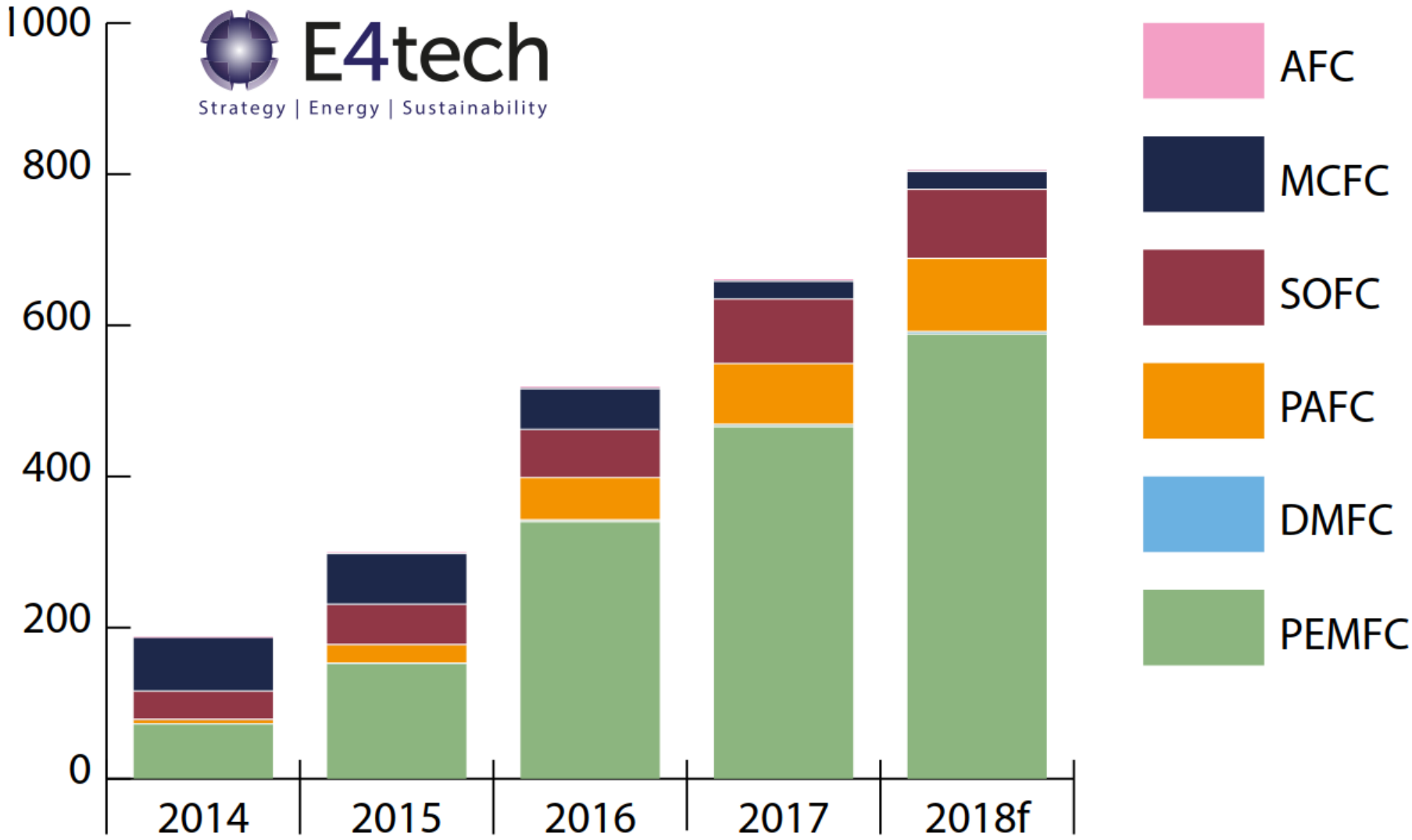
THE FUEL CELL MARKET

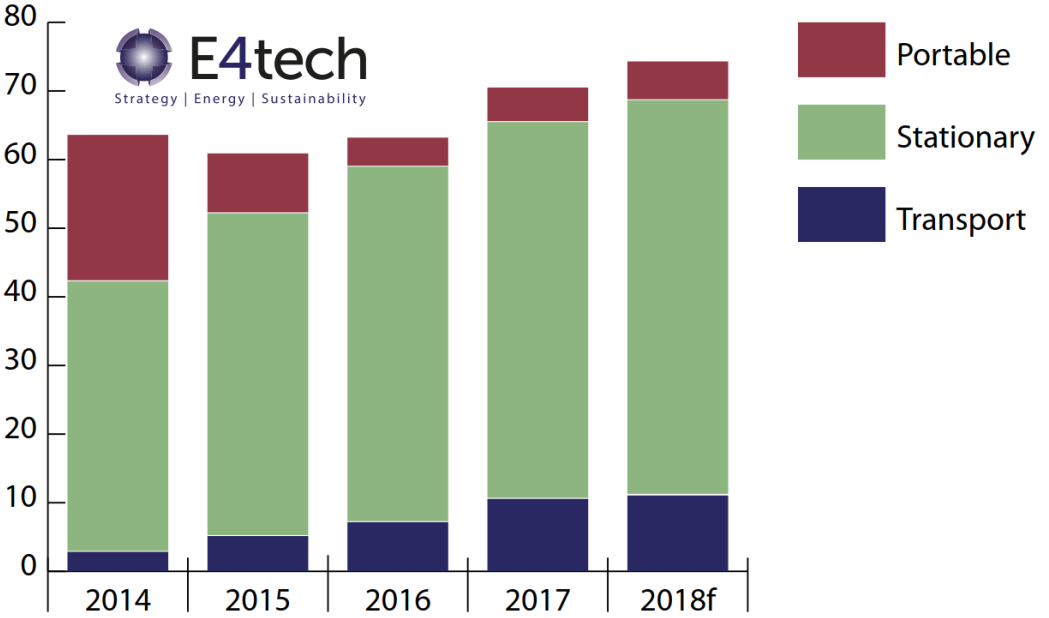
Bengt Ridell Stockholm 2019-05-07

Megawatts by fuel cell type 2014 - 2018

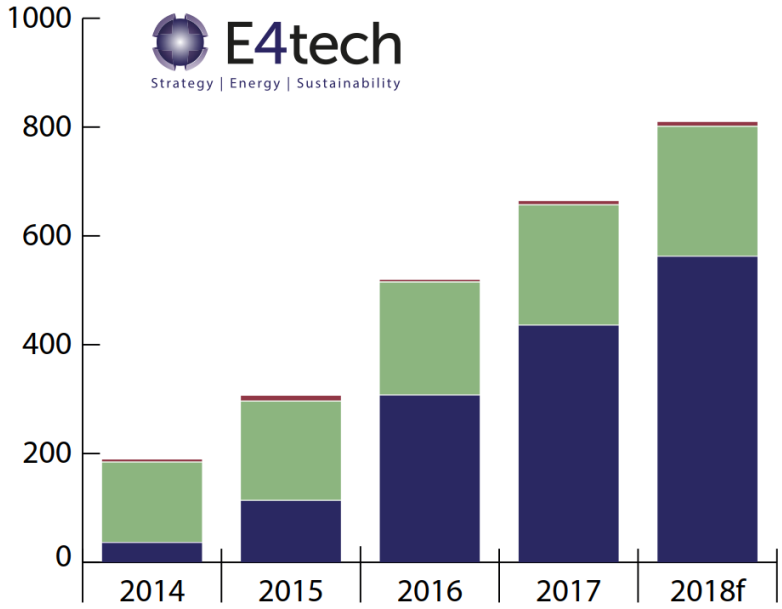


Shipment by application

Shipments by application 2014 - 2018 (1,000 units)



Megawatts by application 2014 - 2018



Portable fuel cells still not taking off battery power banks a strong competitor
Transport has the increase in MWe cars and MHE and China deliver vans.

“Commercial” FCV

Fuel cell vehicles that can be mass produced and bought by normal customers

Toyota Mirai ca 7000 sold
Hyundai Nexo
Honda Clarity
Daimler Mercedes GLC F-Cell

What are the plans from other car manufactures?

