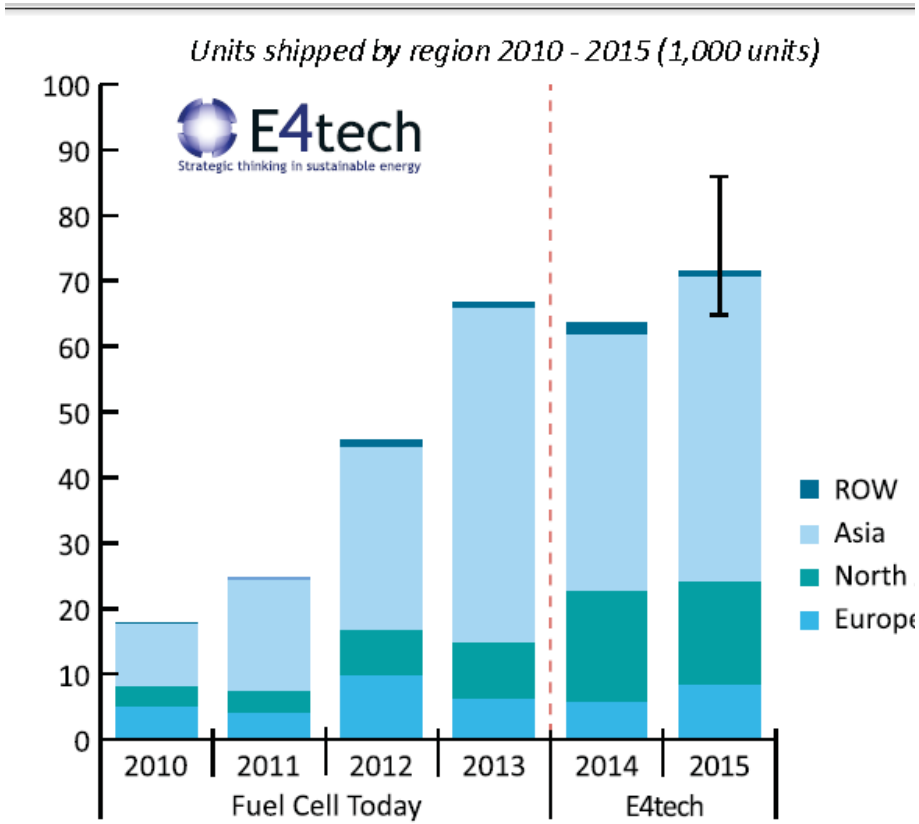
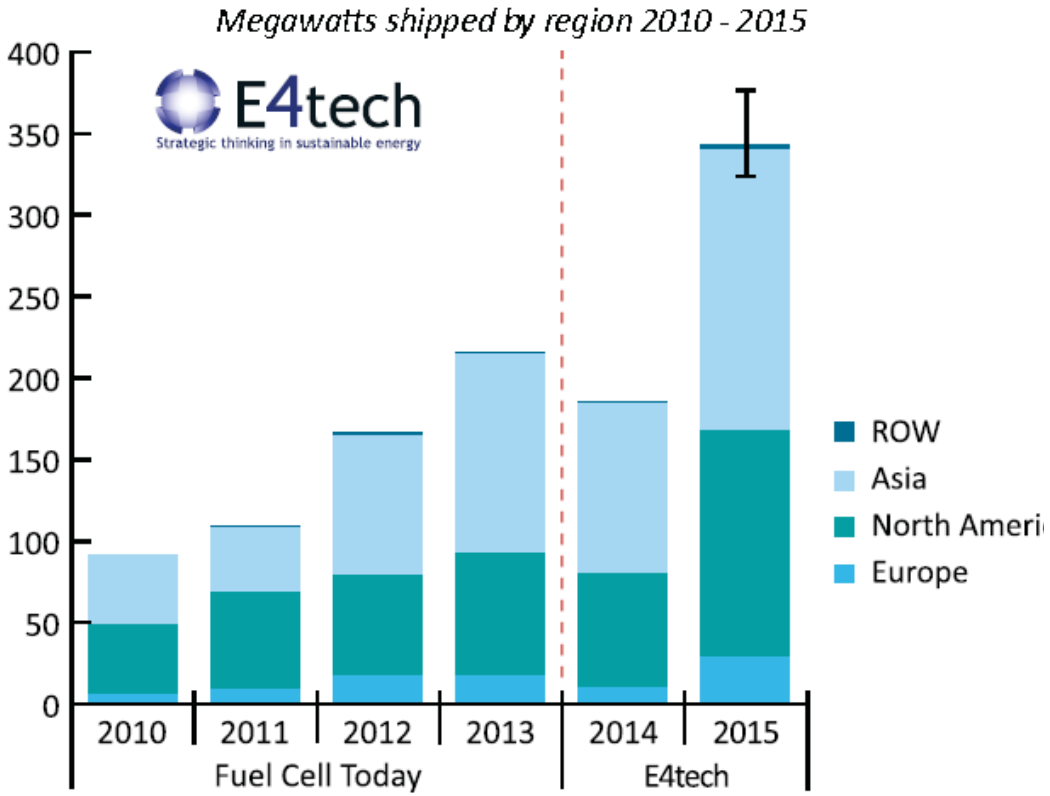
Summary of the Fuel Cell market situation

