Reducing the cost of fuel cells: how can it be done?

Conclusions on cost reduction potential of a light duty hydrogen fuel cell system

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Highlights within this study

	For a fuel cell system (assumed 80 kW_{net} in this study)		For a hydrogen storage system (assuming 94 kWh of useable energy in a light duty FCEV – see slide 7)
How much does a hydrogen fuel cell system cost today?	**>$100/kW**	+	**>$100/kWh**
At what point do hydrogen fuel cell system costs start to align with future battery costs?	**$40/kW**	+	**$40/kWh**

Is this cost reduction achievable for hydrogen fuel cell systems?

- **High potential** in reducing fuel cell system cost if industry can achieve economies of scale from ramping up to 500,000 systems production per year
- Performance improvements, such as power density, will also contribute partially to $/kW reduction in the fuel cell system
- We conclude it is **very difficult** that current hydrogen storage systems go below $40/kWh considering the relatively incompressible cost of carbon fibre

Source: APC & Austin Power Fuel Cell Cost Study (March, 2022)

Overview of key assumptions in this cost study

We predict that as OEMs rationalise their vehicle architectures, the viability and cost related to integrating fuel cell systems may create additional challenges not addressed in this study.
This is a topic we will explore in more detail in a forthcoming APC report.

The cost analysis is based on a light duty fuel cell system suitable for a **passenger car** or **van**

80 kW_{net}

On-board hydrogen storage costs are based on a **3-tank system** design to power the light duty fuel cell system

H_2 **x3**

5.6 kg

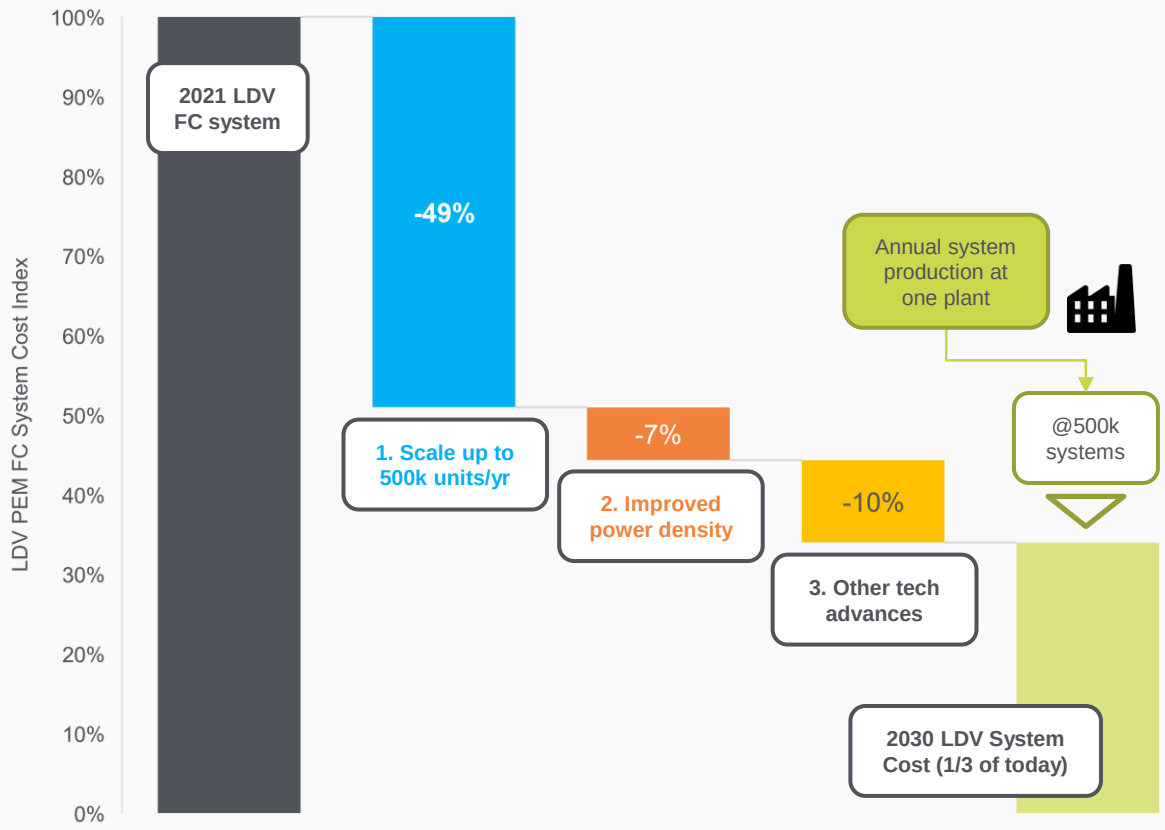
A **dedicated** FCEV platform designed around fuel cell powertrain integration