<u>Official cooperation agreements</u>
AUDI – Hyundai
GM-Honda

Ford – Daimler agreement ended
Nissan –Renault, Ford ?
Nissan – SOFC Bio-Ethanol in Brazil

Diversification of FCEVs

Line-up will be expanded for both passenger and Commercial vehicles in the 2020s

2014:MIRAI

Passenger vehicles

Commercial vehicles

Industrial use

TOYOTA

AISIN

Honda Smart Hydrogen Station

Delivery ready on-site only water and electricity needed
Electrolyser and compressor included

Capacity storage 19 kg H_2 production 1,5 kg/day at 40 MPa

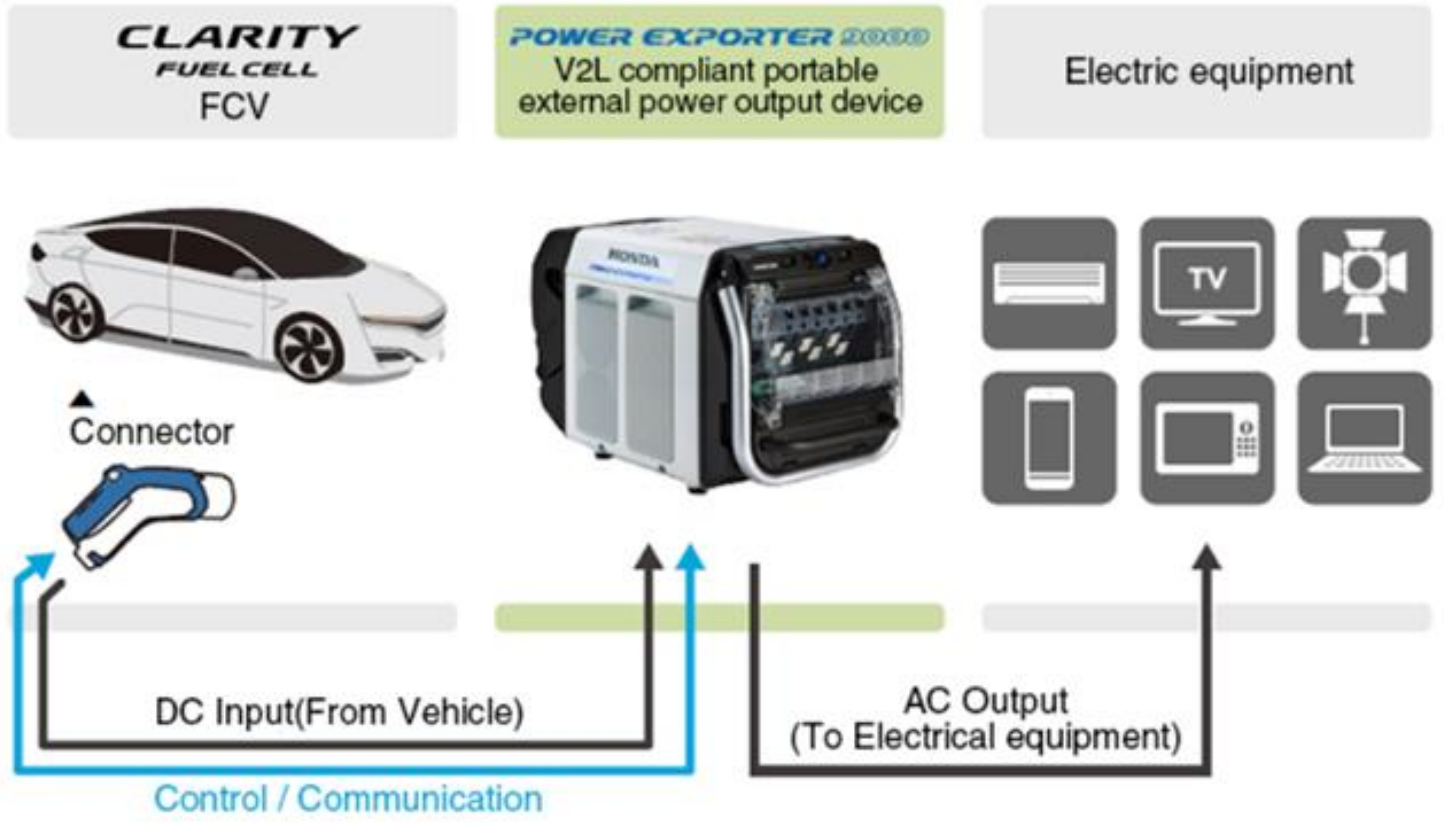
SWECO

Honda Power exporter 9000

9kW power output
at different voltage levels

HONDA
The Power of Dreams

System Overview (with Clarity Fuel Cell)



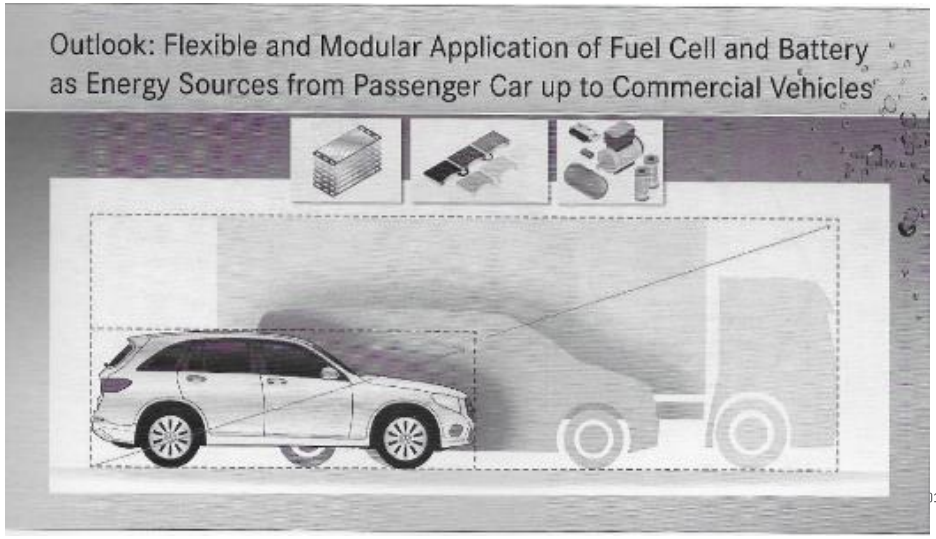
Daimler Mercedes Benz GLC F-Cell

- Approx. 500 km combined electric range NEDC
- < 50 km ranges in battery-electric mode alone
- 700 bar hydrogen refueling in approx. 3 min
- Battery with an energy content of approx. 9 kWh
- 2 carbon fibres coated tanks with ~4 kg capacity

FCV with Plug-in function

Turbo charger instead of screw compressor – higher efficiency in part load

Available and ready for mass-production



GM General Motors USA

GM cooperates with Honda for development of FCV
GM first FCV was built in 1966 Electrovan

The GM group has decided to use the brand name **Cadillac** for their FCV

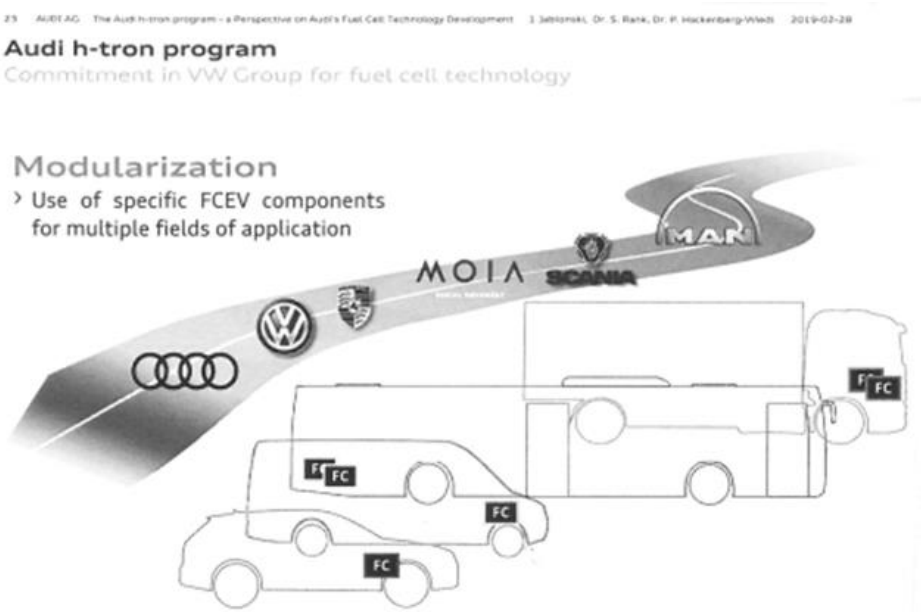
GM works with the US Army for development of FCV this is the TARDEC Colorado ZH2.

