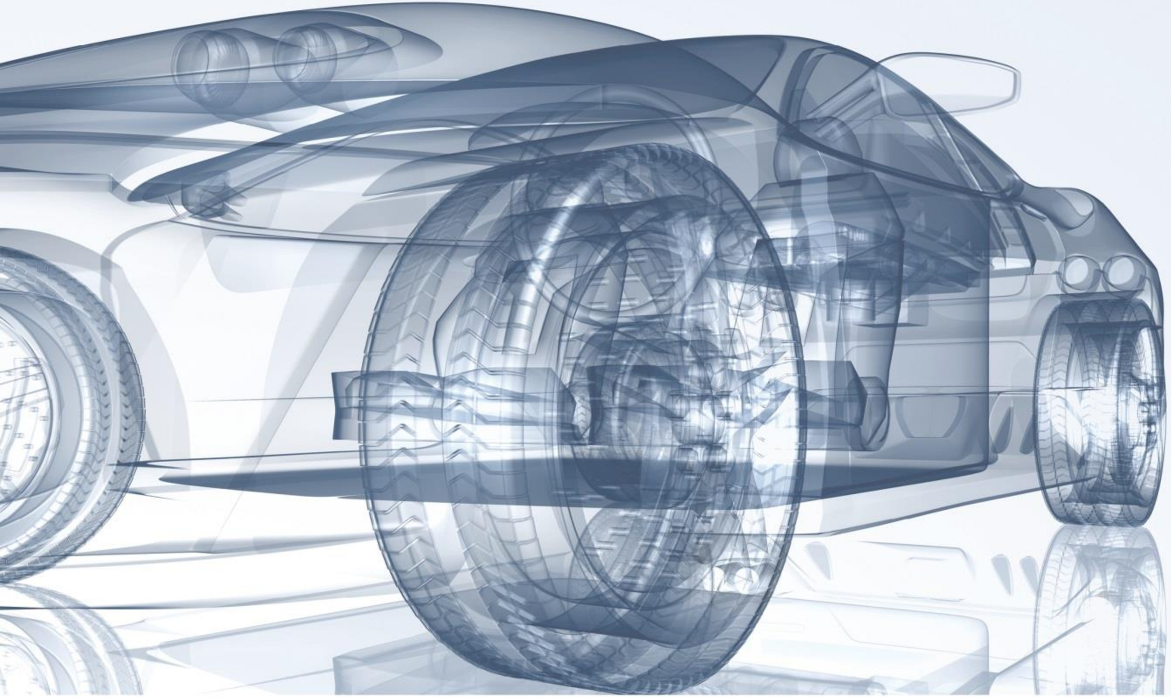
evs 30



The 30th International Electric Vehicle Symposium & Exhibition

October 9–11, 2017
Messe Stuttgart, Germany

www.evs30.org

Infrastructure comparison for battery and hydrogen fuel cell vehicles

Energy footprint from Grid to Mobility

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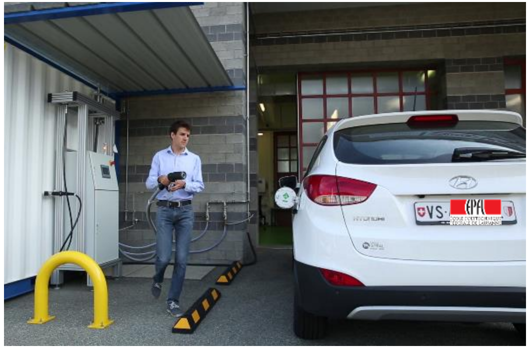
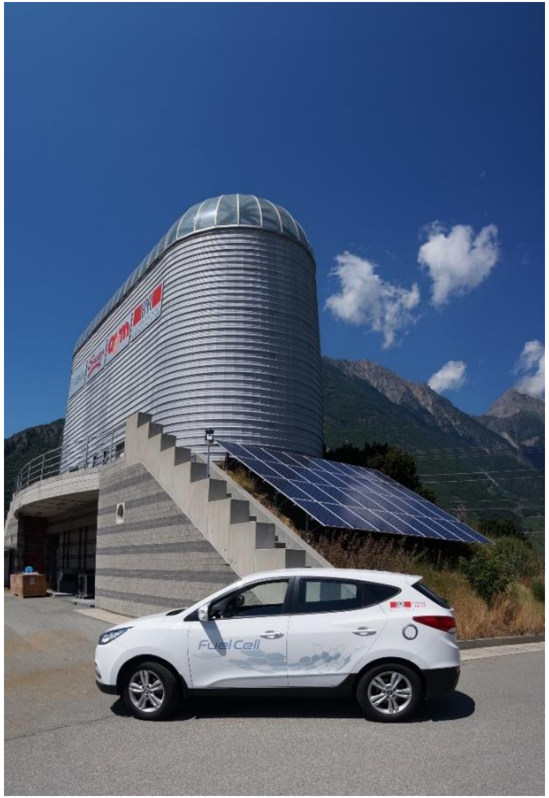
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