FCEV platform

Source: APC & Austin Power Fuel Cell Cost Study (March, 2022), Toyota website

The importance of economies of scale in the expected cost reduction

US DOE cost study highlights the importance of economies of scale in the expected cost reduction (-66% vs today) for an 80 kW_{net} LDV fuel cell system[1]



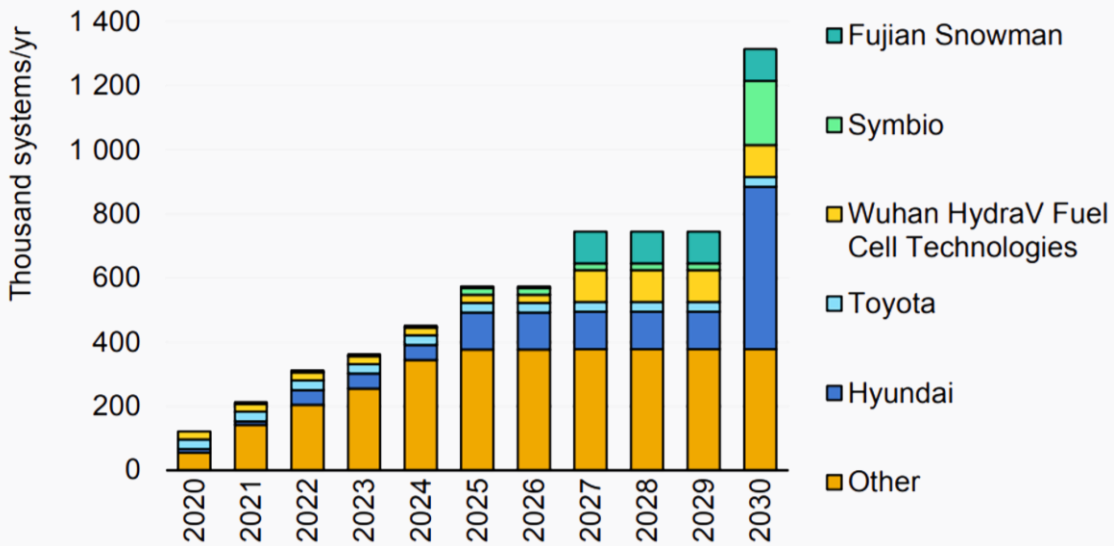
1. Economies of scale could help slash today's fuel cell system costs by almost 50%
2. Improvement in system power density to 850 W/l and specific power to 900 W/kg from both tech advances in membrane and catalyst as well as a reduction in stack active area oversizing
3. Other technology advances include:
   - Compressor Expander Motor (CEM) unit efficiency improvements
   - Move to lower cost membrane materials
   - Other BOP system simplification

Source: Based on Strategic Analysis Inc (2020) for the US Department of Energy Study, 1: Excluding hydrogen storage system

Mass production levels of 500,000 systems per year by 2030

The APC expect that leading fuel cell system manufacturers like Hyundai and Toyota could achieve mass production levels of 500,000 systems per year by 2030

Announced annual automotive fuel cell manufacturing capacity, 2020-2030



OEM	Estimated current capacity	Announced Future Production Plans
HYUNDAI	23,000 systems/year	• Announced $1.1 billion investment to build 100,000 fuel cell systems/year capacity in 2023 • Aims to produce 500,000 fuel cell systems annually by 2030 for FCEVs
TOYOTA	30,000 systems/year	• Announced additional fuel cell module production in Europe from 2021 and 2023 in the US

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Source: APC & Austin Power Fuel Cell Cost Study (March, 2022), Hyundai website, Toyota website, IEA Global Hydrogen Review 2021

Jointly comparing fuel cell system and hydrogen storage costs

Fuel cell system and hydrogen storage cost analyses are typically done separately and use different measures, but we wanted to compare them jointly to batteries

Fuel cell system costs are measured in **$/kW** – their job is to convert hydrogen energy into electrical energy

>$100/kW

For a fuel cell system today (typically 80 – 120 kW for PC)

Hydrogen storage system costs are measured in **$/kWh** because, like batteries, they are energy storage devices

>$100/kWh

For a hydrogen storage system today (we assume 94 kWh of useable energy in a FCEV – see next slide)