Next model based on Silverado also in cooperation with US Army

Volkswagen

Audi

Audi develops FCV together with Hyundai and can use FC components from Hyundai



Speech from the CEO of VW:

“”Exploring other options like carbon-neutral synthetic fuels for combustion engines or vehicles powered by fuel cells “only serves to delay” the change, he argues.””

FC Trucks large and others

Toyota
Kenworth – Ballard
Kenworth – Toyota 10 st T680 with Mirai stacks
Navistar-Hydogenics
Nikola Motor

Mid-size trucks and delivery vans

- Hyundai – COOP a o Switzerland 1600 18-tonne trucks
- Toyota - 7-eleven delivery vans in Japan

- Plug-power Calstart Rex 20kWe for delivery vans UPS, FedEx
- Renault Kangoo now 40 kW Rex

- Concept vans from Daimler, VW

FC Buses are expanding

- From 2025 London, Paris, Madrid and Athens will only buy ZEV buses
- Van Hool will deliver 40 buses to Köln-Wuppertal
- The bus manufacture Caetano in Portugal uses Toyota fuel cells
- New buses in USA California end of 2019 about 50 buses
- China has announced that several hundred are purchased for Shanghai and Datong, Ballard and Hydrogenics will deliver FC-stacks to China
- Tokyo will have 100 Toyota-Hino FC buses next year for the Olympics 2020
- Korea, Hyundai will deliver a few buses will be delivered for the winter Olympics 2022 and the plans are that 1000 FCEB will operate in Korea in 2022

- Several of these fleets belongs to projects
- Some are connected to special events like Olympic games

- **Severe competition from BEV buses especially for local traffic!**

FC Bus

Toyota to start sales of FC buses under the Toyota brand from early 2017
The Tokyo Metropolitan Government plans to utilize as fixed-route buses.

- Toyota aims to engage continuously in the diligent development targeted at the expansion of the introduction of the new FC buses from 2018

*Existing component

Vehicle	Length/width/height	10,525/2,490/3,340（mm）
	Capacity（seated+standing+driver）	77（26＋50＋1）
FC stack*（Fuel Cell）	Name	Toyota FC stack
	Type	PEM
	Maximum output	114 kw x 2units
Motor*	Type	AC synchronous
	Maximum output	113kw x 2units
	Maximum torque	335N･m x 2units
High-pressure hydrogen tank*	Type	Compression hydrogen
	Nominal working pressure	70MPa
	Tank internal volume	600L
	Number of tanks	10
Drive battery*	Type	Nickel-metal hydride
V2H system	Maximum output/voltage	9kW/DC300V

The FC bus was developed using a unit of MIRAI.
Cruising range is approximately 200km

SAIC Fuel Cell Vehicle

SWECO

SAIC FCV80

- From Sep 2017, launched more 100 FCV 80 in Shanghai, Fushun and Foshan.

FCV80 as mini BUS in Fushun

- **Fuel Cell buses for Zhangjiakou Winter Olympics**

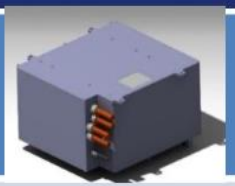
74 FC Buses in operation.: 40 Futon 10m FCV , 25 Yutong 12m FCV.

Technical progress

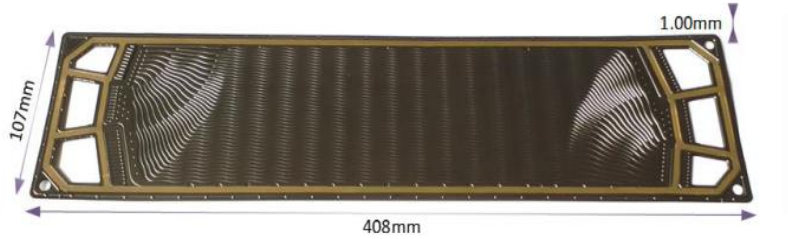
Sunrise Fuel Cell stack

FCV80

FC Roewe950

		
Power/Max Power	36kW/44kW	44kW/56kW
Stack Power density	1.3kW/L	1.9kW/L
durability	>5000h	>4000h
Cold start	-10℃	-20℃
Application	FCV80, FC Roewe750	FC Roewe950

- Ultrathin metal bipolar plate of fuel cell realize large-scale production



SHANGHAI ZHIZHEN bipolar plate

Contact resistance	<10mΩ cm²
Corrosion current	<0.016 mA/cm²
Thickness	<1.0mm
Size	100~500cm²
Mass	0.15~0.20g/cm²

Technology Collaboration Programme on Advanced Fuel Cells

Trains, Ships and maritime applications

Fuel cells can replace engines and batteries.
The advantages of fuel cells in this context are low emissions, low noise and stable operation.

Alstom Coradia will replace diesel trains in Germany
200 kW PEFC from Hydrogenics
Letter of intent for another 50 trains in Germany
Fuel cell train projects are on its way in Toronto, Canada, UK and in China

Ship propulsion, quayside power, APU, Coastal ships, ferries and river boats

at sea hydrogen or other fuels PEFC, MCFC or SOFC projects. Several projects and studies