LEPA Laboratoire d'Electrochimie Physique & Analytique

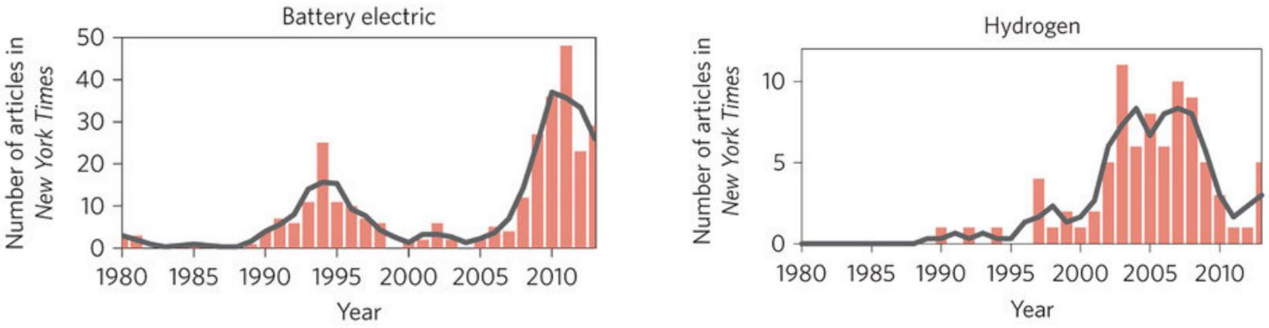


Agenda

- ***Electric mobility and renewable energy sources***
- ***Grid to mobility conversion pathways***
- ***EV comparison results***



3rd wave of electric mobility



Media attention for alternative fuel vehicle technology for 1980-2013
N. Melton, J. Axsen, and D. Sperling, “Moving beyond alternative fuel hype to decarbonize transportation,” *Nature Energy*, vol. 1, p. 16013, Feb. 2016.

Battery or Hydrogen ?

«Does a Hydrogen economy make sense ? Never.»
Ulf Bossel, 2006

«Hydrogen cars are incredibly dumb»
Elon Musk, 2015

«We don't see any battery technology that would allow us to give customers a comparable driving experience»
Toyota Executive, 2015

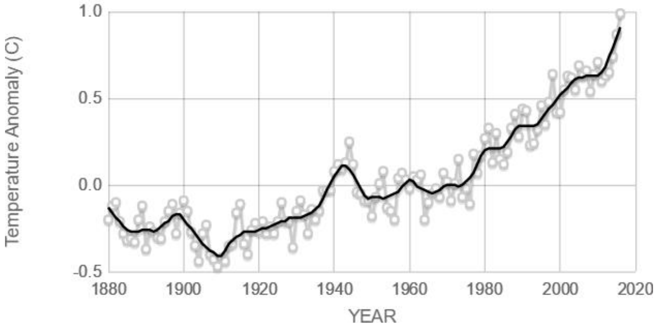
«Electric vehicles powered by fuel cells offer the best conditions»
Alexander Dobrindt, German Minister of Transport, 2015

Standardization

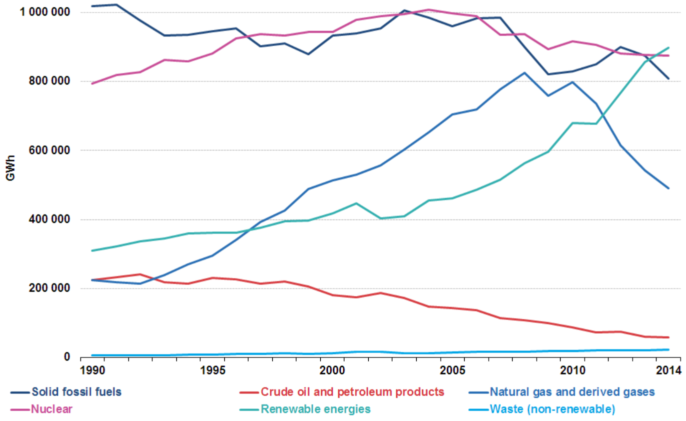
- SAE J1772 incorporated DC charging in 2012
- SAE J2601 70 Mpa refueling protocoll, first version in 2010

Full benefits of electric mobility

- CO2 emission reduction (Global warming issue)
- Local pollution reduction (Air quality and noise issues)
- Energy independence and **renewable electricity integration**



Source: climate.nasa.gov



Source: www.ec.europa.eu/eurostat

Role of a refilling station

- Provide range to customers, deliver a “mobility service“
  - Storing and distributing energy carrier

