HOW MUCH WILL THE FUTURE FUEL CELL VEHICLE COST?

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SWEDISH ICT VIKTORIA

OUTLINE

- Scope of study
- Fuel cell cars on the market
- Cost analyses (3 examples)
- Results and conlusions

+ a few words about a new study addressing powertrain configurations

OBJECTIVE AND SCOPE

The objective was to study fuel cell vehicle (FCV) cost development.

The scope and method was:

- Describe the market development until summer 2015
- Scrutinize cost analyses from 12 different groups of actors
- Interview key person at Hyundai.

The focus was on passenger cars fuelled by hydrogen with PEFC technology.

HYUNDAI IX35 FC

- Deliveries since 2013
- 5,64 kg hydrogen
- Range 500 – 600 km
- USD lease 499 per month

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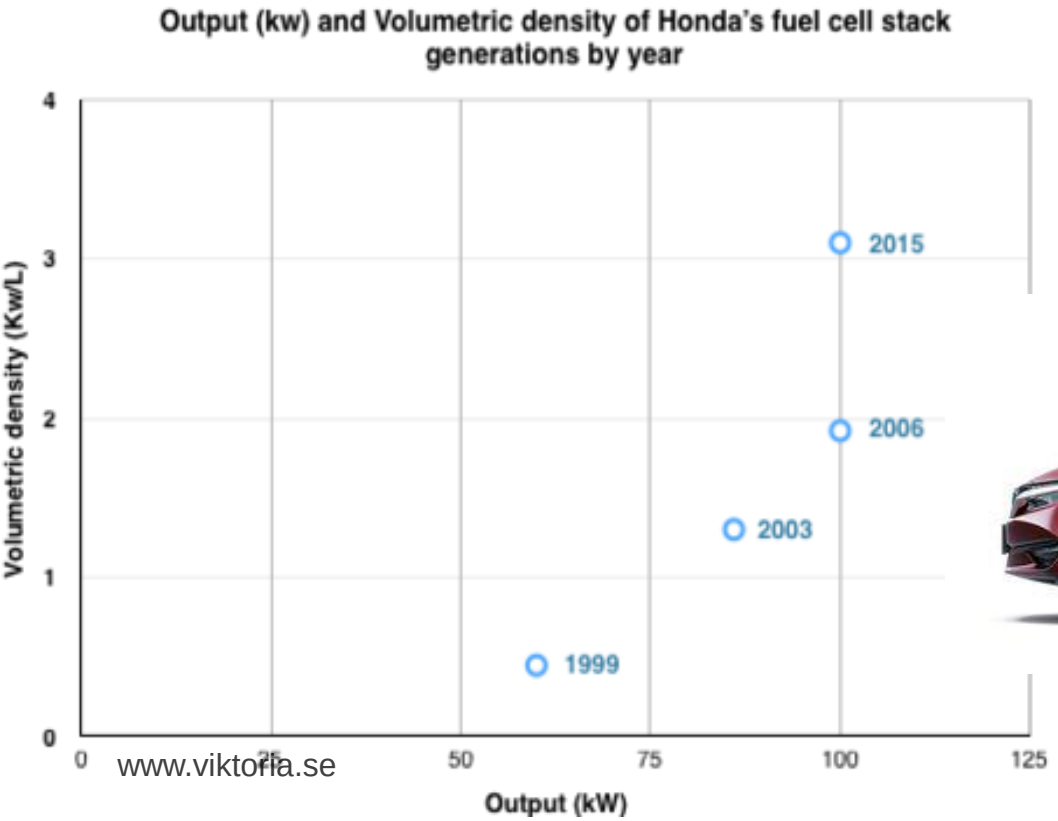
TOYOTA MIRAI

- Sales started December 15, 2014 in Japan
- Price JPY 6.7 million (~USD 57,400)
- Sales have also started in the US and some European countries
- Scheduled production volumes:

Year	Volume
2015	700
2016	2,000
2017	3,000

HONDA CLARITY FC

- Deliveries in Japan start March 2016
- Price 7.66 million yen (USD 63,670)
- Deliveries start in California late 2016
- Range ~500 km



COST ANALYSIS EXAMPLE (USDOE)