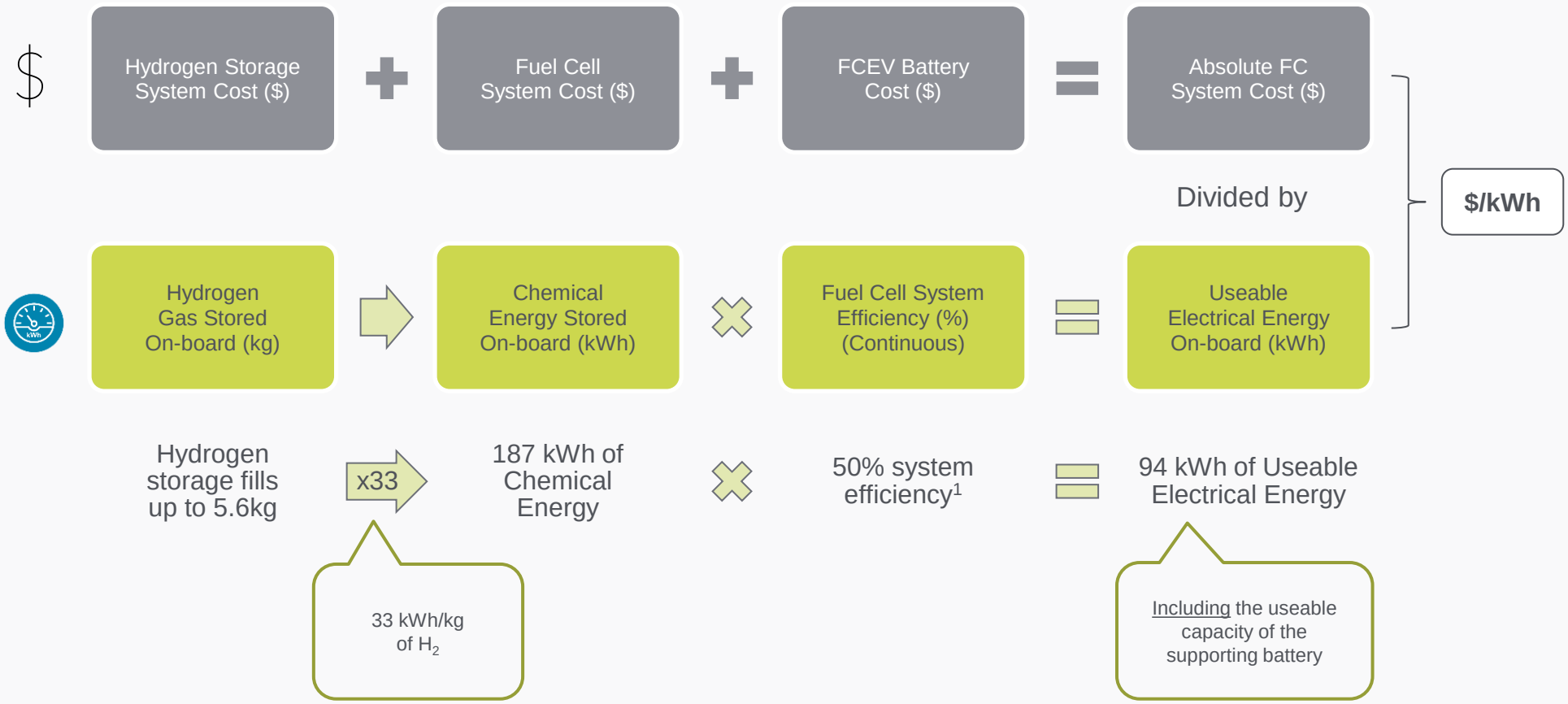
How can we combine the costs so we can compare them jointly to batteries?

? $/kWh

Source: APC & Austin Power Fuel Cell Cost Study (March, 2022)

Method to get the fuel cell and hydrogen tank system costs in $/kWh

We used Austin Power's method to get **both** the fuel cell and hydrogen tank system costs in $/kWh. Here's a worked example based on the Toyota Mirai 2



Source: APC & Austin Power Fuel Cell Cost Study (March, 2022) 1: FEV Mirai 2 Benchmarking

Checking the method: BEV and FCEV comparison

To check our method, we looked at the Model S Long Range model which has a 100-kWh battery (95 kWh useable) and a very similar EPA range to the Toyota Mirai 2

