Grid to Mobility Demonstrator

Infrastructure energy demand for battery and hydrogen fuel cell vehicles

Yorick Ligen, EPFL
LCA of Mobility Solutions – DF66
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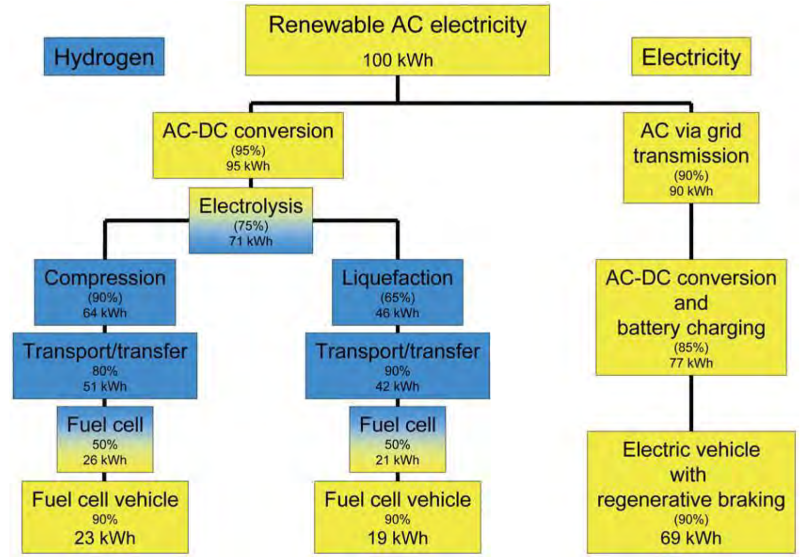
BEV/FCEV comparison

- Efficient use of renewable electricity

$$Efficiency = {}^{Driving\ range}/_{Energy\ input}$$

- Ratio BEV/FCEV efficiency ?
  - Up to 3.6 (comparing energy not distance, Bossel 2006)
  - As low as 1.5 (400km range, Thomas 2009)
  - 1.4 , 1.6 (Well to Tank only, Li 2016, Campanari 2009)



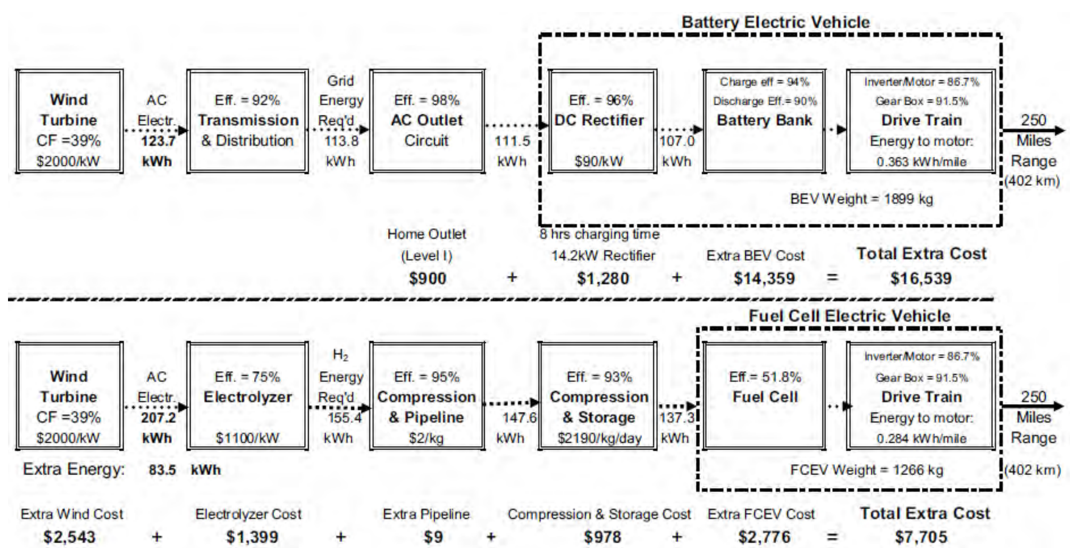
Sources:

U. Bossel, "Does a Hydrogen Economy Make Sense?," *Proc. IEEE*, vol. 94, no. 10, pp. 1826–1837, Oct. 2006.

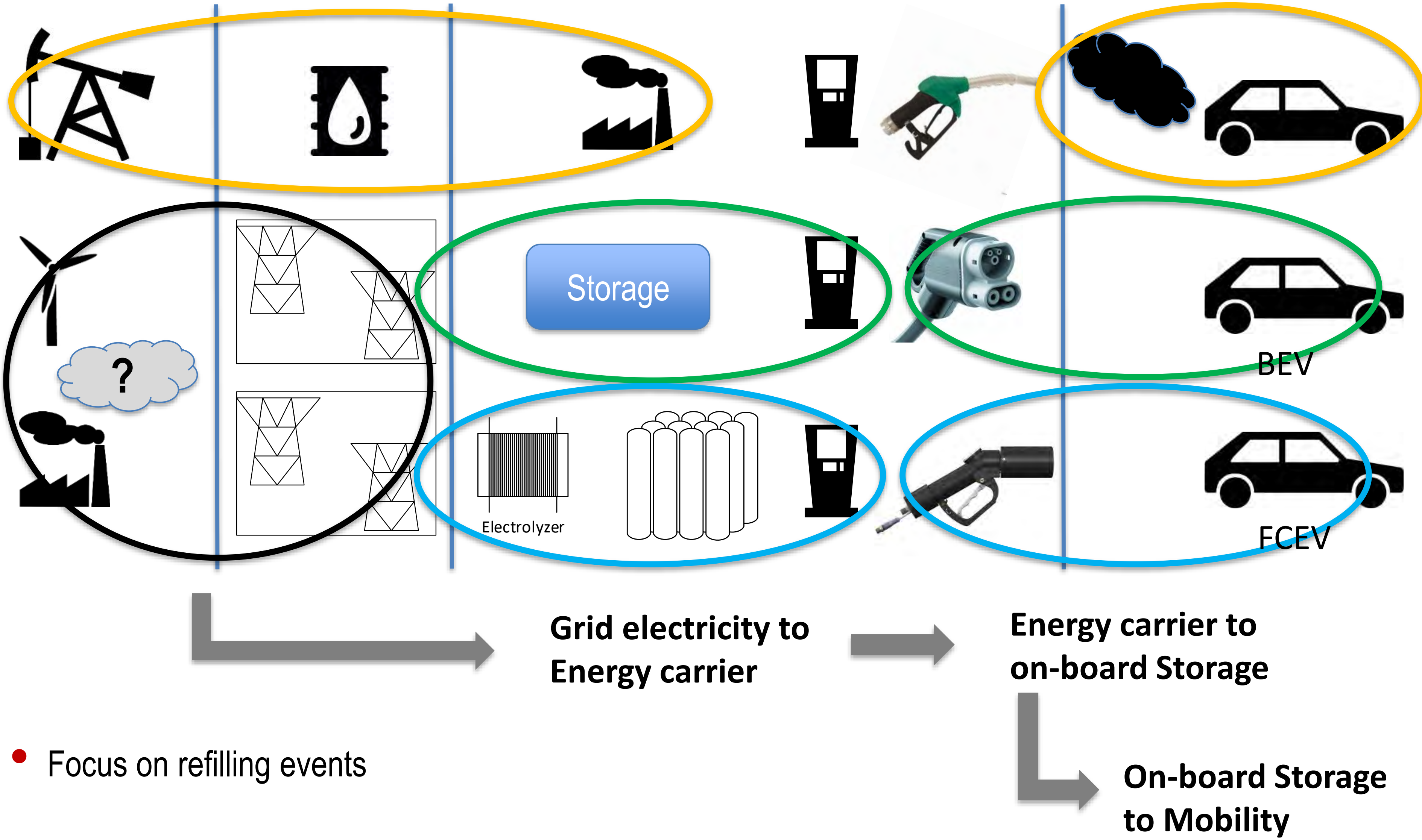
C. E. Thomas, "Fuel cell and battery electric vehicles compared," *Int. J. Hydrog. Energy*, vol. 34, no. 15, pp. 6005–6020, Aug. 2009.

M. Li, X. Zhang, and G. Li, "A comparative assessment of battery and fuel cell electric vehicles using a well-to-wheel analysis," *Energy*, vol. 94, pp. 693–704, Jan. 2016.

S. Campanari, G. Manzolini, and F. Garcia de la Iglesia, "Energy analysis of electric vehicles using batteries or fuel cells through well-to-wheel driving cycle simulations," *Journal of Power Sources*, vol. 186, no. 2, pp. 464–477, Jan. 2009.