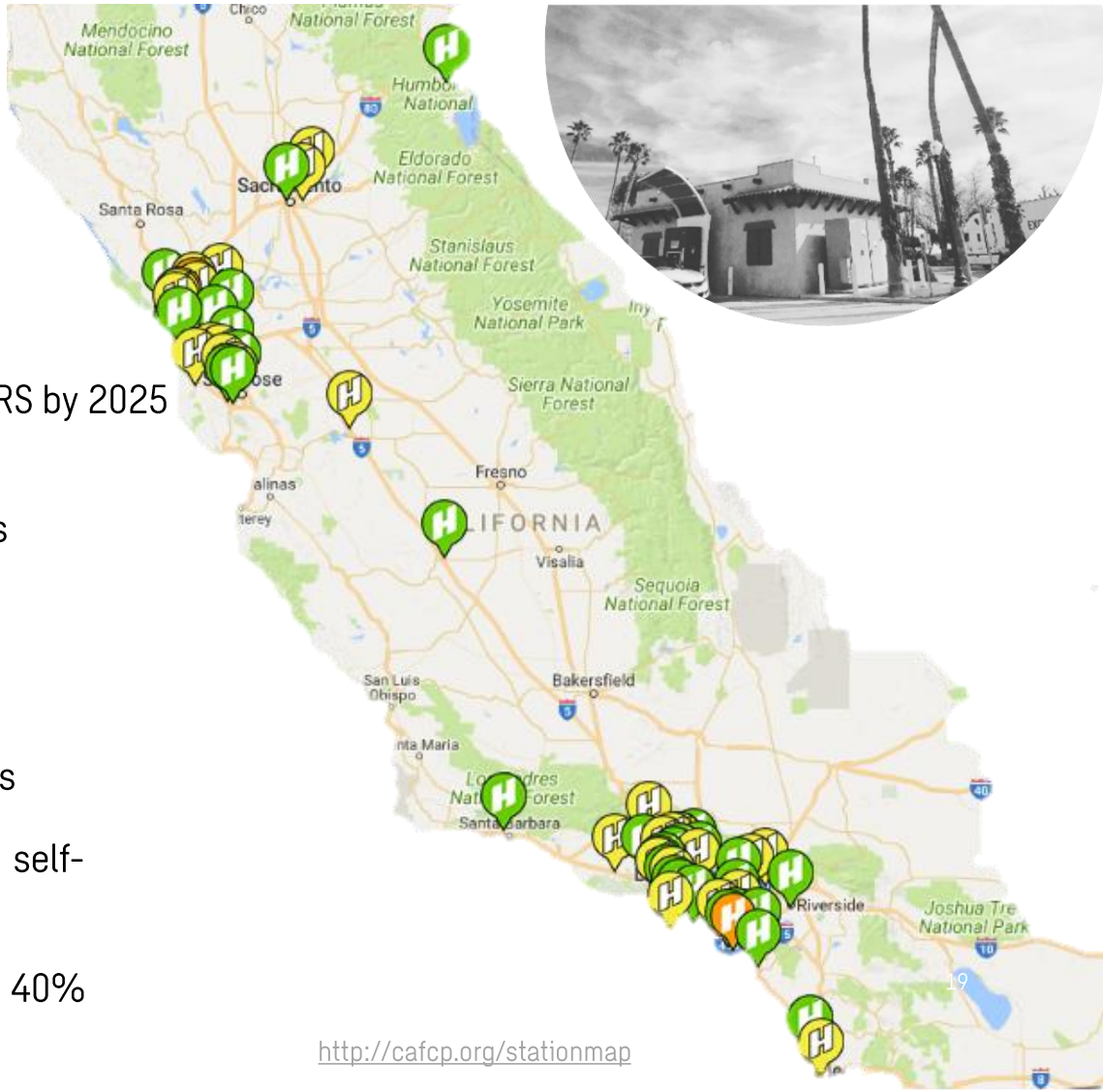
USA, California takes the lead

Fuel Cell Electric Vehicles & Hydrogen Fuel

Numbers as of May 1, 2019	Total
***FCEVs—Fuel cell cars sold and leased in US**	**6,547**
FCEBs—Fuel cell buses in operation in California	30
Retail hydrogen stations open in California	**39**
Fuel cell buses in development in California	22
Fuel cell shuttles in development in California	4
**Retail hydrogen stations in development in California	25

Recent Activities

- Executive Order B-48-18 targets 200 HRS by 2025 and 5MM ZEVs by 2030
- New renewable H2 production facilities
- New heavy duty fuel cell truck projects
- Innovative Clean Transit regulation
- Low Carbon Fuel Standard Amendments
- CaFCP publishes new 2030 vision for a self-sustaining California market
- Aim to increase renewable hydrogen to 40%

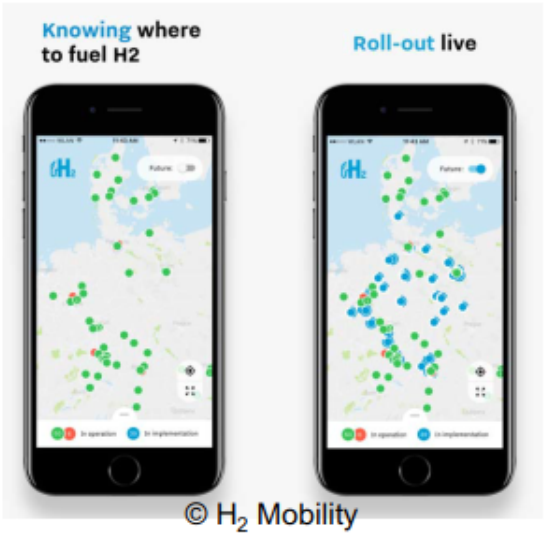


http://cafcp.org/stationmap

Hydrogen refueling infrastructure

H_2 MOBILITY
FUELLING HYDROGEN

www.h2.live



© H_2 Mobility

24th October 2018: Great Wall Motor becomes the 7th shareholder and co-owner of H_2 Mobility

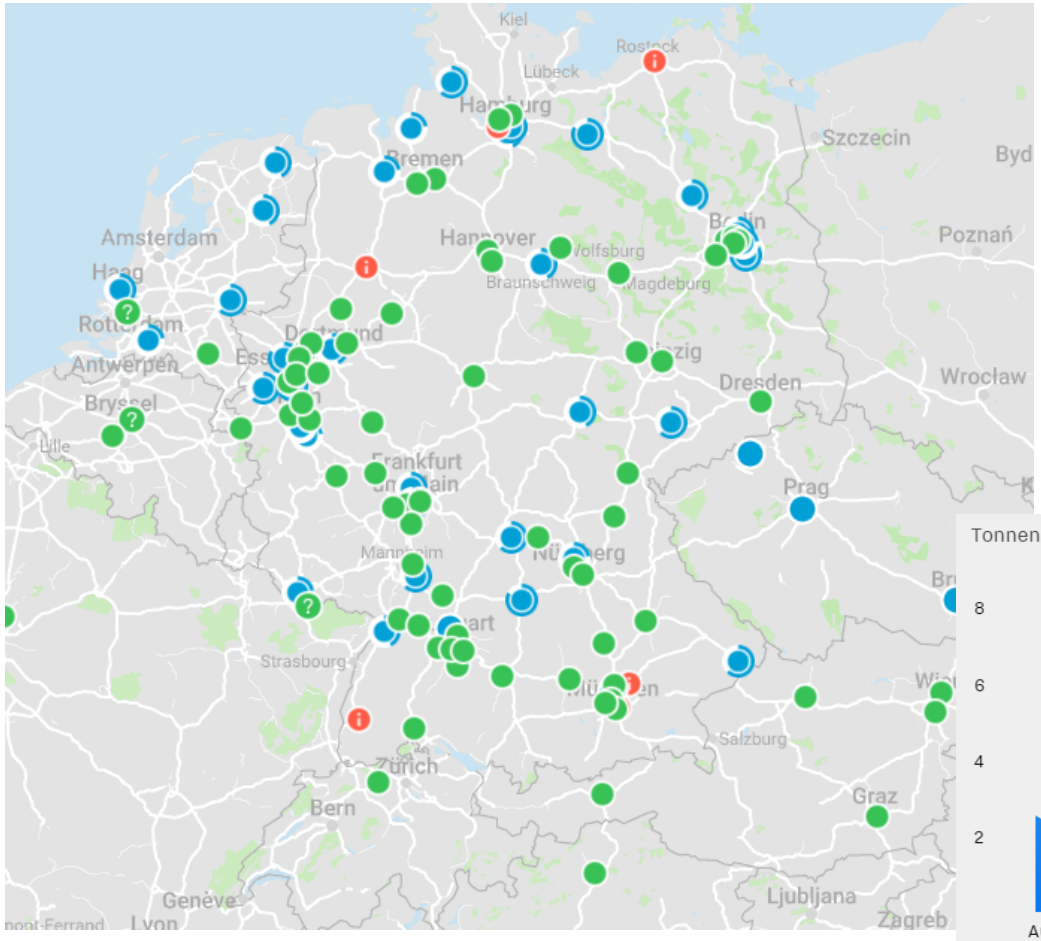
As of October 2018: 52 public stations

In planning: 4
Approval phase: 13
Execution phase: 14
Trial operation phase: 11

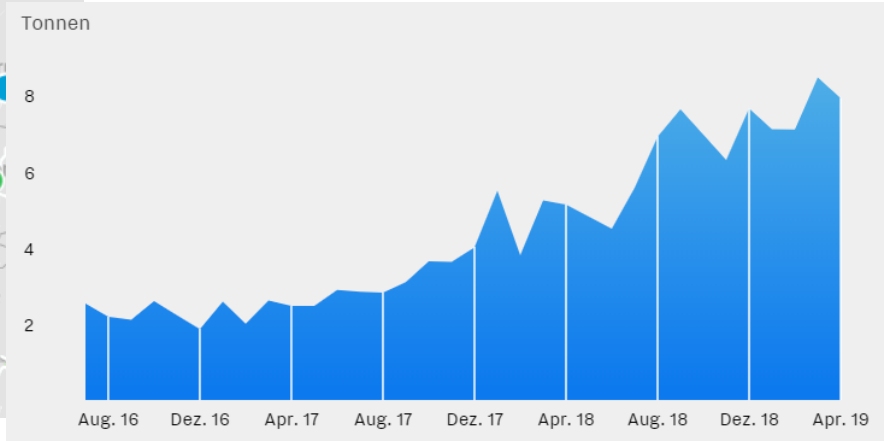
Source: h2-mobility.de

Technology Collaboration Programme on Advanced Fuel Cells

Hydrogen filling stations in Germany and neighbour countries



https://h2.live/



107 8 In Betrieb 52 In Realisierung

Status of Fuel Cells and Hydrogen in Japan

Today May 2019:
113 HRS and about 3000 FCV on the road
target in two years 40000 FCV and 800000 in 2030
Many of the HRS are 350 bar stations, 700 bar considerably more expensive but all new station are 700 bar.