Vehicle	BEV		FCEV	ICEV
Charging mode	Home outlet (16-32 A)	Fast charger	HRS	Conventional refilling station
Energy carrier flowrate	2 to 6 kW	50 kW up to 150 kW	Up to 2 kg·min^{-1}	35 L·min^{-1}
Autonomy flowrate	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}

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Smart charging

Smart station

Scaling infrastructure

- 33 000 km of autonomy delivered (gasoline only) per station per day (double on highways) in CH

→ @ 3-5 km·min^{-1} (50 kW) → 10 plugs occupied all day long. Smart charging → Smart station

Geiselwind, first HRS on the Autobahn and multistall fast charger

Sources:
Union Pétrolière Suisse, Rapport annuel 2015
Wasserstoff Infrastruktur für eine nachhaltige Mobilität, e-mobil BW 2013

Scaling infrastructure

- 33 000 km of autonomy delivered (gasoline only) per station per day (double on highways) in CH

→ 330 kg of H_2 per day

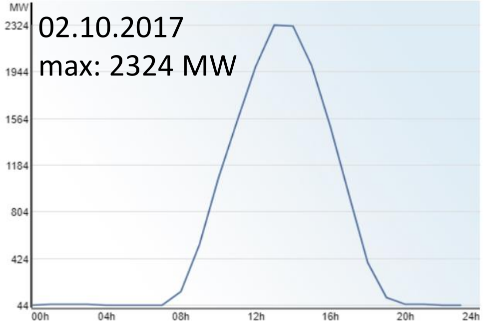
Typ M – Medium
2 Zapfpunkte
6 Betankungen pro Position und Stunde, 2 back-to-back-Betankung[4] pro Position; max. 5 min Wartezeit
Stationäre Lösung
Option zur modularen Erweiterung
Durchschn. 60 Betankungen pro Tag (336 kg/d)
Maximalumsatz 420 kg H_2 pro Tag

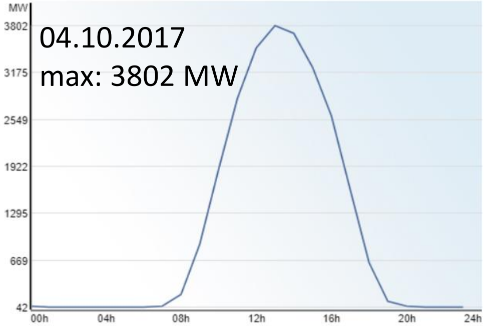
Sources:
Union Pétrolière Suisse, Rapport annuel 2015
Wasserstoff Infrastruktur für eine nachhaltige Mobilität, e-mobil BW 2013

Electric mobility and renewable energy sources

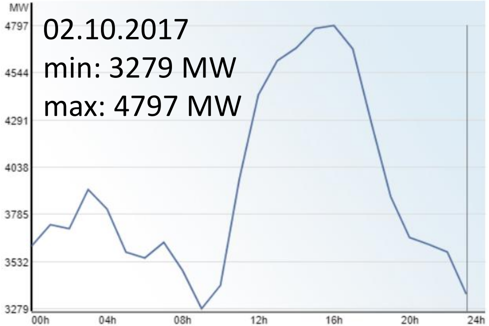
Matching production and consumption profiles

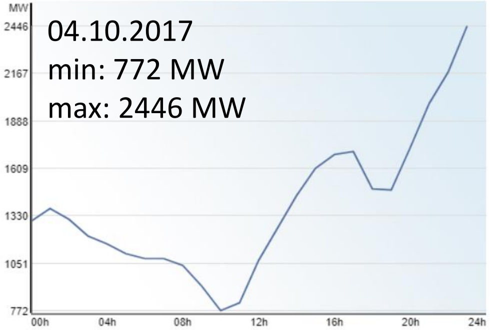
Solar PV





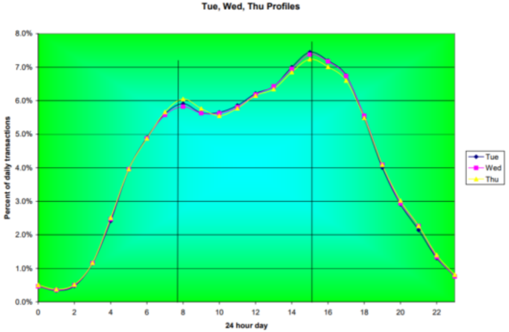
Wind



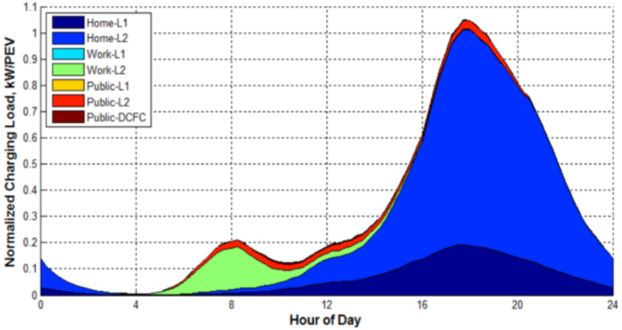


Fueling profiles

Gasoline



BEVs



Sources:
Hydrogen Delivery Infrastructure Options Analysis, DOE, 2014
National Plug-In Electric Vehicle Infrastructure Analysis, DOE 2017