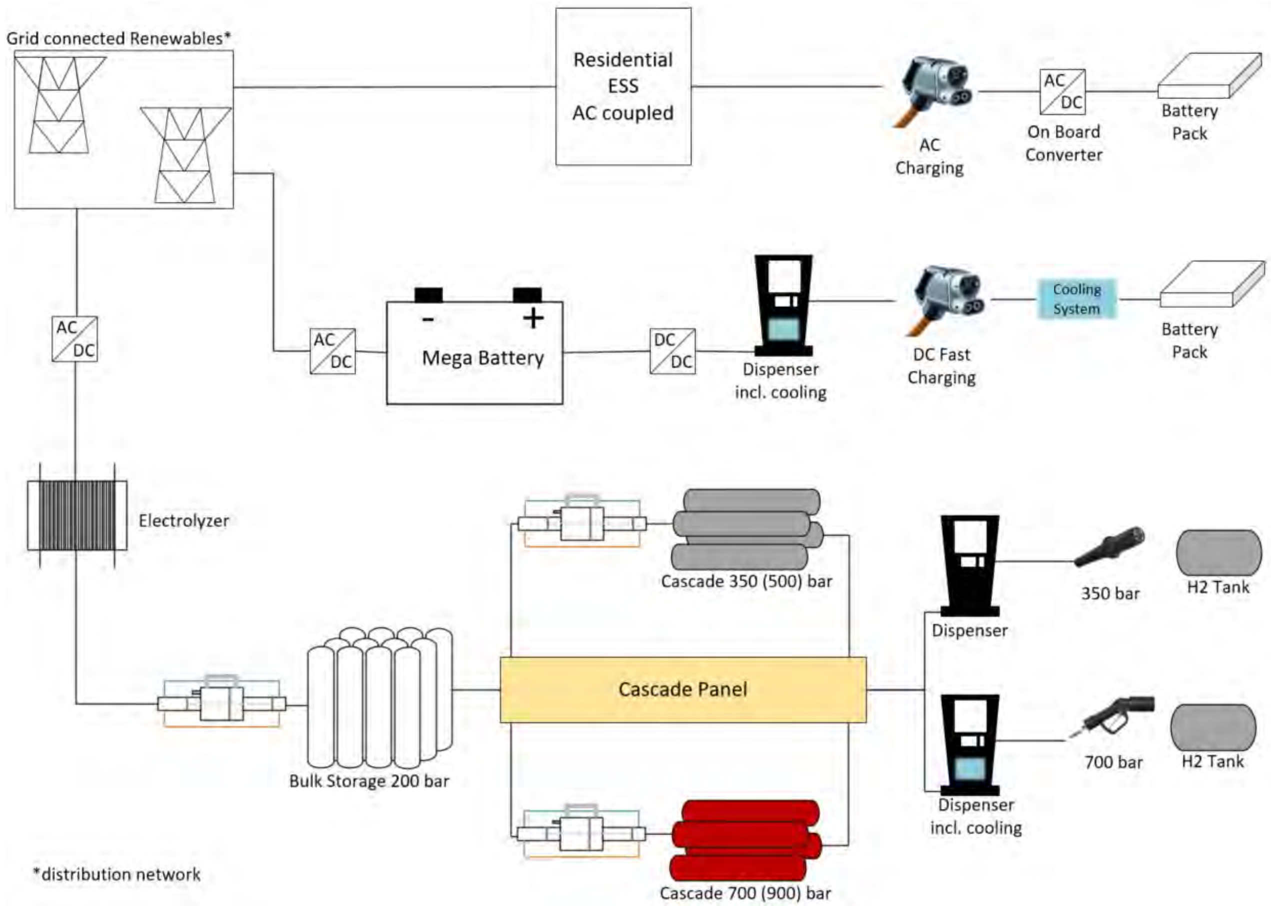
Well to Tank and Tank to Wheel vs Grid to Mobility