Japan hydrogen program launched today 100 Yen/ Nm3 goal 20 Yen/ Nm3
Lignite from Australia with **CCS abroad** road map available for download at METI webpage

ENE-Farm 325000 fuel cell installed

European PEFC fuel cell

Joint Development with VIESSMANN
who is major heating company in Europe

Model for 2018

Panasonic VIESSMANN

■Features

1. **Energy Label :A+++ (Max Class)**
2. **Life Time :80,000 hours (12 years)**
3. **High Efficency :96.8%** (E gas、LHV)

left:
Hot water tank (VIESSMANN)

Right:
Fuel cell (Panasonic)
Back up boiler (Viessmann)

■Specification

Subsidy 9,300 Euro/unit in Germany

【Power Generation】 750w (constant)
【Overall Efficiency】 96.8%(LHV)
(Electricity 39%/heat 57.8%)
【Durability】 Start/Stop 4,000 times
【Dimension】 600W×400W×1800H (FC unit only)

High power (5kw) pure hydrogen FC

High efficient power generation direct from hydrogen
Out put power can be increased for each application such as stationary, apartment and commercial use

Natural gas Fuel Cell

Stationary

Hydrogen Fuel Cell (Power Unit)

Stationary
(Output: 700W)

Expansion of line up

Commercial
(Output: 5kW)
Release 2021

Plural connection

U.S. Snapshot of Hydrogen and Fuel Cells Applications

Examples of Applications

- **>240MW** Backup Power
- **>25,000** Forklifts
- **>30** Fuel Cell Buses
- **>40** H_2 Retail Stations
- **>6,600** Fuel Cell Cars

Example of Emerging Interest in Transportation

Industry plans for hydrogen fuel cell trucks and supporting infrastructure underway

Hydrogen and Fuel Cells Funding Across DOE

EERE – Fuel Cell Technologies Office (FCTO)

Key Activity	FY 2017	FY 2018	FY 2019
	($ in thousands)		
Fuel Cell R&D	32,000	32,000	30,000
Hydrogen Fuel R&D	41,000	54,000	39,000
Hydrogen Infrastructure R&D	-	-	21,000
Systems Analysis	3,000	3,000	2,000
Technology Acceleration	18,000	19,000	21,000
Safety, Codes and Standards	7,000	7,000	7,000
Total	101,000	115,000	120,000

EERE: Office of Energy Efficiency and Renewable Energy

DOE-wide Hydrogen and Fuel Cells Funding

Office	FY 2018 ($ in thousands)
EERE (FCTO)	115,000
Science (Basic/xcut)	19,000
Fossil Energy (SOFC)	30,000
Nuclear Energy (H_2/hybrid specific)	2,000
Total	~166,000

Note: ARPA-E funding dependent on program selected each fiscal year

Approx.
$12M
in the past 3 years

Savings from Active Project Management Go/No Go Decision

SOFC Power Systems
1. *FuelCell Energy 200 kW Prototype Field-Test*

NATIONAL ENERGY TECHNOLOGY LABORATORY

SWECO

- 200 kWe integrated SOFC Power System
- Test site: NRG Energy Center Pittsburgh, PA
- Natural gas fuel, Grid Connected
- Target operating time: 5,000 hrs

Large SOFC USA
DoE program demo phase

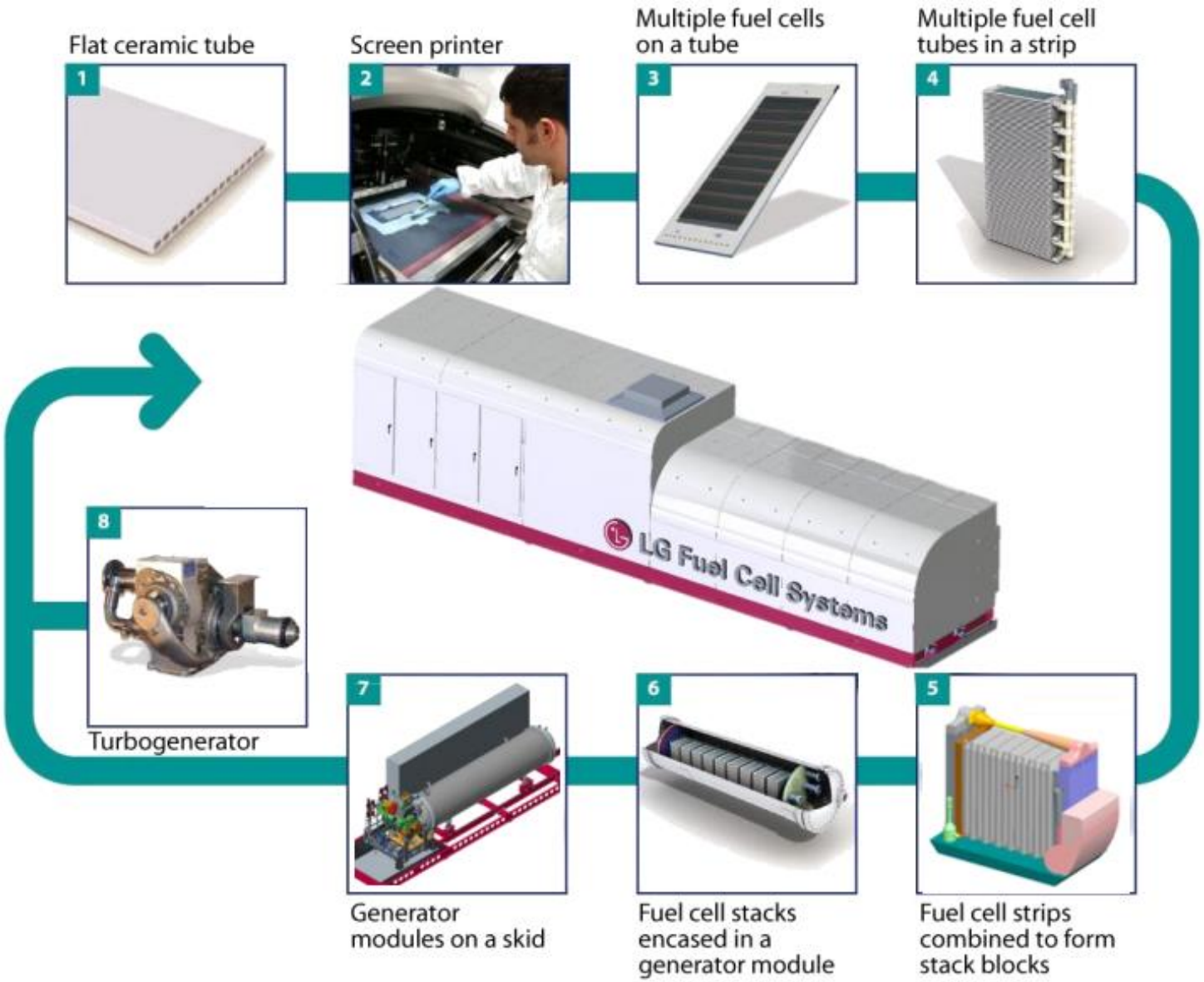
SOFC Power Systems
2. *LG 250 kW Prototype Field-Test*

NATIONAL ENERGY TECHNOLOGY LABORATORY

- 250 kW integrated SOFC Power System
- Test site: Stark State College North Canton, OH
- Natural gas fuel, grid connected
- 1,300 hrs on load
- Efficiency: 55% AC
- Power degradation: 0.3% per 1000 hrs

Photo courtesy LG Fuel Cell Systems

LGFCS SOFC Power Plant



Bloomenergy®

SWECO

Bloom Energy Expands its Market Footprint with Commercial and Industrial Microgrids.