- Continuous work with ~annual reports led by Strategic Analysis
- Bottom-up calculations starting with
  - USDOE goals and assumptions
  - Detailed descriptions of production methods and material requirements
- Costs for different production volumes (up to 500,000)
- Since 2012 also including buses
- Fuel cell system includes:
  - Fuel cell stack
  - Balance of plant

COST ANALYSIS EXAMPLE (USDOE)

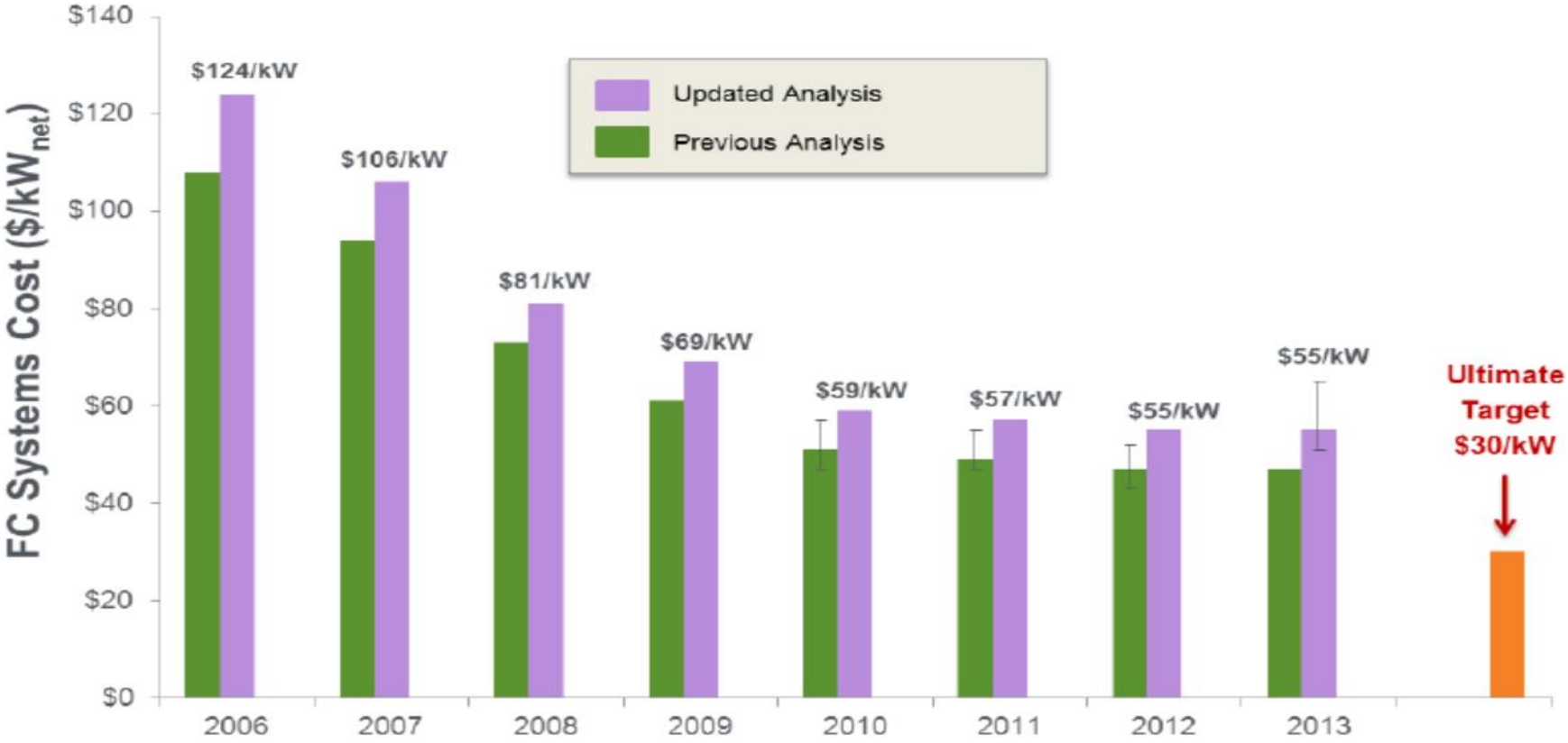


Figure 2. Modeled cost of an 80-kW$_{net}$ PEM fuel cell system based on projection to high-volume manufacturing (500,000 units/year). Reported values from prior year cost estimates were adjusted to account for the higher platinum price, the realigned compressor and expander efficiencies, and the Q/ΔT requirement introduced in 2013.

