 % would mean that some 4,000 to 8,000 VTOLs could be powered by hydrogen in 2030.

Source: Hydrogen Council, September 2018.

Data centers

Data centers as backbone of digital technology – ever increasing demand for green energy



35%
annual growth of data center storage from 2016 to 2021

30-50%
of data center costs are attributed to energy, mostly for cooling

SOURCE: Bloomberg; Cisco; Digital Realty; Enerdata; expert interviews; Forbes; Gartner; IEA; Intellect UK; zdnet

Data centers' demand for green energy

- Data centers represent the backbone of virtually all digital trends and require large amounts of energy.
- The above Exhibit reveals the trend in overall energy consumption of data centers.
- By 2020, data centers are expected to require a total of around 500 TWh, with most of the energy supply coming from conventional energy sources.
- Within the next decade, this demand could double, equalling the energy needs of two Germanys.

Benefits of Hydrogen

- Data centers could benefit from hydrogen being responsive and versatile and can use it irrespective of their location.
- Furthermore, it provides a way to balance and store fluctuating renewable power sources and use this green energy for the data centers when it is required.
- Third, it allows the effective long-term storage of excess energy from renewables to balance the grid.
- Beyond serving as energy source for electricity generation, hydrogen can also be used for cooling of servers in data center. Stored liquefied hydrogen could be used to cool down servers before it's used as a fuel.

Source: Hydrogen Council, September 2018.

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