Fuel Cell Shipment 2010 - 2015





Deliveries stable and increasing in 2015.

More fuel cells for less government money but still large subsidies

1000 FCV 100 MWe

Fuel Cell Cars and vehicles 2015

- FCV cars roughly twice as many as before
- Toyota Mirai roll-out so far a success 700 produced in 2015, that is 70 MWe of PEM fuel cells more than all over PEFC fuel cells produced in 2015, waiting list today three years in Japan.
- The New Honda Clarity follows in 2016 showcased in Tokyo Motor Show 2015 about 200 deliveries expected in 2016
- Hyundai continues to deliver new design planned for 2018
- Daimler, BMW, Nissan and GM coming but no timing confirmed yet

- Range-extender of BEV is also coming:
  - Renault-Kangoo 5 kWe fuel cell La Poste
  - Swiss Hydrogen Fiat 500
  - PowerCell Volvo C30
- Infrastructure is today a problem.
  Some stations change from electrolysers to trucked-in hydrogen for technical and financial reasons

Toyota Mirai 700 produced in 2015
Open for sale in California and it is being offered in selected European markets - the UK, Germany and Denmark.

The new Honda Clarity starts delivery in Japan 2016

Hyundai Tucson continues new model in 2018

Hydrogen infrastructure

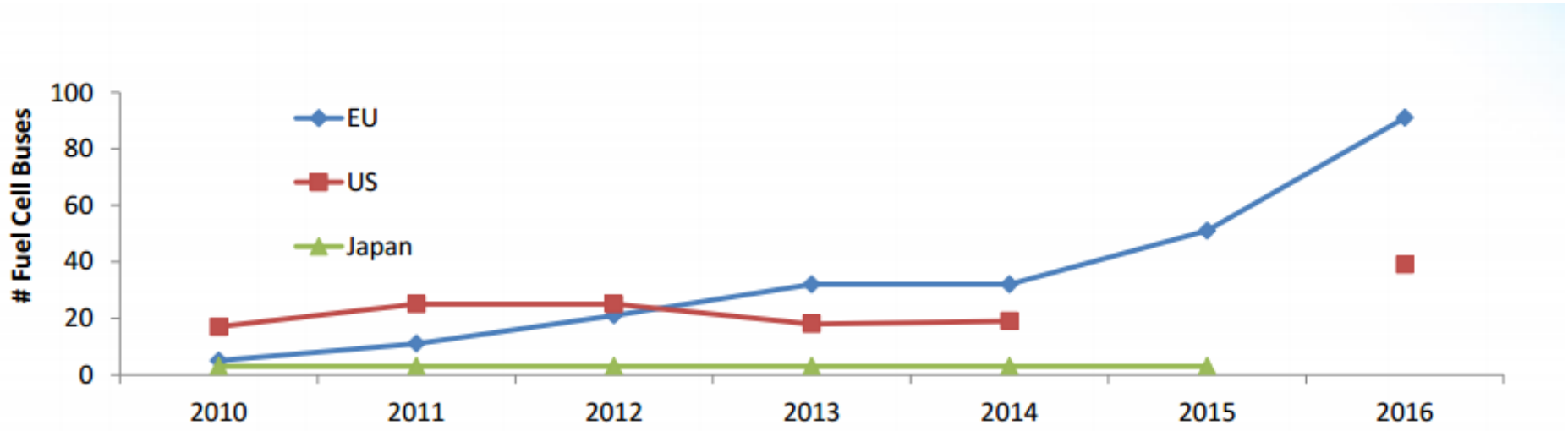
There are impressive plans to build an hydrogen infrastructure in many countries. Today there are not yet so many public stations in operation.