- Focus on refilling events

Grid To Mobility Assessment

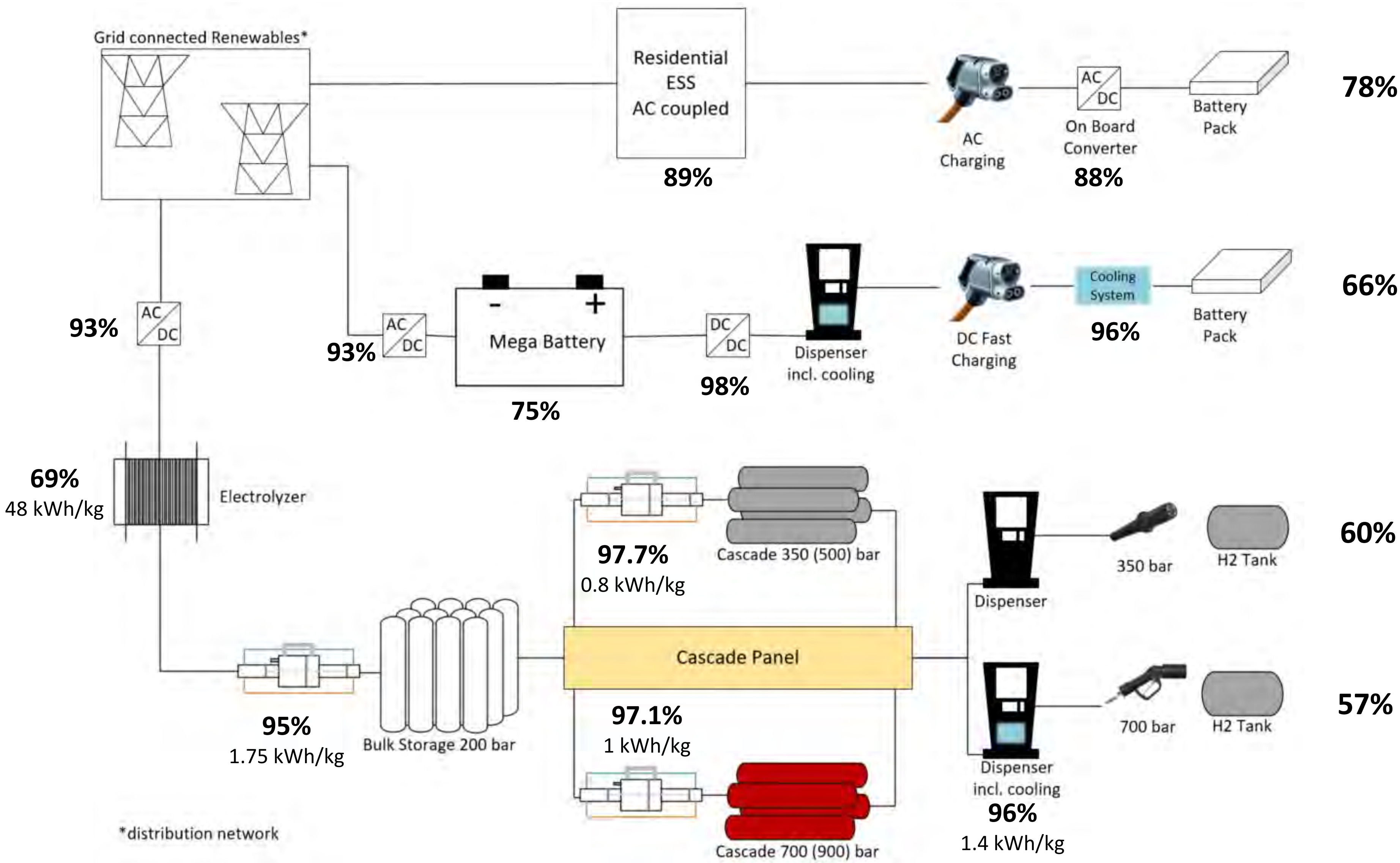
Vehicle type	BEV		FCEV	ICEV
Charging mode	Home outlet	Fast charger	HRS	Conventional refuelling station
Energy carrier flow rate	2 to 6 kW	50 kW up to 150 kW	Up to 2 kg·min^{-1}	35 L·min^{-1}
Autonomy flow rate	0.2 – 0.6 km·min^{-1}	3-5 km·min^{-1} (50 kW) 9-15 km·min^{-1}(150 kW)	160-220 km·min^{-1}	370-430 km·min^{-1}



Holistic overview covering multiple charging modes and EV types within a consistent scope and methodology

