WHEN ARE FUEL CELLS COMPETITIVE?

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SCOPE OF STUDY

WP1 – policy relating to fuel cell vehicles (FCVs)

Emission regulations? Zero emission zones? Other regulations? Refuelling infrastructure needs? Global/local scenarios supporting heavy FCVs?

KTH and SWECO

WP2 – how do fuel cells fit in vehicles?

Most suitable (heavy) applications for fuel cells. Cost competitiveness in relation to other powertrains and fuels

Viktoria Swedish ICT AB

WP3 – how do the OEMs address electrification?

Plans, strategies and actual investments.

Viktoria Swedish ICT and Kanehira Maruo

Legislation and policies for transport effecting the introduction of FCVs

- What are the future emission goals for the transport sector?
  - Current focus on green house gas (GHG) emissions
  - Zero or low emission zones
  - The fuel cell driveline relative other technologies
  - Global/local scenarios supporting heavy FCVs
  - Refueling infrastructure status and progress

- What other legislation can affect the introduction of FCVs?
  - Safety legislations regarding vehicles and refueling
  - Noise legislations in cities and around high-ways

Current focus on (GHG) emissions

- In future emission goals for road traffic there is a heavy focus on CO_2 emissions
- The closest goals are achievable using diesel
- There is a large distribution between countries

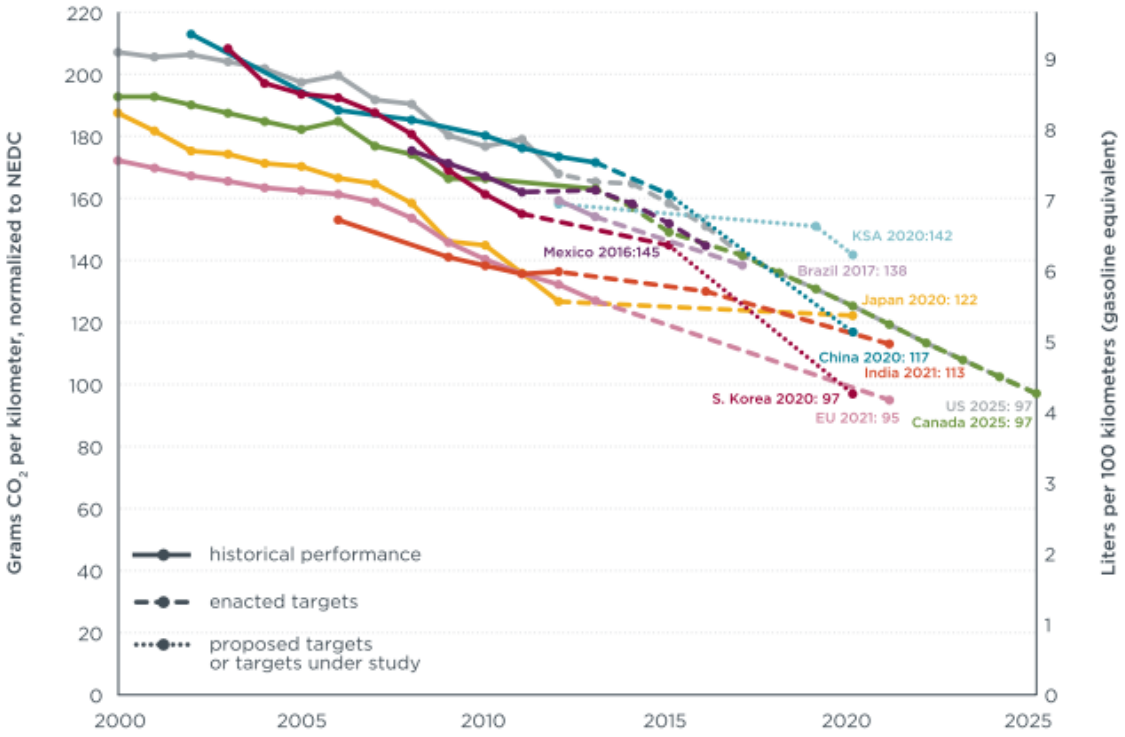
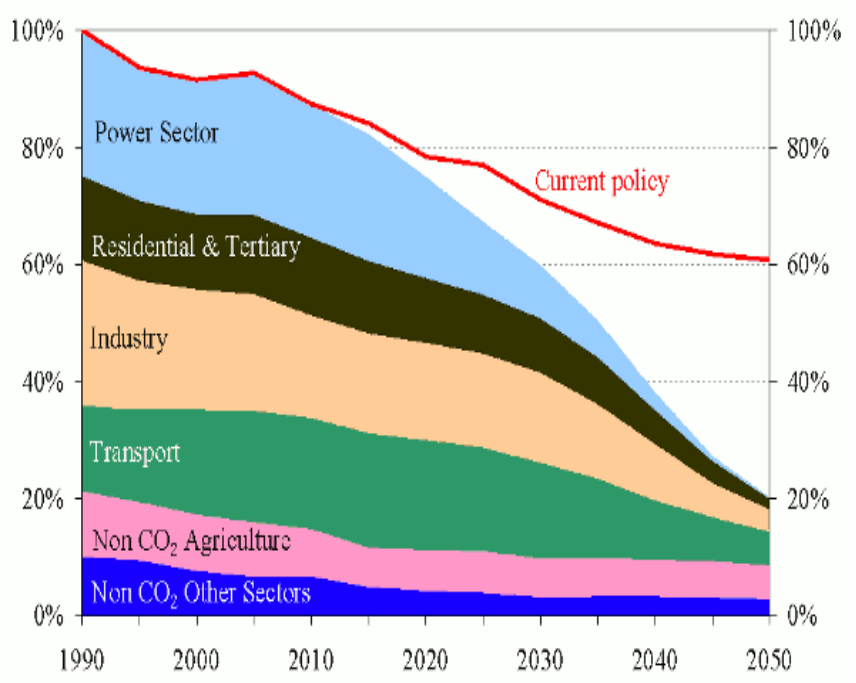


