REAL-WORLD APPLICATIONS OF FUEL CELLS IN HEAVY VEHICLES

Dr. Hans Pohl
Senior researcher
May 2019

Research Institutes of Sweden
RISE VIKTORIA
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Outline

- Introduction
- Case studies:
  - Toyota Project Portal cargo from port
  - Scania Asko deliveries to supermarkets
  - Scania Renova refuse collection
- Other initiatives:
  - Nikola Motor Company
  - Hyundai and H2 Energy 1,600 trucks
- Discussion
- Conclusion
Introduction

- Ambition is to study practical considerations and experiences from fuel cell truck applications
- Timing is difficult, several projects in pipeline but very few fuel cell trucks in operation
- Still, possible to learn something from the projects
- Two large markets not covered (yet):
  - China
  - Fuel cell buses
Toyota Project PORTAL in Los Angeles
Toyota Project PORTAL in Los Angeles

- Heavy Duty Truck (HDT) accounts for 40% of GHG emissions.
- Desire to expand while reducing emissions.
- High impact to disadvantaged communities.
- Clean Air Action Plan:
  - 2030: Terminal Trucks ZEV
  - 2035: All Trucks ZEV
- Requires ZEV solution.
Toyota Project PORTAL in Los Angeles

Specifications
- Class 8 truck chassis
- 2 Mirai fuel cell stacks
- 12 kWh of batteries
- 700 bar storage

Performance
- 670 horsepower
- 1375 lb-ft of torque
- 80,000 lbs GVWR
- 300+ miles of range

670 hp = 500 kW
80,000 lbs = 36,300 kg
300+ miles = 483 km

Beta Truck (July 2018)  Alpha Truck (April 2017)
Toyota Project PORTAL in Los Angeles

**ZANZEFF Project**

- **Demonstration 2019 ~ 2020**
  - 10 Class 8 FC Trucks
  - 2 H2 stations to support HDTs

**CARB Incentive Policy by Phase**

- **Demonstration**
  - Zero/Near Zero-Emis
  - ZEV HDT is still Pre-commercialization

- **Commercialization**
  - $300K rebate
  - HVIP and Low NOx Engine Incentives
  - Zero-Emission Off-Road Voucher Incentive Project

- **Transition**
  - $150K rebate
  - Truck Loan Assistance Program

(Ref.) 3-yr HD Strategy Investment Plan (CARB)

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<thead>
<tr>
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<th>FY18-19</th>
<th>FY19-20</th>
<th>FY20-21</th>
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<td>TTL</td>
<td>$355-640M</td>
<td>$440-755M</td>
<td>$550-955M</td>
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Source: CARB (Low Carbon Transportation Investments and AOIP Funding Plan)
First truck delivered April 23, 2019

Users of trucks:
- Toyota Logistics Services (4)
- United Parcel Services (3)
- Total Transportation Services (2)
- Southern Counties Express (1)
Refuelling stations for trucks

Near Term Station Network

Expansion to a 5 station regional port network

Key locations in the Ports and Inland Empire

Future expansion and scale with multiple partners is needed to support more FC trucks

>1 ton H2/day
Toyota’s experiences

- Drivers very happy
- Truck weight to be reduced
- Refuelling time today up to 40 minutes, to be reduced to less than 15 minutes
- Hydrogen cost today 2 – 3 times diesel, expected to be comparable 2025 – 2030
- TCO competitive towards 2030
- Toyota plans to sell fuel cell systems to others for medium or heavy duty
Asko Regional Distribution Trucks

- Four fuel cell trucks for food deliveries
- Asko in Trondheim project manager and user
- Scania battery-electric truck and some integration
- Hydrogenics fuel cell systems and hydrogen tanks (from Hexagon)
- NEL hydrogen production and refuelling station
ASKO

- Norway’s largest grocery wholesaler
- Ambitious environmental goals
- Homemade electricity: “Approximately 80,000 m² of solar panels and five wind turbines which will account for approximately 85 per cent of ASKO’s energy needs.”

ASKO’s environmental goals by 2020 are:

- to reduce energy consumption by 20 per cent
- to be a self-sufficient provider of clean energy
- to use 100 per cent renewable fuel
Some data

- Specification based on demanding Norwegian drive cycle, 9 times, gives range of ~500 km
- Fuel cells $3 \times 30 = 90$ kW
- Batteries 56 kWh
- Electric machine 290 kW
- Hydrogen 33 kg @350 bar
Hydrogen refuelling station

- Supplier: NEL Hydrogen Solutions
- Electrolyzer with electricity from photovoltaics
- 350 and 700 bar dispensers for cars (700 bar), fork lifts and trucks
- Capacity 300 kg hydrogen per day
ASKO project experiences

- Fork lifts operating on hydrogen
- Refuelling station open
- Trucks, one in Trondheim, soon in commercial operation, three in Södertälje to be shipped soon
- Fuel cells more expensive than expected
- DC/DC converter has caused minor delay, otherwise as planned
- Heating/cooling: five systems(!)
Renova: Refuse collection in Gothenburg

- Renova: pioneer in green vehicle technologies
- BEV truck from Volvo soon in operation:
  - 150 kWh batteries
  - Capacity 4.7 tonnes (standard capacity 5.8 – 6.0 tonnes)
  - Range 80 km (standard range min. 180 km)
- Renova says that the fuel cell truck will not compromise anything, compared to a diesel truck
Preliminary specification

- Truck from Scania with similar specification as for ASKO
- Batteries 56 kWh
- Fuel cell system from PowerCell 90 kW (S3, up to 125 kW)
- Hydrogen tanks from PowerCell/Hexagon; 23 kg @350 bar
- Equipment and integration at JOAB in Gothenburg
Project outline

- Specification of truck currently in its final stage
- Hydrogen station not yet confirmed
- BEV truck(s) delivered from Scania towards the end of 2019
- In operation during 2020:
  - Test 6 months
  - Regular 12 – 18 months
- KTH evaluates

"Scania – hur stavar man det???