COST ANALYSIS EXAMPLE GREENE & DULEEP (2013)

- Interviews with the automotive industry plus other sources
- Cost for complete vehicle

Cost in $	2016 (200K/yr)	2020+ (200K/yr) without breakthrough	2020+ (200K/yr) with technology breakthrough
Fuel cell stack (85 kW)	15,150	13,650	7,575
Hydrogen storage (5 kg)	5,300	4,750	3,500
Battery (35 kW,2 kWh)	1,300	975	975
Electric Motor/Inverter/Drive (110 kW peak, 60kW continuous)	3,150	2,825	2,400
Gearbox	350	350	350
Total Power-train	**25,250**	**22,550**	**14,800**
Electric HVAC/Regen. Brakes (incremental)	750	650	650
Glider (constant weight)	11,000	11,000	11,000
Total FCV cost	**37,000**	**33,200**	**26,300**

COST ANALYSIS EXAMPLE OGDEN ET AL

UC Davis: Introduction scenarios linked to production costs at each point in time

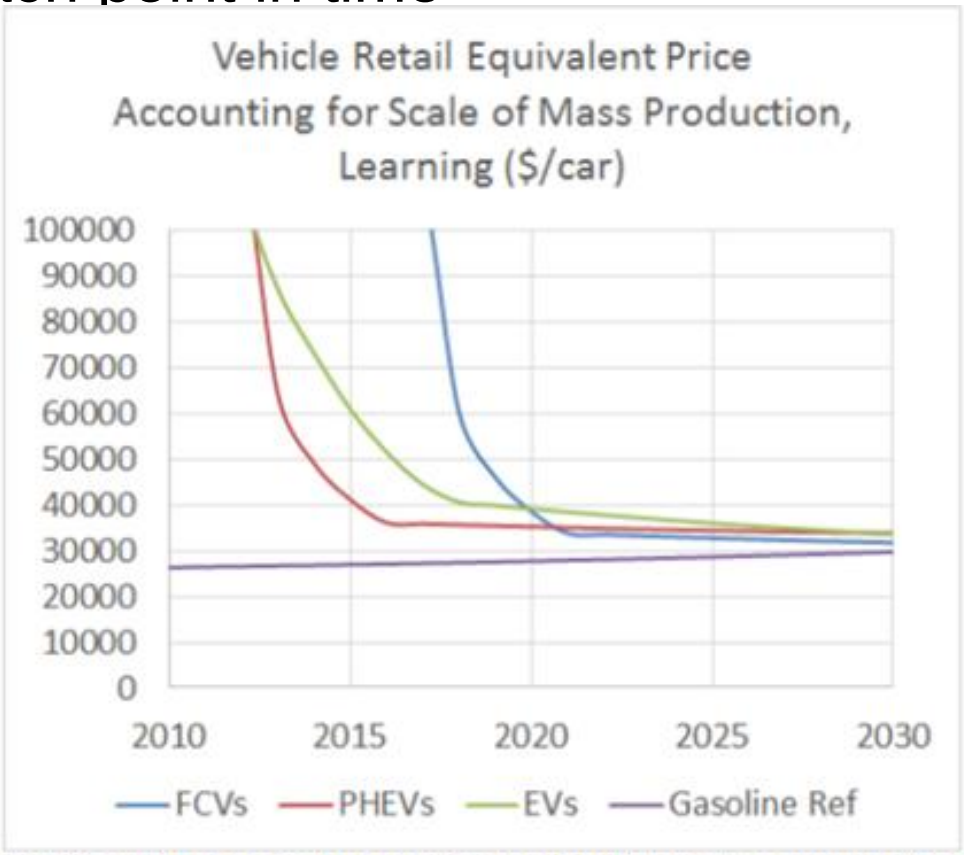
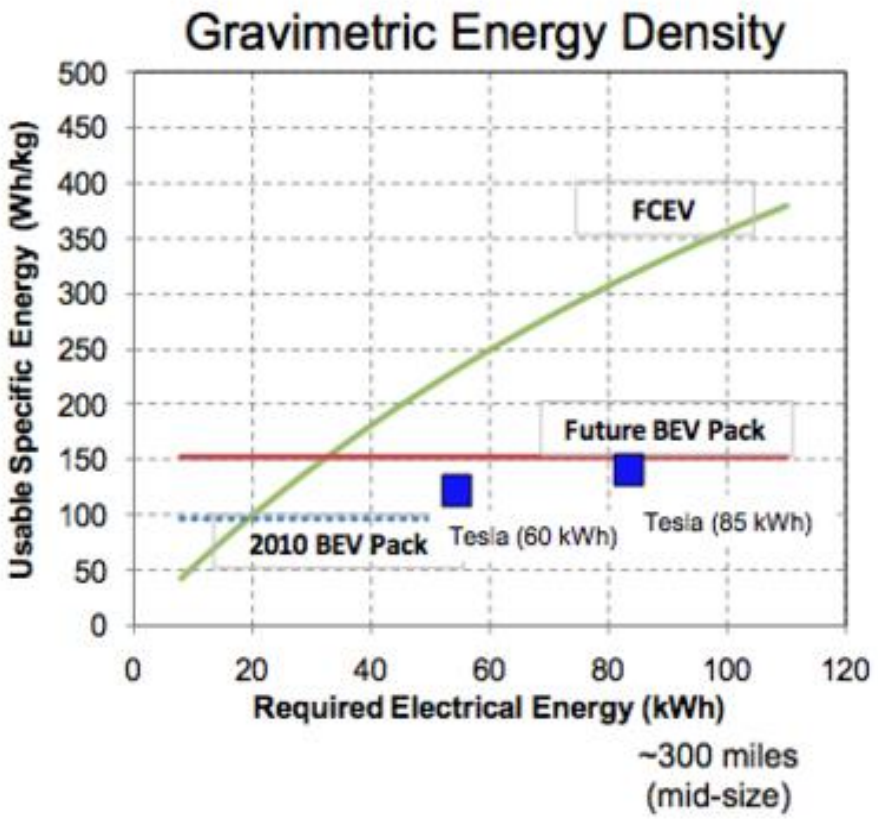
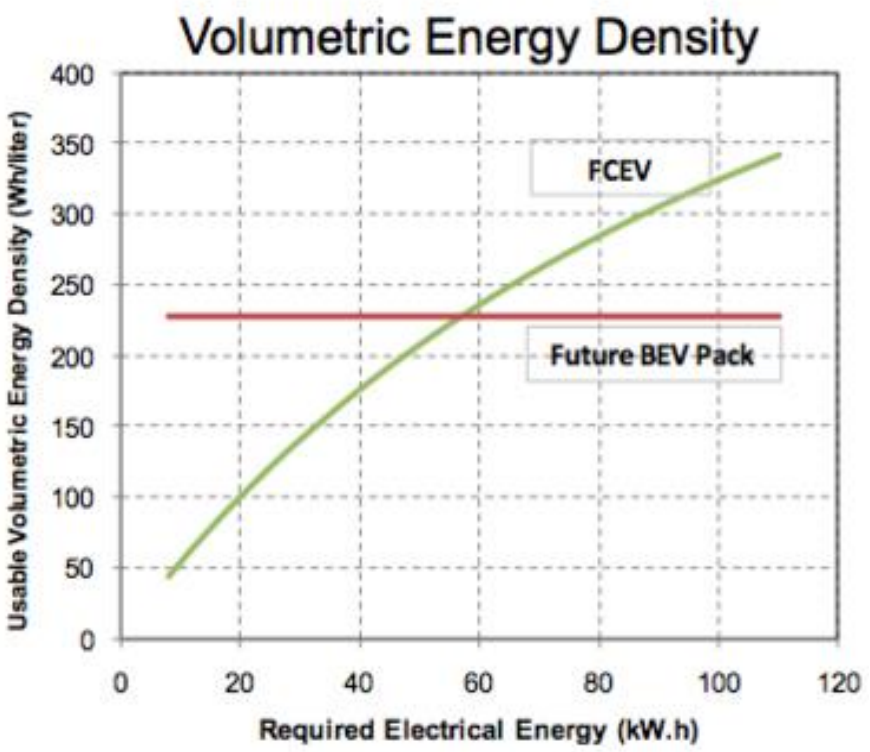


Figure 6. Vehicle retail price equivalent over time based on Figure 5, but accounting for early scale dis-economies at low levels of mass production. By the early 2020s the alternative fueled vehicles have reached mass-production volumes and learned out RPEs (Figure 4). The RPE is not the same as the showroom price of the vehicle, which can include marketing strategies such as "forward pricing" to build sales (Ogden, Fulton and Sperling, 2014).