Large SOFC now on the stock market value 1,2 BUSD (10 Mdr SEK)

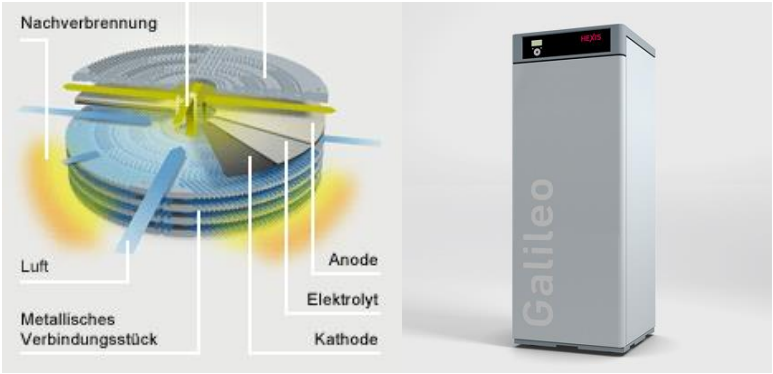
312 MWe of fuel cells deployed, 58.5 megawatts are early generation fuel cells.
One module of 500 kWe

Large organizations are customer Google, Bank of America, Coca-Cola, FedEX, Walmart eBay etc

AISIN Seiki and European SOFC

SolidPower, INNO-SOFC Finland

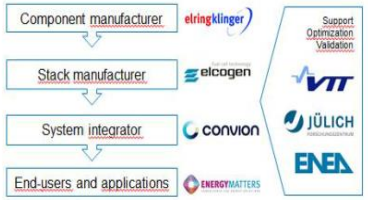
Hexis and Sunfire



AISIN ENE-Farm

INNO-SOFC

- Design and manufacturing of a State of the Art 60 kW SOFC system with 60% electrical and 85% total efficiency
- 3.5 years project started in 2015
- System assembly starts in autumn 2018, system start-up early 2019



SFC EFOY Germany DMFC Methanol

EFOY
ENERGY FOR YOU

EFOY Pro 2400 Duo

45W / 110W / 500W

3700 sold in 2018 probably the most profitable fuel cell today
4Q/2018 generated a profit

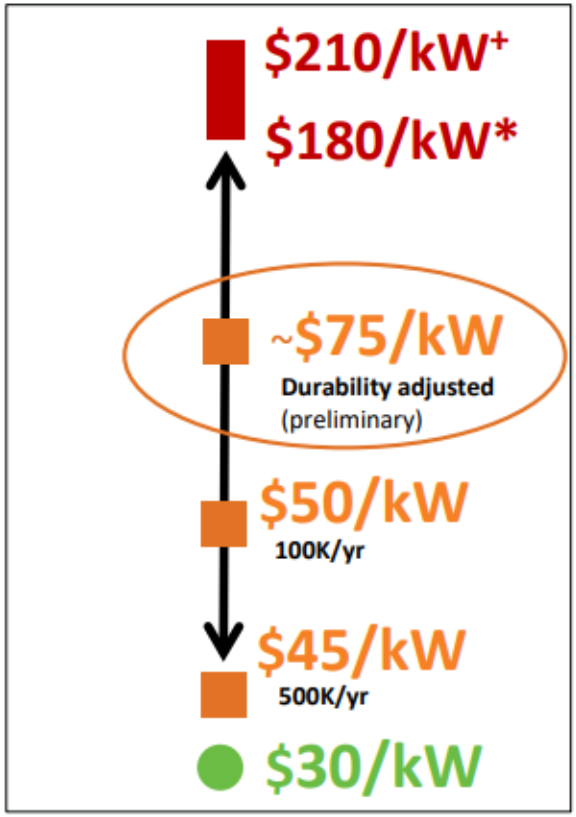
SFC ENERGY

USA DOE Targets

Fuel Cell R&D

Cost Status

(Fuel cells system cost)



Low-Volume Estimate

High-Volume Projection

Ultimate Target

+Based on commercially available FCEVs

*Based on state of the art technology

Overview: Strategy and Plans

ElectroCat Electrocatalysis Consortium

PGM-free catalysts to ultimately enable $30/kW

FCPAD FUEL CELL PERFORMANCE AND DURABILITY

Address performance and durability, including low PGMs

- **Expand beyond passenger cars**
  - Heavy duty and other applications
- **Contribute advances to enable H_2**
  - Reversible fuel cells, electrolyzers, electrochemical compression, sensors, etc.

Notes: Graphs not drawn to scale and are for illustration purposes only.

Hydrogen Production

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Cost Status

(H_2 cost at the pump)

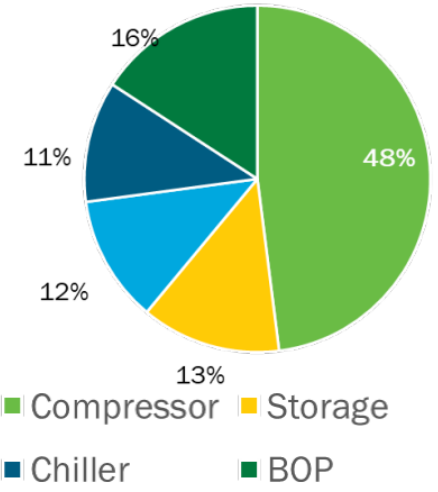
†Range assumes current production from NG and delivery and dispensing
*Highest possible cost at high vol., assumes H2 from electrolysis at $5/gge and deli
**Lowest possible cost at high vol., assumes H2 from SMR at $2/gge and delivery

The customer price today is 16 USD per kg in Ca

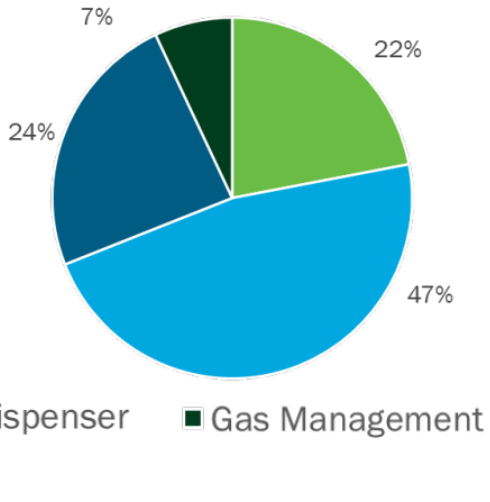
Big difference between SMR and electrolysis
700 bar compression is expensive

Real World Data and Analysis Guides R&D

Capital Costs of Gaseous Stations[1]



Maintenance Hours at Fueling Stations[2]



1. Assumes 180 kg/day station supplied by tube trailer.
Source: HDSAM, ANL
https://hdsam.es.anl.gov/index.php?content=hdsam

2. Composite Data Product 21, NREL
https://www.nrel.gov/hydrogen/hydrogen-infrastructure-analysis.html

Natural gas and nuclear power are most important sources for hydrogen, renewables are expanding