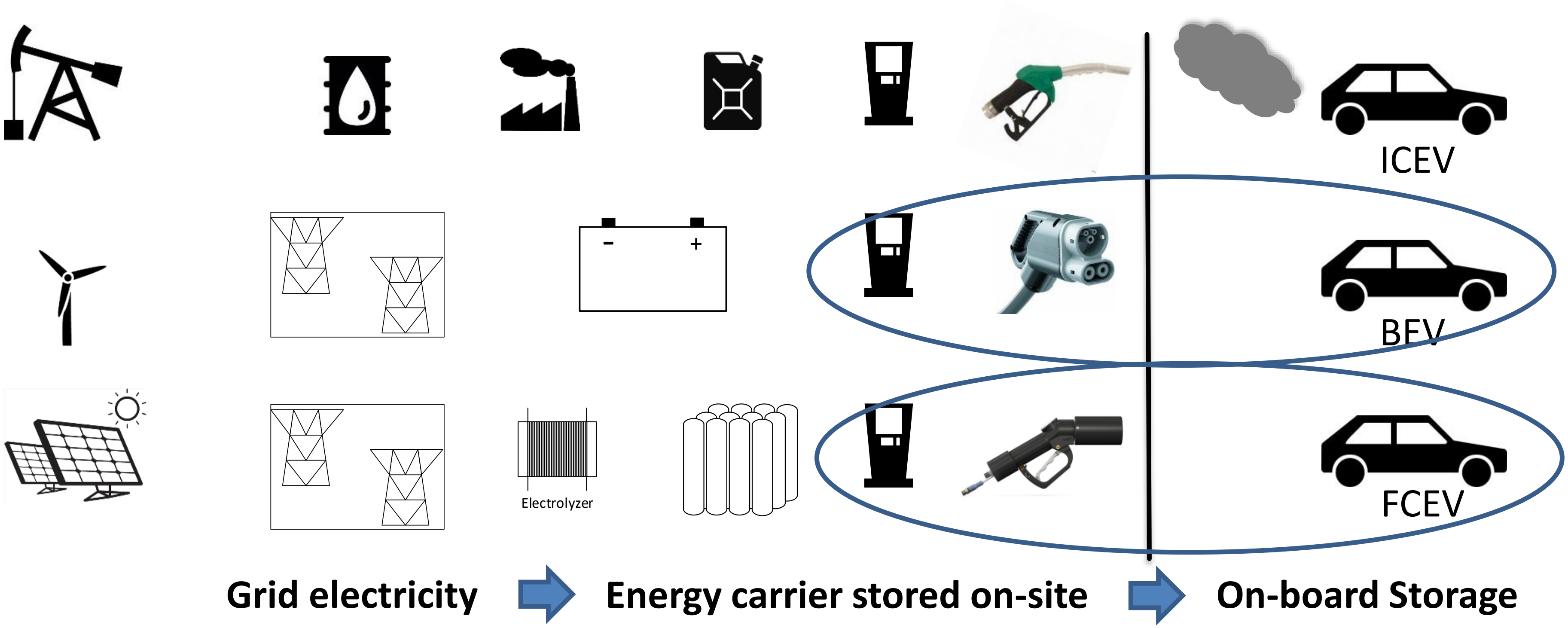
Electric mobility and renewable energy sources