Economy is one major problem as a filling stations needs cars and hydrogen from natural gas is far less expensive than electrolysis.

- Germany: today ~20 HRS, 50 HRS 2016 and in total 400 HRS by 2023
- California: today 4 public HRS + 9 private in total 65 by 2016 where of 50 public
- Japan: today ~44 HRS the aim is to have 100 in operation by March 2016
- Denmark: 7 HRS + 4 HRS 2016

Fuel Cell Buses

- In Europe most buses financed by EU FCH JU2 today in total 91 in operation or very soon in op.
- USA: less than 20 buses nearly all in California
- Japan: Hino plans to have 100 buses in operation 2020 Olympics in Tokyo (comp. Beijing 2008, Vancouver 2010)



Situation and Outlook:
91 buses in operation or about to start + call 2016(?)

Ongoing EU-funded fuel cell bus projects

CHIC

- ✓ Bolzano, IT– 5 FC buses (2013)
- ✓ Aargau, CH –5 FC buses (2011)
- ✓ London, UK – 8 FC buses (2011)
- ✓ Milan, IT – 3 FC buses (2013)
- ✓ Oslo, NO – 5 FC buses (2013)

- ✓ Cologne, DE* – 4 FC buses (2011/14)
- ✓ Hamburg, DE* – 6 FC buses (2011/2015)

High V.LO-City

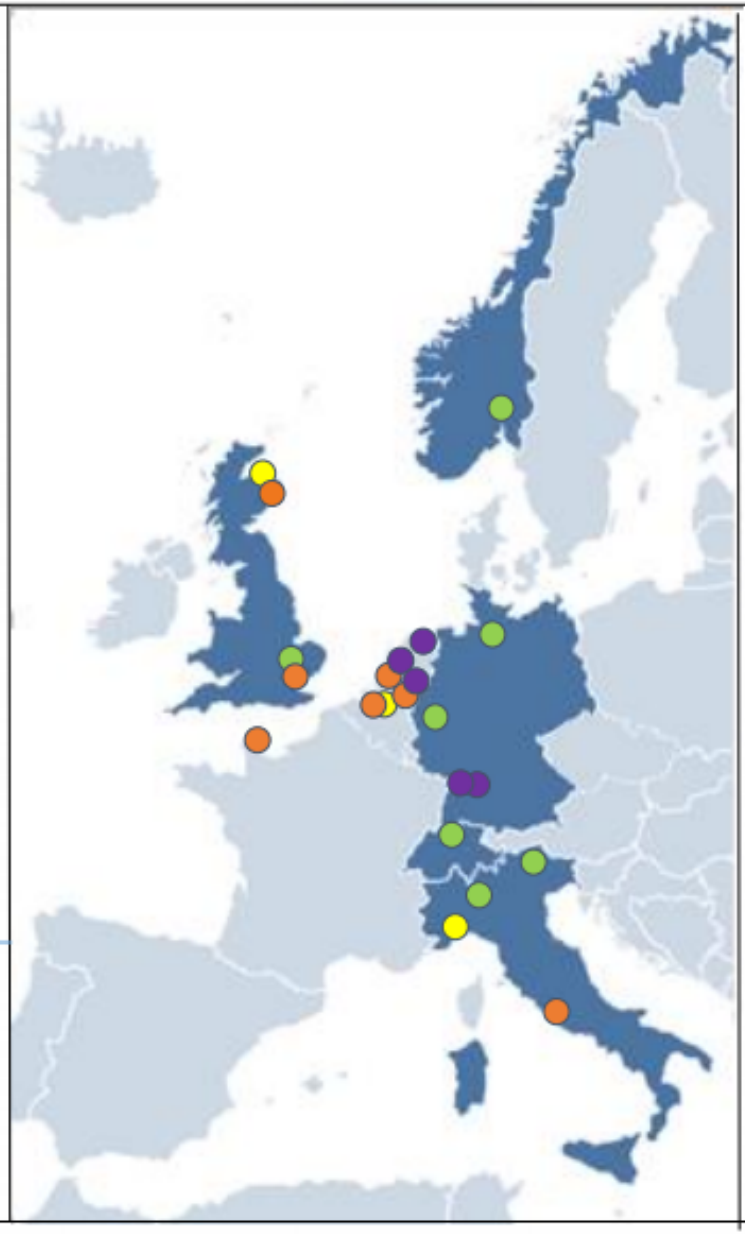
- ✓ Liguria, IT – 5 FC buses (2015)
- ✓ Antwerp, BE – 5 FC buses (2015)
- ✓ Aberdeen, UK – 4 FC buses (2015)