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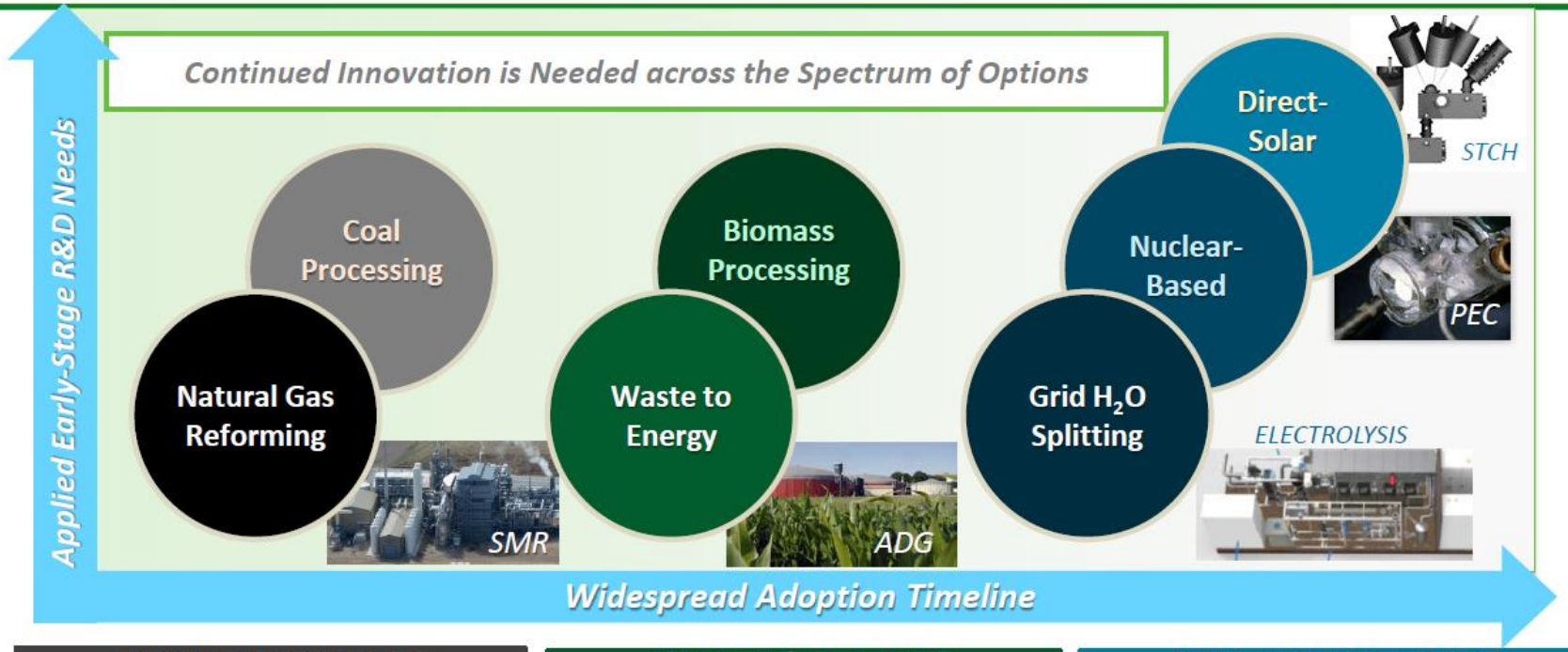
H_2 Production from Diverse Domestic Resources



FOSSIL RESOURCES

- Low-cost, large scale H_2 production with CCUS options
- New options offer scalability and byproduct benefits (e.g. CHHP)

WASTE/BIOMASS

- Options include innovative biogas reforming & fermentation of waste streams
- Byproduct benefits include clean water, electricity & chemicals

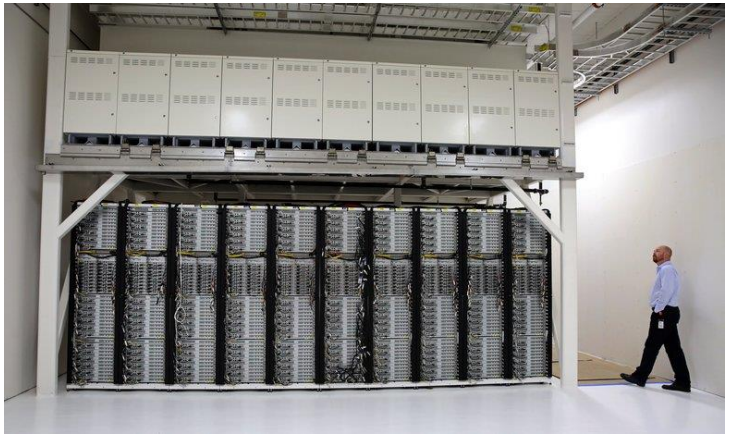
WATER SPLITTING

- Grid electrolysis is proven process being improved with innovation
- Emerging nuclear/solar options offer long-term sustainable H_2

A broad portfolio of near- to longer-term H_2 production technology options is being addressed through early-stage R&D

Stationary fuel cells

- The stationary fuel cells heavily rely on subsidies North America and Asia in the lead Europe is still in R&D and the demonstration phase
- Large scale MW-class only in the USA and Korea; PAFC, MCFC and SOFC
- Emergency and remote power for telecom and data centers and other buildings are expanding markets
- Smaller micro-CHP PEMFC and SOFC in Japan, Europe and Korea
- There are not any major surprises, the volumes are increasing and subsidies are still ruling the market



OVERVIEW OF DOOSAN H_2 FUEL CELL PRODUCT

Doosan H_2 Fuel Cell

- Fuel cell that directly takes H_2 as fuel to generate electricity and heat

OUTPUT

- Electrical Output: 440 KW (~46%)
- Heat: High Grade Heat ~250F

RELIABLE

- 20-Year system life, 10-Year stack life
- Continuous onsite power
- Grid-independent critical power

CLEAN & QUIET

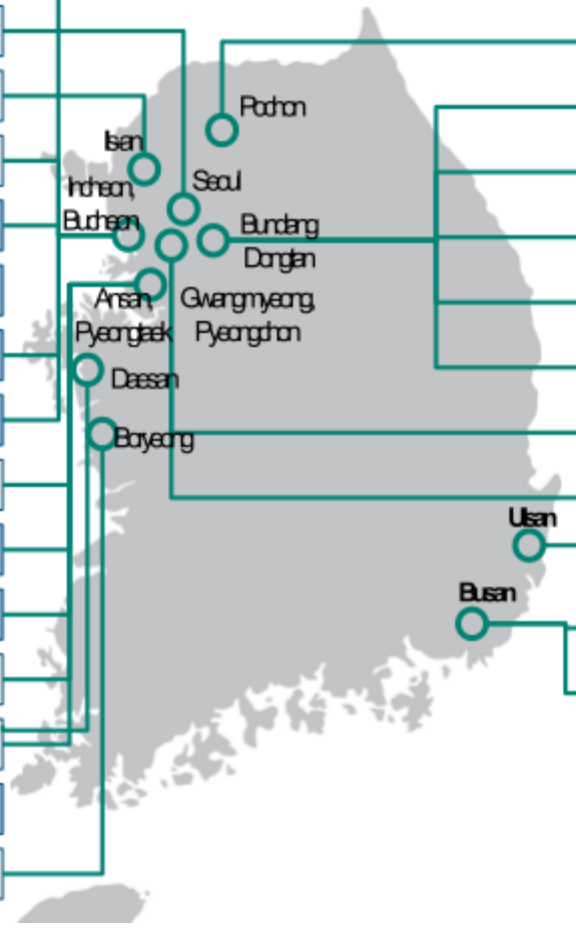
- No CO_2, NOx, and SOx emissions
- Low noise and vibration

DOOSAN

KOREA PURECELL 400 FLEET INSTALLATION

Total		
243.3MW (554 Units)	Operation	104.3MW (238 Units)
	Under Construction	139.0MW (316 Units)

SK IPC Hydrogen	`2019, 0.44MW
제2롯데월드	`2013, 0.8MW
동서 일산4단계	`2018, 5.28MW
서부 서인천2단계	` 2016, 5MW
남부 신인천2단계	`2019, 18.48MW
남부 신인천3단계	`2019, 20.24MW
서부 서인천3단계	`2019, 18.04MW
GS파워 부천	`2019, 10.56MW
평택에너지서비스 1단계	`2013, 3.08MW
평택에너지서비스 2단계	`2018, 3.08MW
오성연료전지	`2018, 9.68MW
안산 배곧신도시	`2017, 6.16MW
남동 안산	`2013, 2.64MW
한화 대산 Hydrogen	`2020, 50.16MW
중부 신보령	`2017, 7.48MW