Matching production and consumption profiles: energy buffers

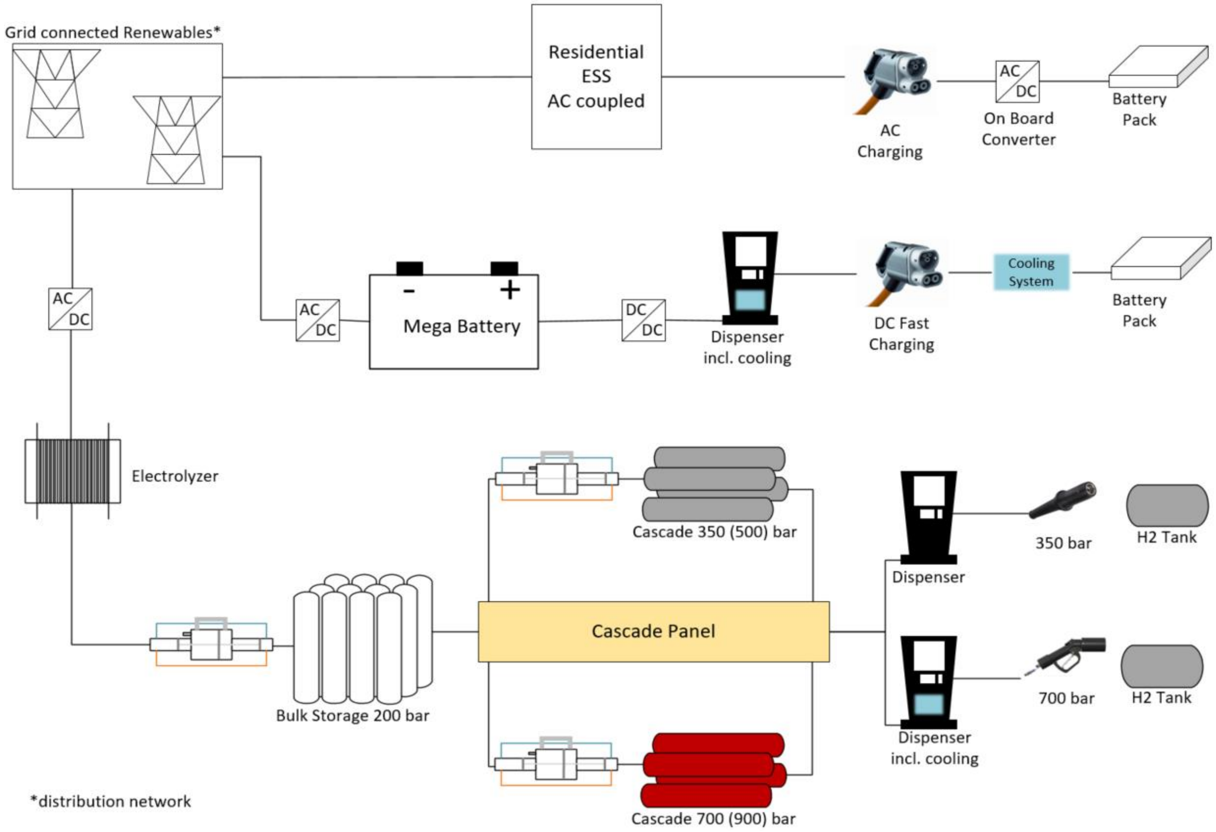
- FCEVs: variable load electrolysis
- BEVs: mega batteries and smart charging

- Grid services as side benefits:
  - Load levelling
  - Peak shaving
  - Arbitrage
  - Increase autoconsumption