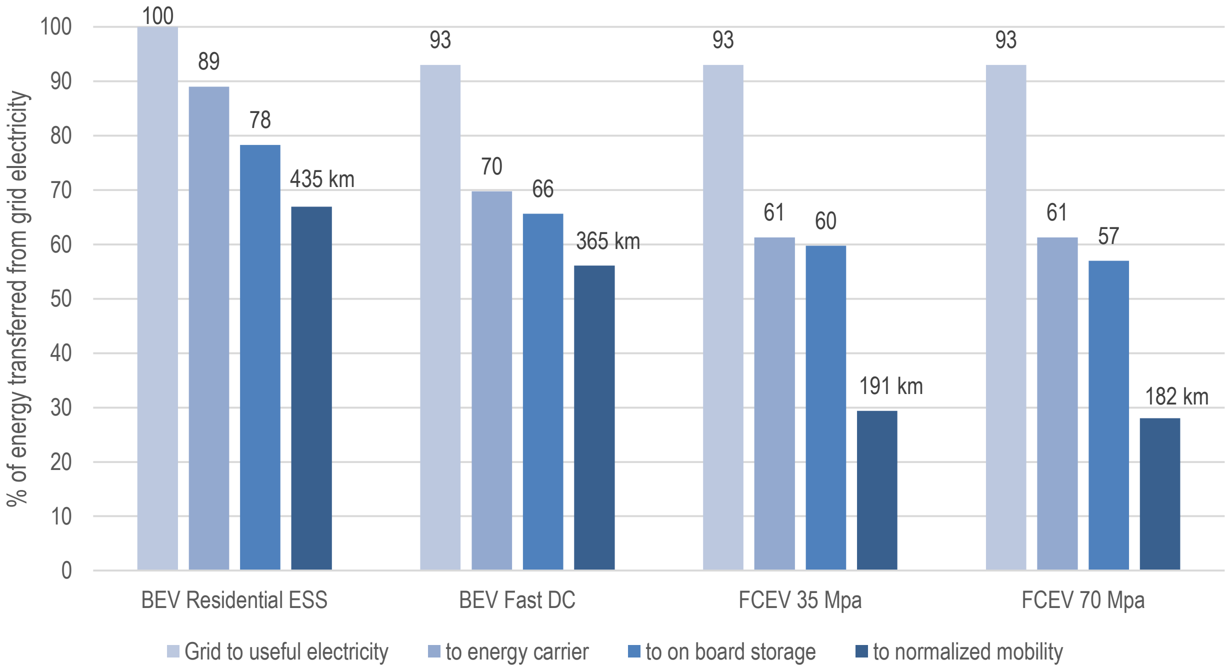
Systematic quantification of all conversion steps occuring from grid to on-board storage

Grid To Mobility Assessment - Infrastructure



Grid To Mobility Assessment

Step	BEVs Slow	BEVs Fast	FCEVs 35MPa and 70MPa
Grid to useful electricity	No conversion required	AC/DC conversion	AC/DC conversion
Useful electricity to energy carrier	Storage in stationary battery AC coupled	Storage in stationary battery DC coupled	Variable load electrolysis Purification 20 MPa compression
Energy carrier to on-board storage	On-board AC/DC conversion	Dispenser DC/DC conversion Battery Thermal Management	50 MPa cascade compression 90 MPa cascade compression –40°C precooling Dispenser Vent
On-board storage to mobility	EPA combined cycle 18 kWh/100km	EPA combined cycle 18 kWh/100km	EPA combined cycle 0.94 kg H_2/100km