HyTransit

- ✓ Aberdeen, UK – 6 FC buses (2015)

Legend

- CHIC countries
- ✓ In operation
- ✓ Planned operation
- (2015) Operation start/planned start
- * Co-financed by regional/national funding sources



Ongoing EU-funded fuel cell bus project

3Emotion

- ✓ Cherbourg, FR – 5 FC buses (2016/17)
- ✓ Rotterdam, NL – 4 FC buses(2016/17)
- ✓ South Holland, NL – 2 FC buses
- ✓ London, UK – 2 FC buses (2016/17)
- ✓ Flanders, BE – 3 FC buses (2016/17)
- ✓ Rome, IT – 5 FC buses (2016/17)

Current national/regional-funded fuel cell bus projects

- ✓ Karlsruhe, DE * – 2 FC buses (2013)
- ✓ Stuttgart, DE * – 4 FC buses (2014)
- ✓ Arnhem, NL* – 3 FC buses (2016/17)
- ✓ Groningen, NL* – 2 FC buses (2016/17)
- ✓ Brabant, NL* – 2 FC buses (2016/17)

Last update: October 2015

Stationary a.o.

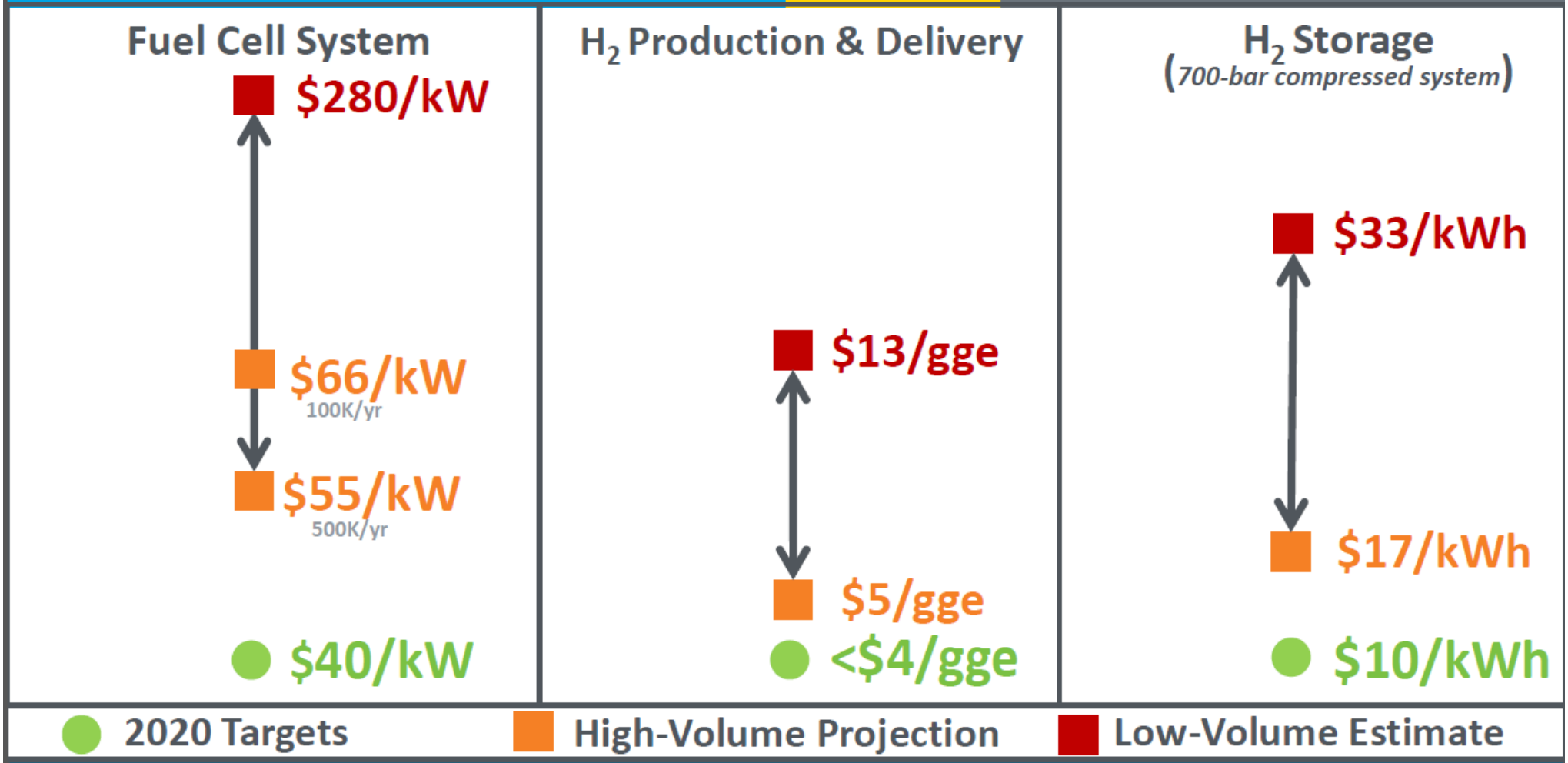
- The stationary side heavily rely on subsidies
  North America and Asia in the lead Europe only 10 %.
- Japan Ene-Farm now over 140000 fuel cells systems installed
- Telecom back up and remote power now a solid competitive market about 8000 systems delivered
- Residential microCHP fuel cells subsidized in Japan, EU, Germany and Korea
- Material handling. Fork-lift continue to expand in North America. Plug Power alone shipped 3500 in 2015 the total number well above 10000.
- Small chargers has not yet succeeded new models on its way