Figure 4. Comparison of light-duty vehicle efficiency standards (passenger cars only, light-duty trucks excluded)

Kodjak, D., 2015. Policies to reduce fuel consumption, air pollution, and carbon emissions from vehicles in G20 nations, u.o.: International council on clean transportation.

Emission goals and reduction possibilities

Current policy relative goal in Europe



Potential for CO2 emission reduction in different countries

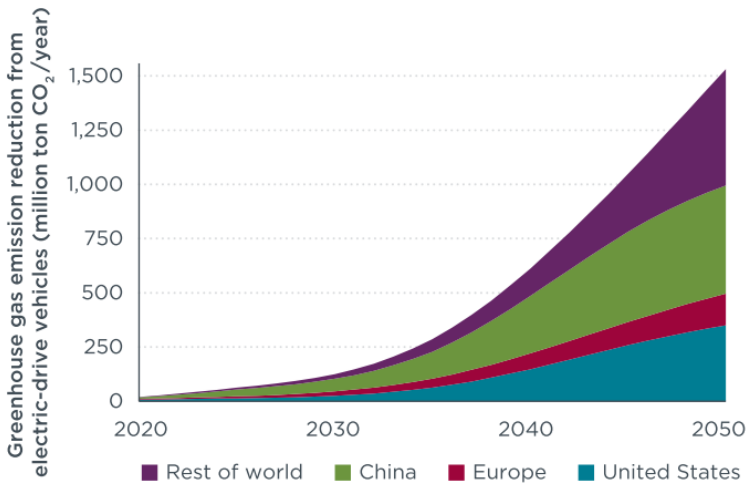
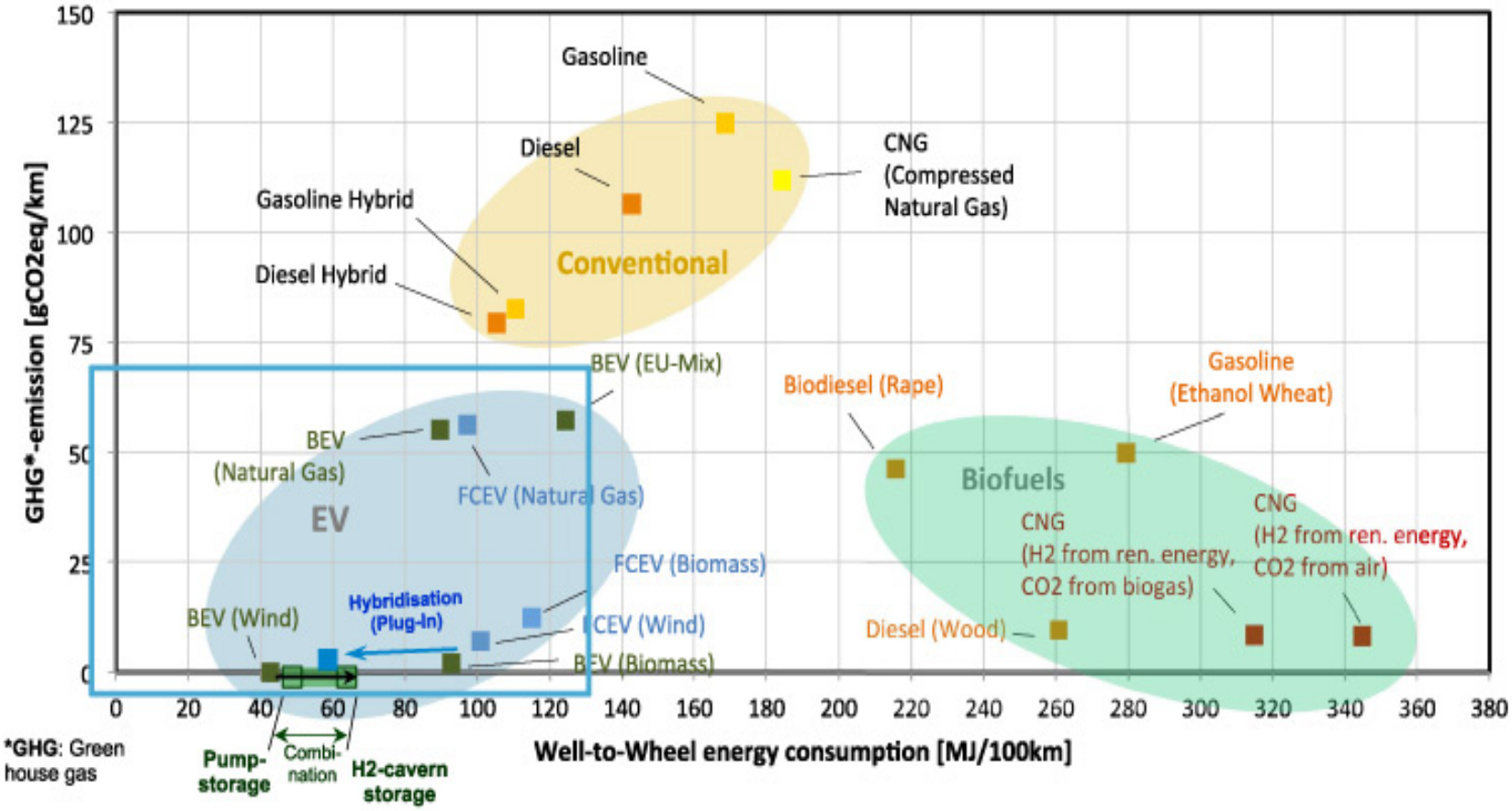


Figure 12. Global greenhouse gas emission reduction from increased penetration of electric vehicles through 2050

1. European Commission, 2016. *European Commission Climate action.* At: http://ec.europa.eu/clima/policies/strategies/2050/index_en.htm
2. Lutsey, Nic, ICCT working paper: Global climate change mitigation potential from a transition to electric vehicles, 2015

The fuel cell driveline relative other technologies



Wind, J., 2015. IPHE Workshop: Energy and transportation systems –A 2020 perspective, Grenoble, 03rd December 2015.

Global/local scenarios supporting heavy FCVs?

- Efficiency and greenhouse gas emission regulations for heavy-duty vehicles

Table 3. Estimated implementation timeline for heavy-duty vehicle efficiency standards

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Japan				PHASE 1					PHASE 2					
U.S.			PHASE 1					PHASE 2						
Canada			PHASE 1					PHASE 2						
China	PHASE 1		PHASE 2						PHASE 3					
EU							MONITORING, REPORTING			PHASE 1				
India									PHASE 1					
Mexico									PHASE 1					
S. Korea									PHASE 1					

Hashed areas represent unconfirmed projections of the ICCT.

Lutsey, Nic, et al. ICCT: http://www.theicct.org/us-phase2-hdv-efficiency-ghg-regulations-policy-update , 2015

Global/local scenarios supporting heavy FCVs?

- Japan:
  - Subsidies same as for passenger cars
  - Demonstration projects
  - Infrastructure build-up
- Europe:
  - Demonstration projects
  - Infrastructure build-up
- California:
  - Demonstration projects
  - Infrastructure build-up

What other legislation can affect the introduction of FCVs?

- Safety legislation regarding vehicles and refueling
  - Currently very small limitations on vehicle movement
  - Refueling stations same limitations as bio-/natural gas

- Noise legislations in cities and around high-ways
  - EU-legislation on noise at low velocities
  - Noise reduction at higher velocities

HOW DO FUEL CELLS FIT IN HEAVY VEHICLES?