COST COMPARISON FCV – BEV (1)

Electrification with Li-ion Battery or Fuel Cell System

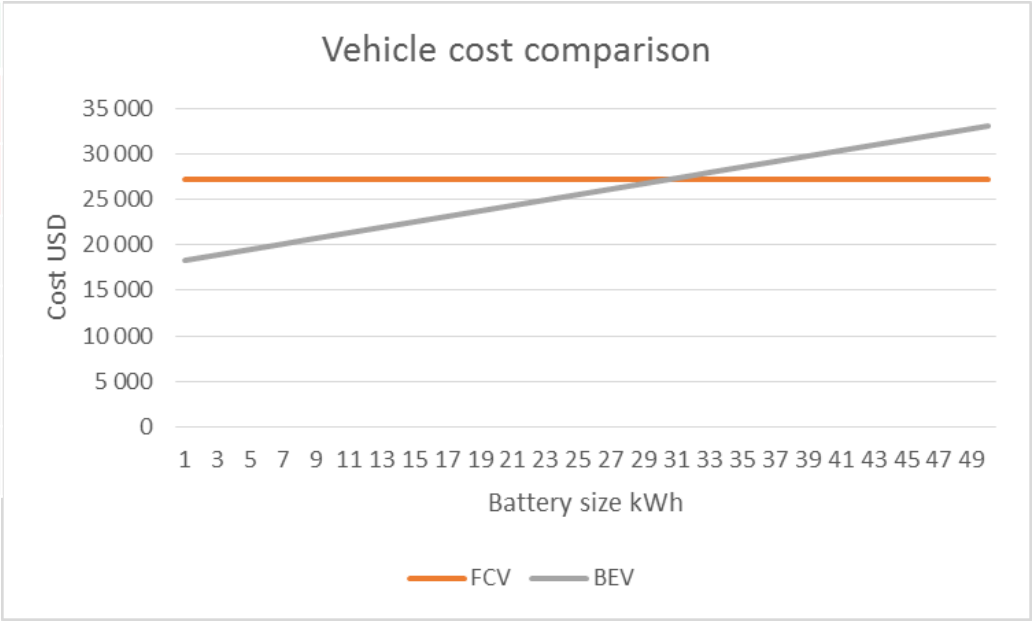




COST COMPARISON FCV – BEV (2)

A very primitive cost comparison indicates equal costs at a battery size of approximately 30 kWh

	USD
BEV	
Tractionary battery	300 /kWh
FCV	
Hybrid battery 1 kWh	1 000
Fuel cell system	5 000
Hydrogen storage	3 200



RESULTS

- Several ambitious cost analyses exist but they are all different in terms of methods and assumptions
- The cost for the fuel cell system has not reached the targets and the cost reduction ratio has been close to zero in the latest available studies
- The estimated cost for a FCV is 21,000 – 33,500 USD
- The results of Total Cost of Ownership (TCO) analyses span a large range but within each analysis, FCVs become competitive to other alternatives a some stage in the development

FURTHER RESULTS

- Increasingly difficult to carry out relevant cost studies
- Additional car models on the market open for other methods to assess the costs, among them:
  - FCV procurement
  - Buy and demount FCVs
  - Market analyses
- For actors in the automotive industry it might also be relevant to ask for quotations for sub-systems

TO CONCLUDE

There is a lot to learn from existing cost analyses

There is an interesting mismatch between:

- Current cost analyses results indicating that the costs are not yet acceptable for market introduction

and

- Automakers' activities on the market

FUEL CELL CONFIGURATIONS

A study of existing and possible combinations of fuel cells and other energy converters in vehicles:

- What exists on the road?
- How are different solutions positioned on the market?
- How do the powertrains for buses and cars differ?

New project involving Chalmers/SHC, Vätgas Sverige and Viktoria Swedish ICT.

FUEL CELL CONFIGURATIONS (2)

One result of the project is a better understanding of the relationships between:

- driving patterns
- powertrain configurations
- costs of use

When is, for example, a electric powertrain with a large battery and fuel cells as a range extender a winning solution?