Gross Revenue and Cost of Revenue for Select Public Fuel Cell Companies (Thousands US$ except where noted)						
Companies	2014		2013		2012	
	Gross Revenue	Cost of Revenue	Gross Revenue	Cost of Revenue	Gross Revenue	Cost of Revenue
Ballard Power Systems (Canada)	68,721	58,475	61,251	44,492	43,690	36,321
FuelCell Energy[1] (U.S.)	180,293	166,567	187,658	180,536	120,603	120,158
Hydrogenics Corp. (Canada)	45,548	34,334	42,413	30,352	31,697	26,448
Plug Power (U.S.)	64,230	69,092	26,601	37,849	26,108	40,463
Ceramic Fuel Cells, Ltd.[2, 3] (Australia)	6,102	24,540	4,266	21,544	6,717	27,228
Ceres Power[2, 4] (U.K.)	1,224	10,128	523	13,255	226	18,480
SFC Energy AG[5] (Germany)	53,631	37,970	32,413	22,4886	31,260	18,497

[1] Year ends October 31 [2] Year ends June 30 [3] AU$ Thousands [4] £ Thousands [5] € Thousands [6] Updated (audited) number from SFC Energy's 2014 Annual Report. Source: Annual reports and investor presentations

- The companies that deliver large volumes are most successful
- Fuel Cell Energy: stable volume large MCFC plants
- Ballard: stacks for fork lifts, telecom 3000 ElectraGen telecom
- Plug power: Forklifts
- Volumes are important look at CFCL and Ceres Power
- MicroCHP is difficult require subsidies

DOE Cost Targets and Status



Key Challenges- Examples

- PGM loading
- Catalyst and membrane durability
- Electrode performance and durability