Refilling events: A significant role in energy efficiency



Grid to mobility conversion pathways



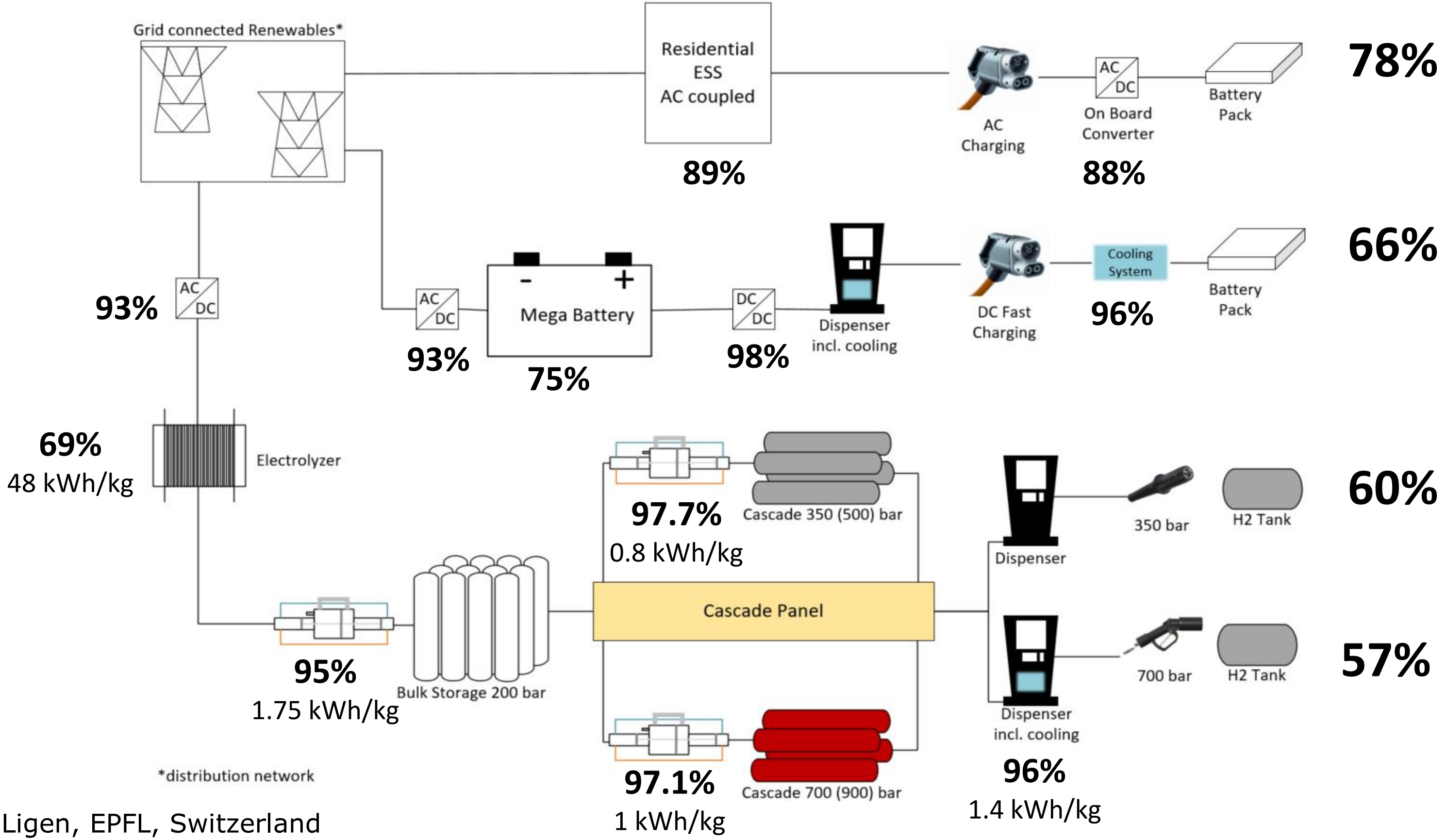
Empirical data and technical reviews:
INL Vehicle Testing, CEP, NREL, UC Irvine…

Datasheets:
LG Chem, Linde, Tesla Powerwall, EVTEC…

How to assess the energetic performance of refilling stations ?

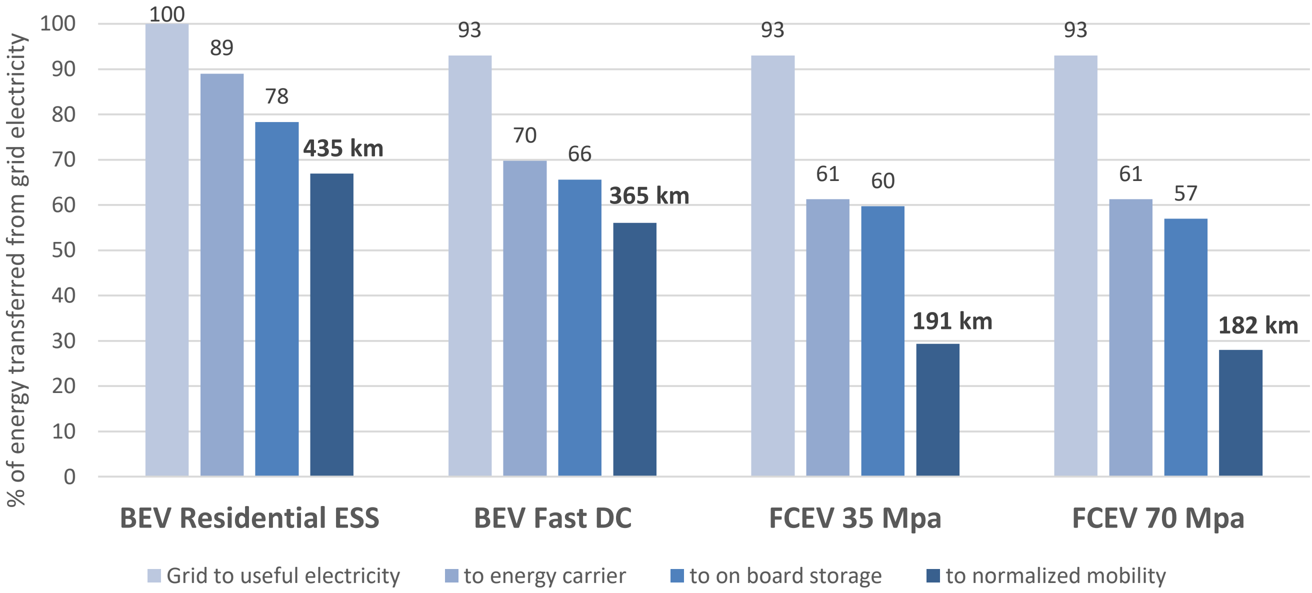
- Driver perspective : kWh/100km
- Operator perspective : km/100kWh, energy cost to deliver a mobility service