(Receptionist at Renova, 2018)
Nikola Motor Company

- Five year old company based in Phoenix, Arizona
- Leasing of long haul trucks including hydrogen for up to 16,000,000 km, maintenance, tires and more (or purchase)
- Nikola will establish 700 hydrogen stations in the USA
- Three truck types for long haul:
  - Electric machines up to ~750 kW
  - Range up to 800 – 1,600 (Tre: 1,200) km
  - Batteries 240 – 320 kWh
  - Hydrogen @700 bar
  - Fuel cell power in first truck demonstrated in April 2019 approximately 200 kW
- Announced in February 2019; also BEV versions of Two and Tre for short haul with batteries 500 kWh, 750 kWh or 1,000 kWh
NEL for hydrogen stations
Bosch for some technologies; digital vision system, steering system, keyless digital key
AVL for the (fuel cell) laboratory
Wabco for brakes
Ryder System for sales and maintenance

Trucks and fuel cells will be developed and manufactured in-house(!?)
Nikola Motor Company – huge ambitions

- Big Nikola World event April 16-17, 2019
- Limited news about fuel cell trucks
- Customers (examples):
  - U.S. Xpress Enterprises
  - Anheuser-Busch (800 Nikola Two)

USD 14 billion in truck pre-orders (not accepting new orders at this time...)
1,600 trucks in Switzerland

- Joint-venture formed with Hyundai and H2 Energy AG: Hyundai Hydrogen Mobility (HHM)
- Hyundai delivers 1,600 heavy-duty fuel cell trucks from 2019 through 2025 to HHM
- HHM leases trucks to H2 Mobility Switzerland Association
- H2 Energy produces hydrogen based on PEM electrolysis and hydropower and distributes it
- NEL will deliver a 2 MW electrolyzer during autumn 2019 (part of 30 MW agreement)
The chicken and the egg

The Swiss Hydrogen Association is coordinating built-up of HRS-network and members will operate fc-truck-fleet

- Association founded May 17th, 2018
  - Jointly operating ~1’600 petrol stations (>50%) and ~2’000 heavy duty trucks in operation
  - Associated to major third party logistic partners
  - Dedicated to jointly establish nationwide refueling station network in Switzerland until 2023
Hyundai truck specification

- 190 kW fuel cell system (2 * 95 from Nexo car)
- 350 kW electric motor
- ~50 kWh batteries? (my guess)
- 33 kg hydrogen @350 bar
- ~400 km range
- Refuelling time ~7 minutes
Cost competitiveness

- TCO similar today thanks to tax exemption
- Leistungsabhängige Schwerverkehrsabgabe (LSVA) tax depends on weight, emission standard and distance traveled
- Example:
  - 40 ton Euro 6: 91.2 CHF/100 km (824 SEK/100 km)
  - ~500,000 SEK per 40 ton truck and year
Discussion – time to market?

- Small-scale demo projects:
  - Scania – Renova
  - Scania – ASKO

- Medium-scale demo projects:
  - Toyota Project Portal
  - Toyota Fuel Cell Buses in Tokyo (100 vehicles)

- Large-scale market introduction ambitions:
  - Hyundai & H2 Energy
  - Nikola Motor Company
Discussion – hydrogen supply

- Vehicles and hydrogen stations in the same project
  - Scania – ASKO (350 bar)
  - Hyundai and H2 Energy (350 bar)
  - Nikola Motor Company (700 bar t b c)

- Vehicles and hydrogen mainly in separate projects
  - Toyota Project Portal (700 bar)
  - Scania – Renova (350 bar)
## Discussion – powertrain configuration

<table>
<thead>
<tr>
<th>Project</th>
<th>Fuel cells</th>
<th>Batteries</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Toyota trucks and buses</td>
<td>2 * Mirai fuel cells</td>
<td>Small hybrid power</td>
<td>Car fuel cells</td>
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<tr>
<td>Hyundai</td>
<td>2 * Nexo fuel cells</td>
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<td>Scania trucks</td>
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<td>Nikola MC</td>
<td>~200 kW fuel cells (tbc.)</td>
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<td>Heavy-duty fuel cells (tbc.)</td>
</tr>
</tbody>
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Synergies heavy and light duty vehicles

HD Scale -> Fuel Demand - H2 Cost -> FC Volume - FC Stack Cost -> LD Scale

H2 Society
Concluding summary

- Rapidly growing interest for fuel cell trucks
- Huge market potential
- Limited worries about technology
- Cost competitiveness depends on:
  - Hydrogen cost
  - Incentives and regulations
- Still an early stage - it would be interesting to do the same study in one or two years
THANK YOU!

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Comparison fuel cell and battery trucks

- **In a few minutes**
  - **Short haul**
    - Still charging
    - Light Duty Truck
    - Pay-load Low
  - **Long haul**
    - Fully charged
    - Heavy Duty Truck
    - Pay-load High

- **EV Truck**
  - less loads

- **FCEV Truck**
  - more loads
Toyota Project PORTAL in Los Angeles

16 ton