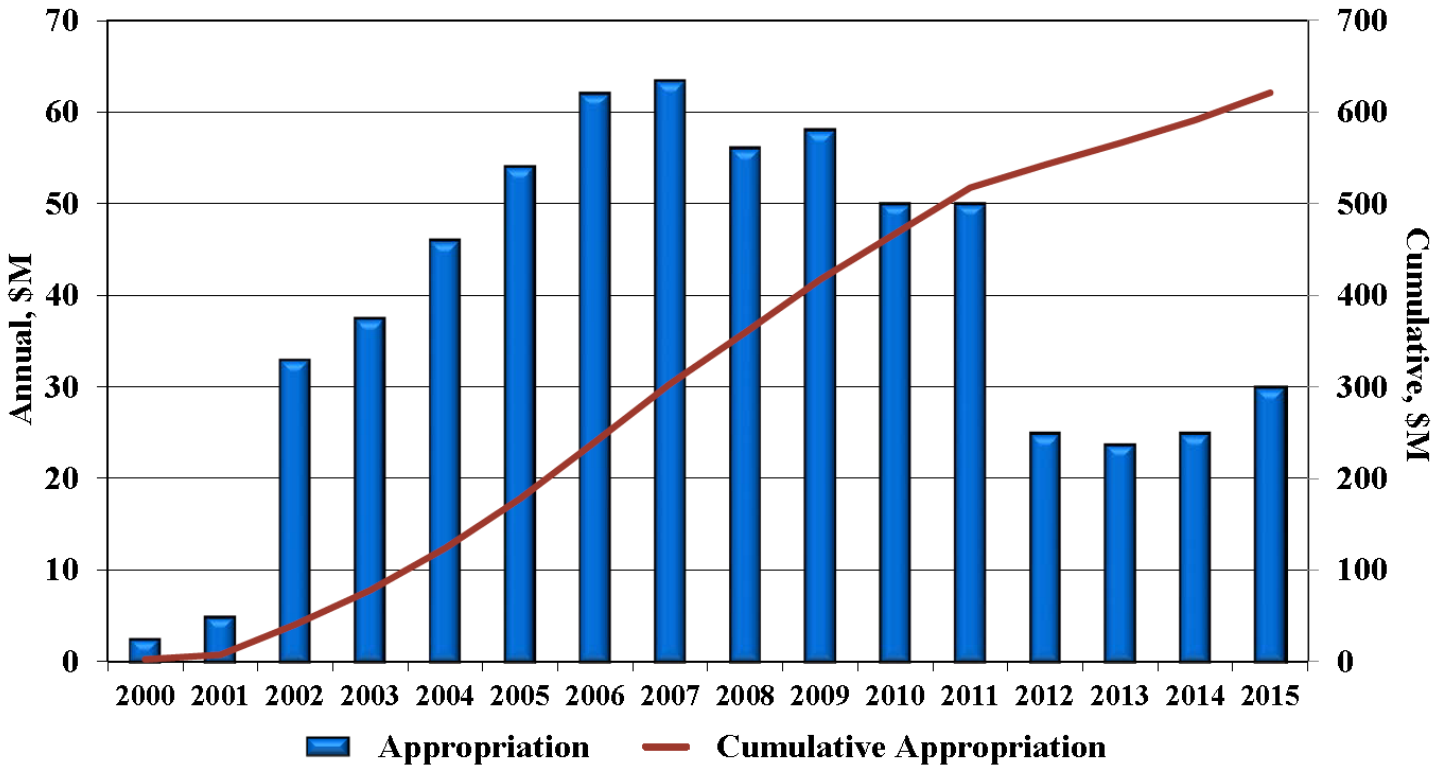
- Efficiency and Reliability
- Feedstock and Capital Costs
- Compression, Storage and Dispensing (CSD) Costs

- Carbon fiber precursors and conversion
- Composite/resin materials
- BOP and assembly costs