Grid to mobility conversion pathways



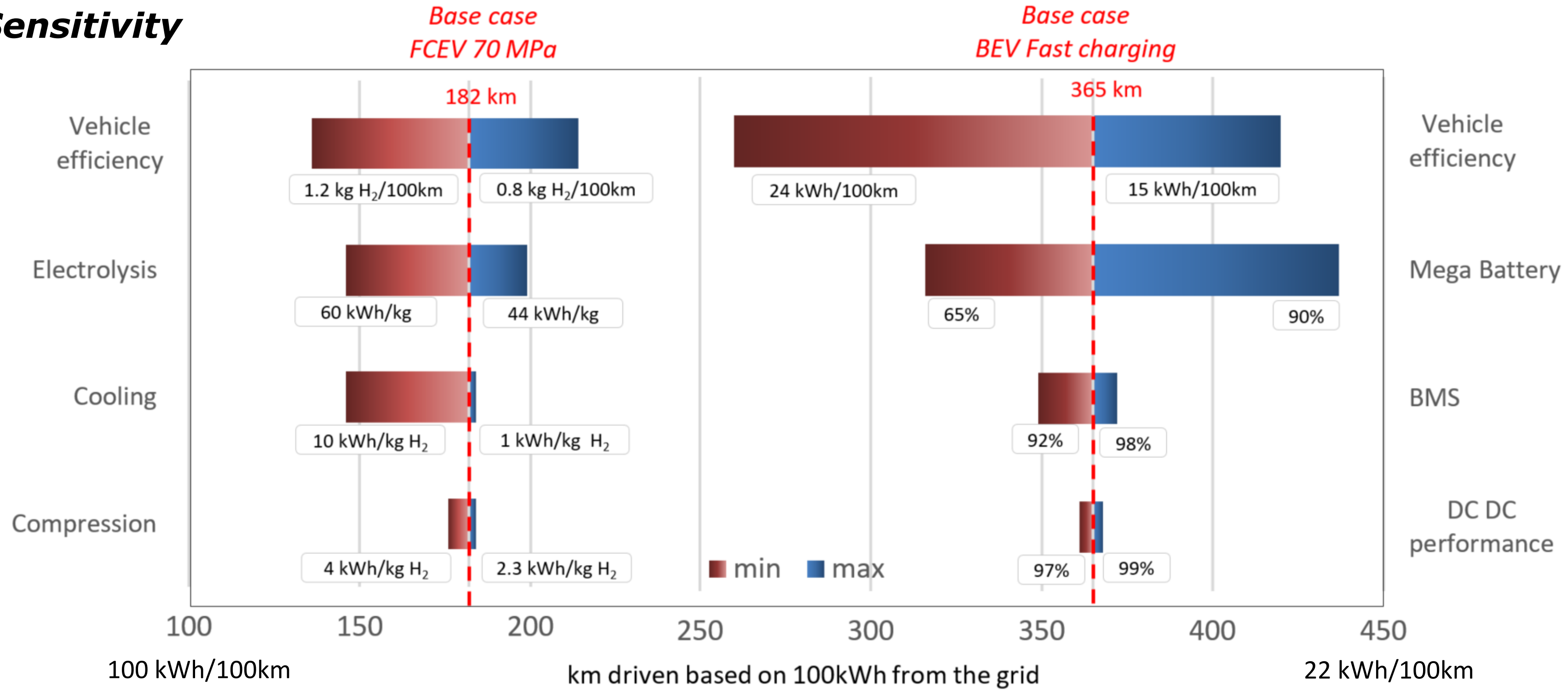
EV comparison results

From on board storage	18 kWh/100km	18 kWh/100km	31 kWh/100km	31 kWh/100km
From on site storage	20 kWh/100km	19 kWh/100km	32 kWh/100km	33 kWh/100km
From the Grid	23 kWh/100km	27 kWh/100km	52 kWh/100km	55 kWh/100km