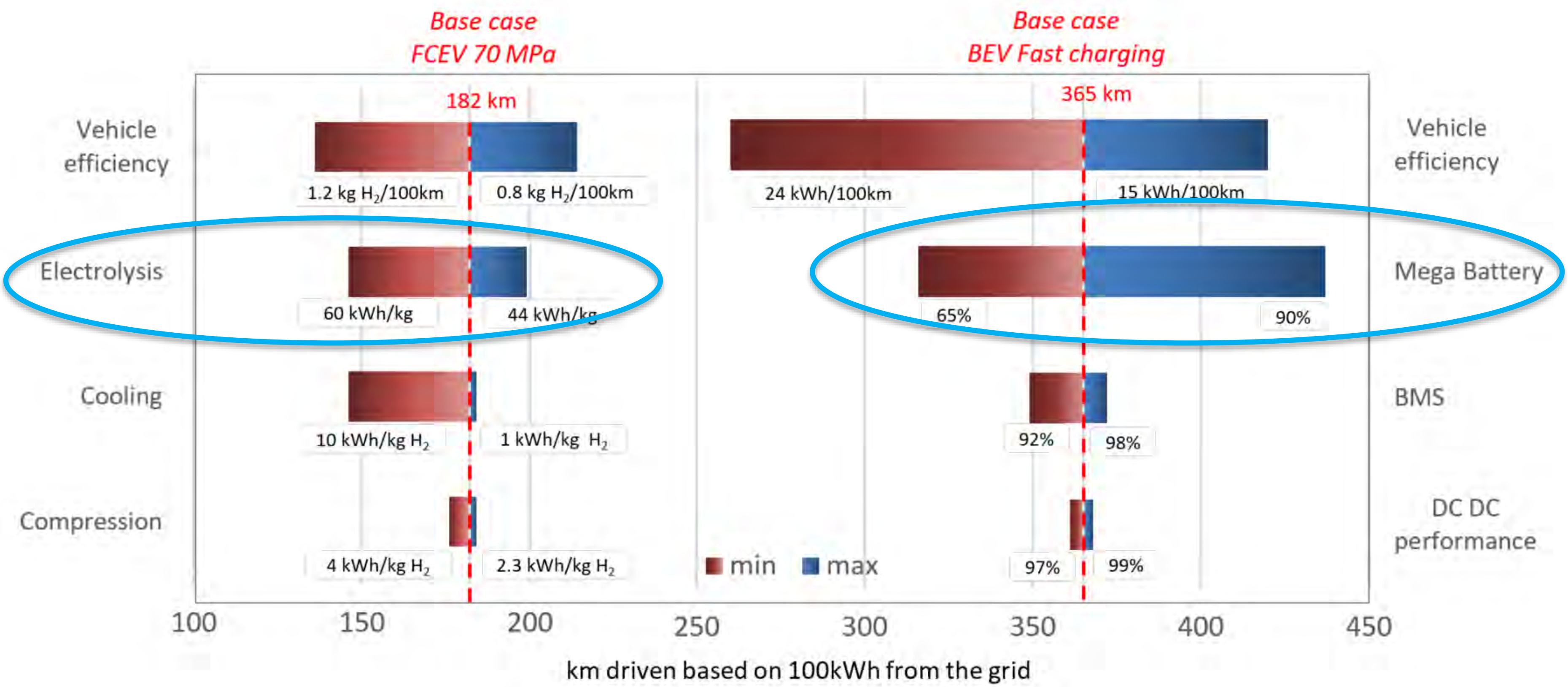


Market data and test bench measurements (Idaho National Laboratory, Advanced Vehicle Testing, EPA, Linde, UC Irvine)

Ratio BEV/FCEV :

1.9 to 2.4

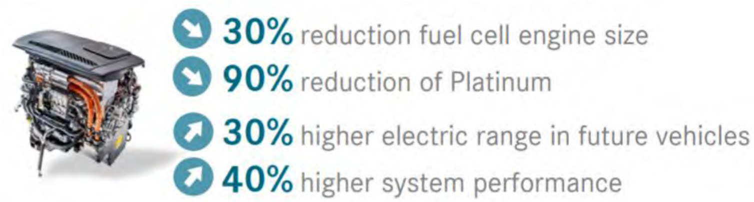
Grid To Mobility Assessment - Sensitivity



- Other effects:
  - Winter conditions: +5.3 kWh/100 km (0° C) and +15.3 kWh/100 km (-20° C) energy consumption compared to driving conditions at 20° C (Karlsson, 2017)
  - Vehicle weight: Tesla Model S 2017 60D versus 100D : 17.1 versus 18.6 kWh/100km (www.fueleconomy.gov)

Technology Progress – Vehicle side

- FCEV
  - Hyundai (ix35 Fuel Cell 2013 // FE Concept 2018)
    - 55.3% → 60% fuel cell efficiency (+9% in 5 years)
  - Toyota (FCHV-adv 2008 // Mirai 2015)
    - 1.4 kW/L & 0.83 kW/kg → 3.1 kW/L & 2.0 kW/kg
  - Mercedes (B Class 2010 // GLC Fuel Cell 2017)



- BEV
  - Tesla Model S AWD: 2014 // 2017
    - 85 kWh & 21.8 kWh/100km // 100 kWh &18.6 kWh/100km (EPA)
  - Nissan Leaf: 2011 // 2016
    - 24kWh & 20.5 kWh/100km // 30kWh & 17.4 kWh/100km (EPA)
  - Renault Zoé: 2010 (Q210) // 2017 (R240)
    - 22 kWh & 14 kWh/100km // 41 kWh & 12.8 kWh/100km (NEDC)
  - Infrastructure: 50 kW → 150 kW → 350 kW (water cooled cables)

ÉCOLE POLYTECHNIQUE
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Thank you for your attention

Yorick Ligen

Ing., PhD student

yorick.ligen@epfl.ch – www.electromobilis.ch

evs30

October 9-11, 2017

Co-located with BATTERY+STORAGE and f-cell

Session: Renewable energy and electric mobility – synergies and obstacles

11.10.2017, 11:30 – 11:50

Useful mobility service derived from renewable electricity: a comparison between battery electric and hydrogen fuel cell vehicles infrastructure