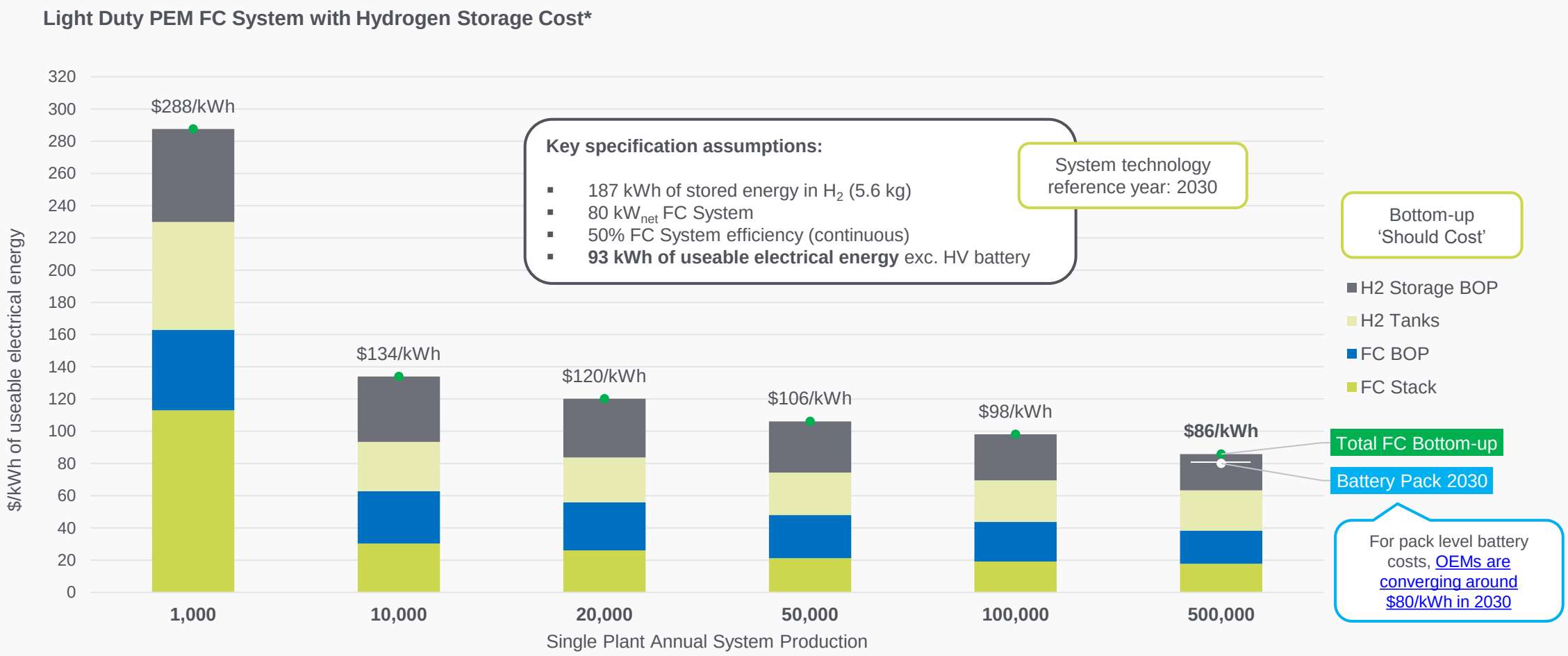
BEV Model	**Tesla Model S LR**
Useable Battery Capacity (est.)	**95 kWh**
EPA Range	**405 mi**

FCEV Model	**Toyota Mirai XLE**
Useable Electrical Energy (calc.)	**94 kWh**
EPA Range	**402 mi**

Source: ev-database.uk, Tesla website, Toyota website

Combined cost of the fuel cell system and hydrogen storage

If we look at the combined cost of the fuel cell system and hydrogen storage system in $/kWh, we have an equivalent measure to that of batteries. Our study suggests that the respective technology costs could converge at high volumes



Source: APC & Austin Power Fuel Cell Cost Study (2022), *Excluding the HV battery cost

Key conclusions

- The APC projects an installed cost of a light duty fuel cell and hydrogen tank system equivalent to **$86/kWh** in a comparable measure to battery costs. This cost could be achieved when a fuel cell system manufacturer has a large-scale plant making **500,000 systems** per year
- The APC predict fuel cell system suppliers such as Toyota and Hyundai could reach **500,000 systems** p.a. production at one plant by 2030
- This means that fuel cell powertrains could be a **cost-competitive complementary solution** to batteries for some use cases such as larger SUVs and vans

Key enablers

- **Economies of scale** are expected to be the main cost-down driver for the fuel cell stack and system. Performance improvements and material innovations also expected to play a significant role in lowering $/kWh cost
- **Optimising carbon fibre usage** and simplifying ancillary systems are key drivers in the cost reduction of on-board hydrogen storage systems.

Source: APC & Austin Power Fuel Cell Cost Study (2022)

Contact APC for further information

Funding for

Fuel Cell projects

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Thank you

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