EV comparison results

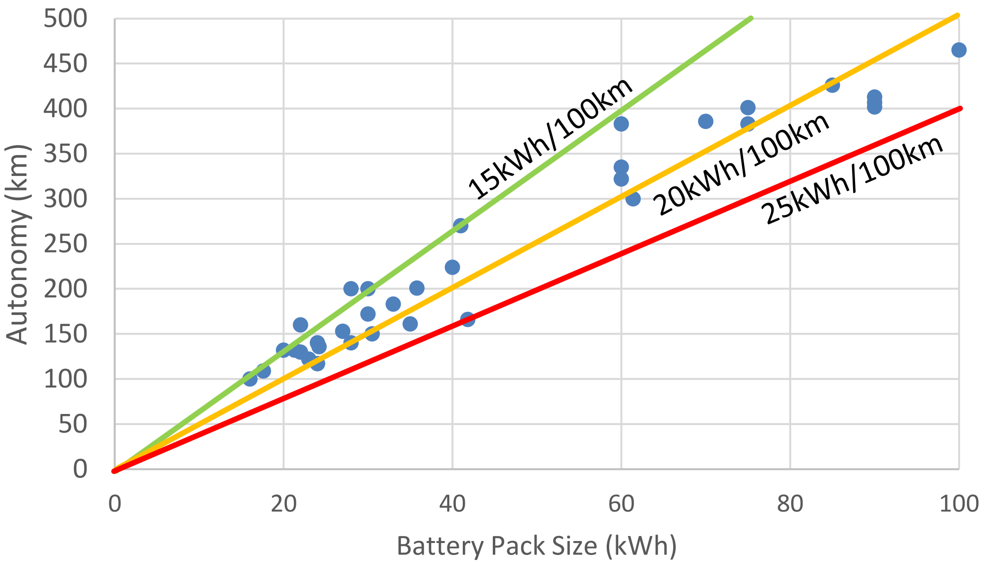
Sensitivity



EV comparison results

Discussion

- Range versus efficiency, winter conditions
- For FCEVs: limited set of vehicles on the market, not the same segment coverage



Temperature adjustment factor for energy consumption of BEVs

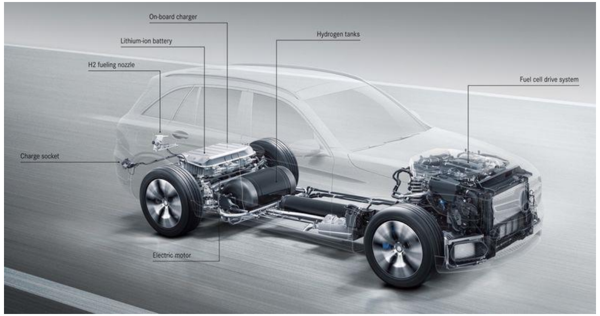
Trip Avg Speed, mph	Ambient Temperature, °C												
	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40
2.5	203%	193%	186%	178%	167%	154%	141%	132%	129%	136%	153%	180%	213%
7.5	177%	168%	162%	155%	146%	135%	123%	115%	113%	119%	134%	157%	186%
12.5	163%	155%	149%	143%	134%	124%	114%	106%	104%	109%	123%	145%	171%
17.5	146%	139%	134%	128%	121%	111%	102%	95%	93%	98%	110%	130%	153%
22.5	135%	128%	123%	118%	111%	102%	94%	88%	86%	90%	102%	120%	141%
27.5	132%	125%	120%	115%	108%	100%	92%	85%	84%	88%	99%	117%	138%
32.5	135%	128%	123%	118%	111%	102%	94%	88%	86%	90%	102%	120%	141%
37.5	141%	134%	129%	124%	116%	107%	98%	92%	90%	94%	106%	125%	147%
42.5	147%	139%	134%	129%	121%	111%	102%	95%	93%	98%	111%	130%	154%
47.5	155%	147%	142%	136%	128%	118%	108%	101%	99%	104%	117%	138%	163%
52.5	164%	156%	150%	144%	135%	125%	114%	107%	104%	110%	124%	146%	172%
57.5	168%	159%	154%	147%	139%	128%	117%	109%	107%	113%	127%	149%	176%
62.5	182%	172%	166%	159%	150%	138%	126%	118%	115%	121%	137%	161%	190%

Sources:
National Plug-In Electric Vehicle Infrastructure Analysis, DOE 2017
U.S. Environmental Protection Agency, www.fueleconomy.gov

To be continued...

- 350 kW: water cooled cables
- Charging patterns home/fast chargers
- MW scale batteries, MW scale electrolysers:
  centralized or decentralized ?
- FCEV technology improvements
  - 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)

30% reduction fuel cell engine size
90% reduction of Platinum
30% higher electric range in future vehicles
40% higher system performance



Conclusion

Significant role of infrastructure in the overall picture

- On-site energy carrier production and storage (electrolysis, mega batteries)
- Energy carrier conditionning and distribution (compression, power electronics, cooling)

On-board components play an active role in charging efficiency

- Not assessed with driving cycles and lack of transparency from car manufacturers

How to consider non mobility services of electric mobility

- Provided by the vehicles (heat recovery in FCEVs)
- Or by the stations (heat recovery from compression, grid services)
- Optimization target: Efficiency ? Flexibility ? Costs ? Rare material consumption ?

Acknowledgments

Swiss Federal Office for Energy, City of Martigny, Prof. H. Girault, Dr. H. Vrubel, Dr. V. Amstutz