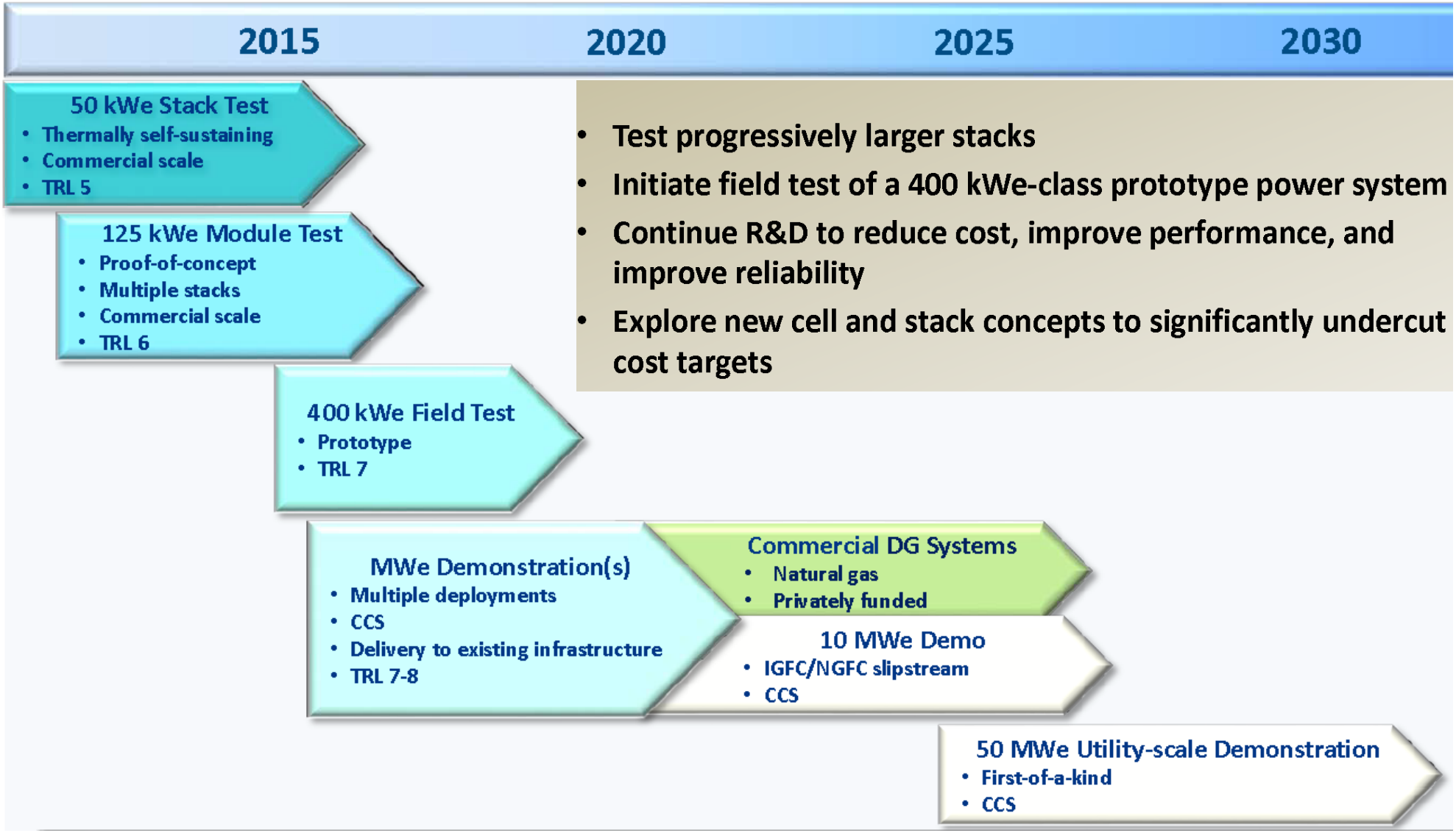
Systems Development

FuelCell Energy*
LG Fuel Cell Systems*
General Electric
Redox Power Systems
NETL (Systems Analysis)

SOFC Program Funding History



SOFC Technology Development Timeline



The near future ?!

- The overall market is still fragile as it depends heavily on subsidies
- Several important Governmental programme are under discussion
  - the US tax credit program 3000 USD/kWe is scheduled to end in 2016 funding is typical to be renewed annually
  - In Japan the Ene-Farm will most probably be extended also for 2016
- Competing technologies are moving like BEV, Plug-in hybrids, energy storage
- Renewable hydrogen will come later as natural gas is less expensive today
- The utilities are under pressure and has difficulties to invest in fuel cell projects

- Fuel cells are rapidly improving performance and lower cost is on its way
- The new Bloom Energy module 500 kWe in the same space as 100 kWe before
- Biogas is used in 30 % of all large fuel cells
- The new Honda Clarity significantly improved stack performance the fuel is now under the hood and range about 500 km
- The prognosis is that in 2020 there will be 35000 FCV on the road in Japan and California
- Doosan start to deliver the 400 kWe PAFC again
- Fuel Cell Energy and POSCO have increased production capacity for MCFC
- Air quality, local environment is a growing issue as well as GHG emissions

4 Technology

有轨电车领域 Power for Tram

- 中国青岛南车四方公司生产的燃料电池有轨电车下线，额定载客380人，续驶里程100km,最高时速70km/h.

A prototype tram powered by hydrogen fuel cells was unveiled at the CSR Sifang factory in Qingdao on March 19,2015 ;

A three-car tram capable of carrying as many as 380 passengers; running for 100km at speeds up to 70km/h.