Conclusions from US study how to reach climate neutral truck transports until 2050:

- Fuel cell propulsion dominant among electrified powertrains as
  - Battery electric vehicles are not considered relevant for long distance transport
  - Fuel cell vehicles will probably cost less
- Slow transition means that biofuels and energy efficient diesel engines will probably be needed

Lew Fulton and Marshall Miller (2015) Strategies for transitioning to low-carbon emission trucks in the United States, National Center for Sustainable Transportation and ITS UC Davis Institute of Transportation Studies

HEAVY VEHICLE APPLICATIONS

- Long-distance trucks
- Distribution trucks
- City buses

SWEDISH ICT VIKTORIA

LONG DISTANCE TRUCKS (1)

”Facts”

- Different design over the world but highly standardized trailers

Implications for fuel cells

- Powertrain and fuel preferably on truck
- Limited space, particularly in European design
- Hydrogen fuel cell powertrain easiest to introduce in customized vehicles for one particular purpose (but probably not easy)

SWEDISH ICT VIKTORIA

LONG DISTANCE TRUCKS (2)

”Facts”

- Almost always in operation
- 150,000 – 200,000 km/year
- Operation primarily planned in relation to regulations for driver’s work periods
- At least 1,000 km autonomy

Implications for fuel cells

- Long range required, otherwise higher cost of operation
- Alternatives to compressed hydrogen probably needed
- Last mile solutions for electric roads might be interesting (with hydrogen)
- Quick turn-over of vehicles => facilitates introduction of new technologies

LONG DISTANCE TRUCKS (3)

”Facts”

- 440 hk for 40 ton vehicle
- 150 kW average electric power
- Undermotorized (diesel engines)
- High fuel use per hour in operation (25 liter diesel)

Implications for fuel cells

- Long periods at high power
- Hybrids require large batteries or high power fuel cells

HOW DO FUEL CELLS FIT IN HEAVY VEHICLES?

Further studies needed.
One approach for this is proposed in the project ”Fuel cell vehicle powertrain configurations” as outlined by Anders Grauers, Chalmers/SHC.

OEMS ADDRESSING ELECTRIFICATION

Data:

- Interviews in Japan with Toyota, Nissan and METI
- Study trip to Japan (reports from)
- Presentations at FC Expo in Japan March 2016 and September 2016
- Test drive of Mirai and meeting with Toyota Sweden
- Media and literature

TOYOTA

Katsuhiko Hirose (Sept 2016):

Fuel cells more complex than expected

Fuel cells much better than batteries

Experiences so far? Difficult to assess the demand. No more Mirai sales in Japan, all vehicles until and including 2019 already sold.

Bengt Dalström (Nov 2016):

Battery business not sustainable, a risk for a backlash

Mirai leasing only in Europe due to limited infrastructure

In 2020, same price for HEV (Prius) and fuel cell car.

TOYOTA AND BATTERY CARS

In November it was announced that Toyota will produce battery-electric cars in 2020.

Kanehira Maruo has searched for more info:

- Slow development of hydrogen infrastructure in California mentioned
- Maintained resources to fuel cell vehicles indicated
- Limited development resources announced for the battery-electric vehicle.

TOYOTA FUEL CELL BUS

- Production of bus announced. Same technologies as Mirai but two stacks and seven hydrogen tanks at 700 bar
- Cost savings is the main motivation to the use of the same sub-systems
- If the stacks do not last the entire bus life time it is easy to exchange them