- 南车四方和佛山市计划于2017年首先部署运营线路和配套的加氢站。

Foshan city is going to be the first customer, a fuel cell tram line and hydrogen refueling stations are in design.

FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

CEC Commissioner Janea Scott Visit to Tri-gen Site

Hydrogen Fuel Cell Truck being refueled with green H_2 at Orange County

Tack för att ni lyssnade !

bengt.ridell@sweco.se

Energiforsk

SHC SWEDISH ELECTRIC & HYBRID VEHICLE CENTRE

Energimyndigheten

Large fuel cells business model

Total subsidies in California can climb up to **USD 8250 per kWe** when biogas supplements and all federal and state programs are added.

- Federal subsidies for fuel cells
- SGIP (Self-Generation Incentive Program) in Ca
- The use of renewable fuels, biogas
- Local subsidy feed-in tariff for CHP up to 1 MWe

California has high electricity prices and high subsidies for fuel cells

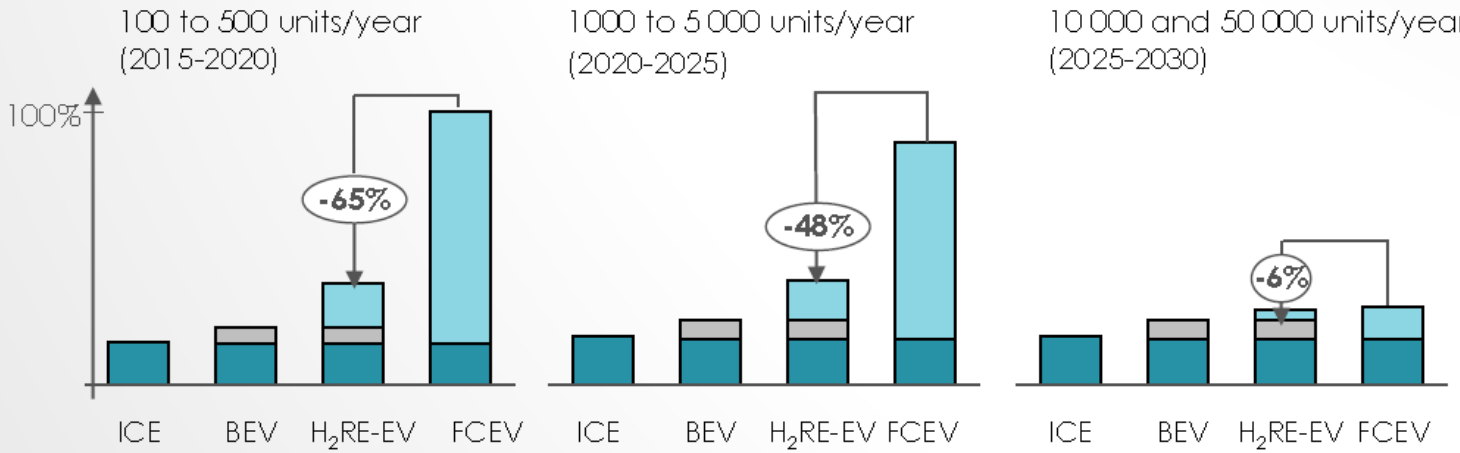
STARTING WITH RE-EVS: 65% LOWER VEHICLE COST VS. FULL POWER FCEVS AT LOW VOLUMES

Additional fuel cell powertrain costs

Battery cost premium (leasing or ownership model)

Vehicle glider cost (including bonus for electric powertrains between 2015-20)

Comparison of van purchase costs including existing bonus/malus*



ICE : diesel, **BEV** : Battery Electric Vehicle, **H_2RE-EV** : H_2 Range Extended EV, **FCEV** : Fuel Cell Electric Vehicle

- Fuel Cell Range-extended Electric Vehicles offer a significantly lower cost route to market than full power FCEVs at low volume, due to smaller fuel cells and lower pressure hydrogen tanks
- At high volumes, **purchase premium** relative to EV falls to 3 000€ for the RE-EV and 6 000€ for the FCEV

* Current bonus of ~6 000€ reduces cost premium of electric powertrains relative to a diesel van, although a cost premium due to the battery remains. By 2020, battery cost reductions are expected allow a competitive EV cost without the bonus, and the remaining battery cost will be offset by fuel cost savings during the life of the vehicle

Source : Mobilité Hydrogène France