TOYOTA MIRAI TEST DRIVE

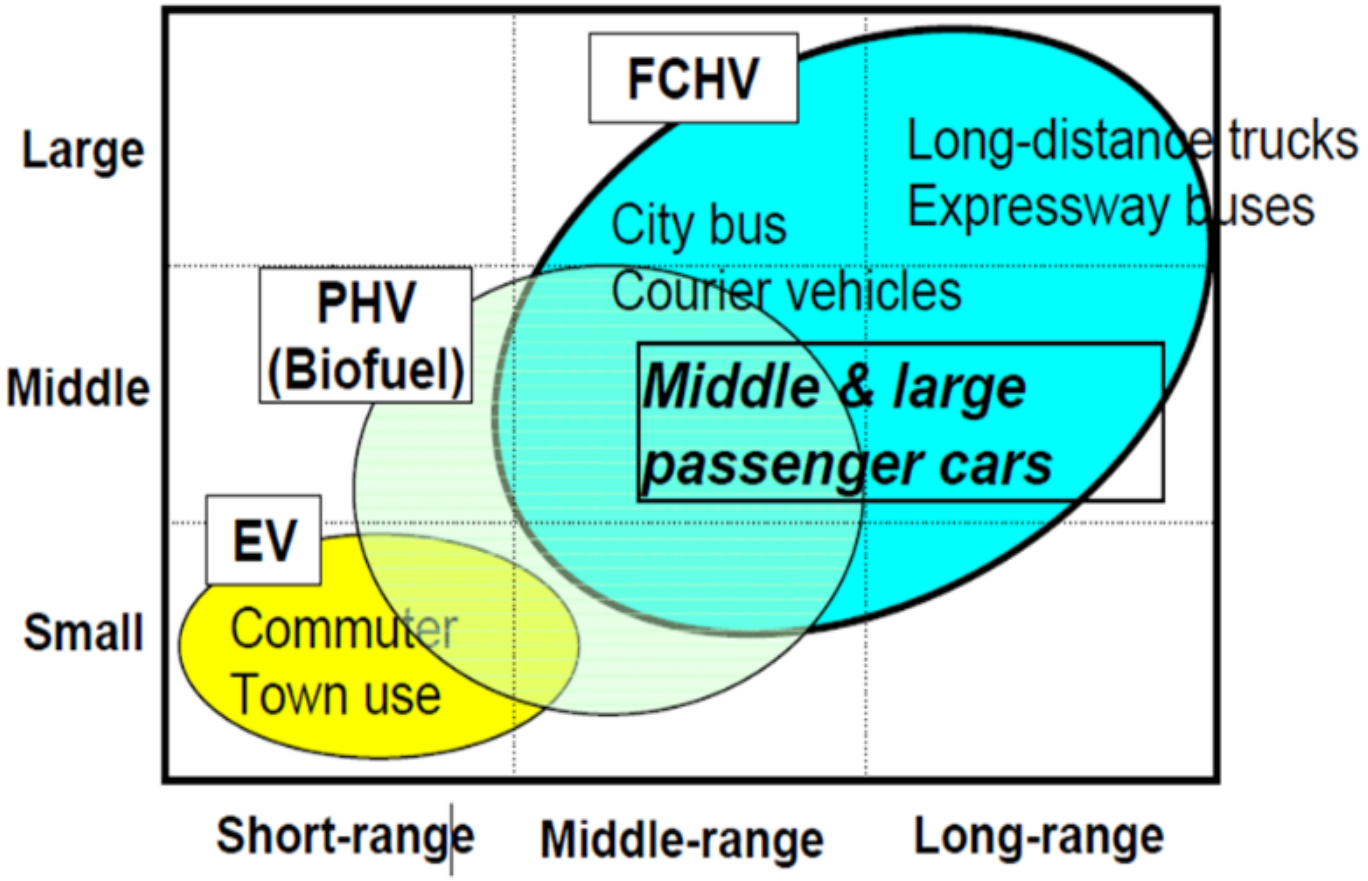
SWEDISH ICT VIKTORIA

NISSAN

Haruhito Mori (Sept 2016):

- Nissan has sold 250,000 battery-electric vehicles. Still difficult to earn money. Main reason: battery cost.
- Hydrogen fuel cell vehicle development continues.
- But no market introduction until OK costs and sufficient hydrogen infrastructure.
- Ethanol fuelled SOFC as range extender for battery electric vehicle niche product only.

POSITIONING FCVS



HOW ARE DIFFERENT SOLUTIONS POSITIONED ON THE MARKET?

For small cars for city use, the choice of batteries or fuel cells depends to some extent on the cost/price.

Fuel cell cars available today are in broad market segments but it is likely that the premium segment will be targeted initially. Motives:

- Better chances to make profits
- Small production volumes are natural
- FCVs require no changes in customer requirements and behaviour

(assuming a covering network of hydrogen stations)

CONCLUSIONS

- Policy still focusing on CO_2 emissions
- Heavy vehicles: In the short and medium term; hydrogen fuel cell powertrains probably only relevant for niche applications. More research needed…
- OEMs are active and invest large resources in hydrogen fuel cell vehicles.
- Among electrification alternatives, rechargeable vehicles dominate in the showrooms and HEVs on the roads.
- With Toyota as an important exception, slow market introduction of fuel cell vehicles appears to be the strategy in 2016.