포천민자	`2017, 0.44MW
남동 분당2단계	`2013, 3.08MW
남동 분당3단계	`2016, 5.72MW
남동 분당5단계	`2018, 5.72MW
남동 분당4단계	`2018, 16.72MW
한난 동탄	`2018, 11.44MW
GS파워 평촌	`2011, 4.8MW
삼천리 광명	`2017, 2.64MW
SK가스 LPG	`2018, 0.44MW
부산그린에너지	`2017, 30.8MW
부산국제금융센터	`2013, 0.4MW

'18. 11 standard

Fuel Cell Firm	2015 Revenue (Loss)	2016 Revenue (Loss)	2017 Revenue (Loss)	2018 Revenue (Loss) through Q3	Market Cap
Bloom Energy SOFC Systems	NA	$209M ($280M)	$376M ($263M)	$528M ($135M)	$1.2B
Ballard Power Stacks, PEM	$57M ($6M)	$85M ($21M)	$121M ($8M)	$68M ($16M)	$493M
Plug Power PEM Systems	$103M ($56M)	$86M ($57M)	$103M ($127M)	$122M ($61M)	$320M
SFC Energy DMFC Systems	$53M ($12M)	$50M ($6M)	$61M ($2M)	$50M ($1M)	$92M
Hydrogenics Stacks	$36M ($11M)	$29M ($10M)	$48M ($11M)	$23.4 ($10)	$71M
FuelCell Energy MCFC Systems	$163M ($29M)	$108M ($51M)	$96M ($54M)	$72M ($44M)	$45M

Source: company reports

What about the future for fuel cells and hydrogen?

SWECO

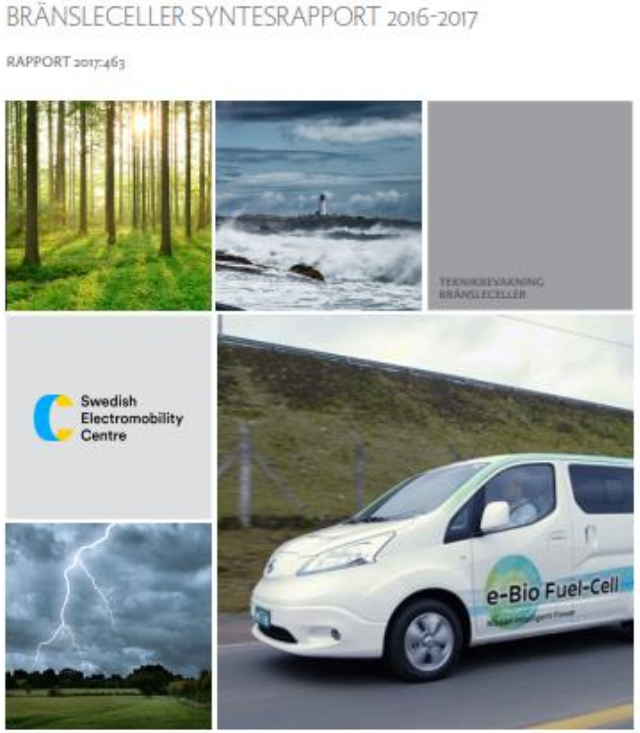
- FCV cars will increase but at what pace? Several car manufactures have now models ready for mass production
- Hydrogen infrastructure is essential for the expansion of the FCV
- Electrolyzers will be more and more important all kinds AEC, PEMEC and SOEC
- The electrification of heavy trucks will open up for fuel cells, Toyota, Hyundai, Nikola etc
- China is coming with buses and heavy vehicles
- Stationary fuel cells can have bright future especially for emergency and remote power
- The future for MCFC looks difficult
- Subsidies are back: The US tax credit program and NEDO ENE-Farm is extended

- The overall market is still fragile as it depends heavily on subsidies
- The broad introduction of FCV is depending on the deployment of the hydrogen infrastructure
- The European market is slow and is still in the demonstration phase
- How much of the hydrogen will be green from renewable sources?
- The utilities are under pressure and they have difficulties to invest in fuel cell projects

Two reports are coming

Synthesis report covering the SEC fuel cell programme and other public funded activities in Sweden and FFI, IEA and EU

Fuel cell market report: latest news the global market, international programs, EU, IEA and analysis and comments for stakeholders in Sweden



GM Electrovan 1966 with technology from NASA Apollo program

Tack för att ni lyssnade !

Energiforsk

Swedish Electromobility Centre

Energimyndigheten


SWECO

SWECO

Callux

- Period: **2008 – 2015**
- Total budget: **€75 million**
- German NIP co-financing: 50%
- **500 systems installed in Germany**
- > 5 million operating hours
- **CO_2 reduction by 30% on average per year**

ene.field

- Period: **2012 – 2017**
- Total budget: **€52 million**
- EU co-financing (FCH JU/FP7): 50%
- **> 1,000 systems** installed in **11 European countries**
- > 3 million operating hours so far

PACE

- Period: **2016 – 2021**
- Total budget: **€90 million**
- EU co-financing (FCH JU/Horizon 2020): 37%
- **> 2,500 systems** to be installed in **11 European countries**
- **500 units/manufacturer**

KFW433

- Period: **started in 2016**
- **German NOW NIP grant scheme** administered by KfW bank
- Beneficiaries: **End customers**
- Eligible size: 0.25 kWe – 5 kWe
- Grant value per system: **€5,700 – €28,000**

Fuel Cell micro-Cogeneration units have demonstrated initial technology readiness in previous European and national demonstration projects

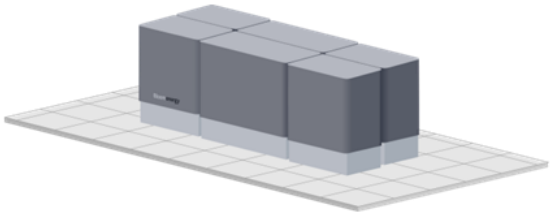
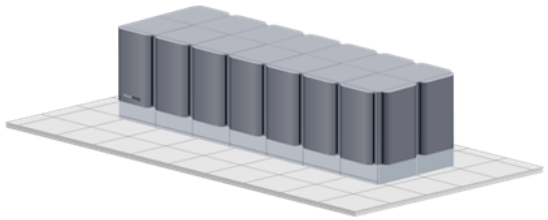
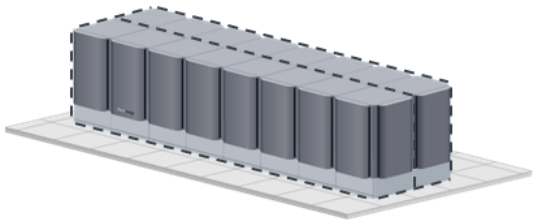
Fuel cells 2018 Important events

- The shipment of fuel cells increased in 2018
- Costs of fuel cells are coming down
- The US tax credit system is reinstalled
- Bloom Energy on the stock market value 1200 MUSD
- New car models on the road ready for mass-production
- Heavy vehicles with fuel cells is an important issue
- Hyundai order on 1000 trucks for Switzerland
- The political interest is rising; EU ministers signed a European Hydrogen Initiative as Japan and China
- Electrolyzers are getting bigger and more efficient
- SFC are showing profit on DMFC fuel cells
- Large companies are taking position; Car companies, Bosch, Panasonic, AISIN, Toshiba is back

Daimler and Ford ceased their cooperation AFCC

China has started with buses and heavy trucks

Bloomenergy® Power Density Evolution

Capacity:	100 kW	200/250 kW	500 kW (2 x 250 kW)
			
	1st Generation	2nd Generation	Current Generation

MyFC and portable fuel cells have severe competition from power banks

Linocell 1X Powerbank 2600 mAh Blå

Extrabatteri för mobilen

Art. 96858 | Modellnr: 1X

99:90

MyFC aktiekurs

July 2017: 26.- SEK
Today below 1 SEK

En lyckad nyemission kan ge nytt hopp?

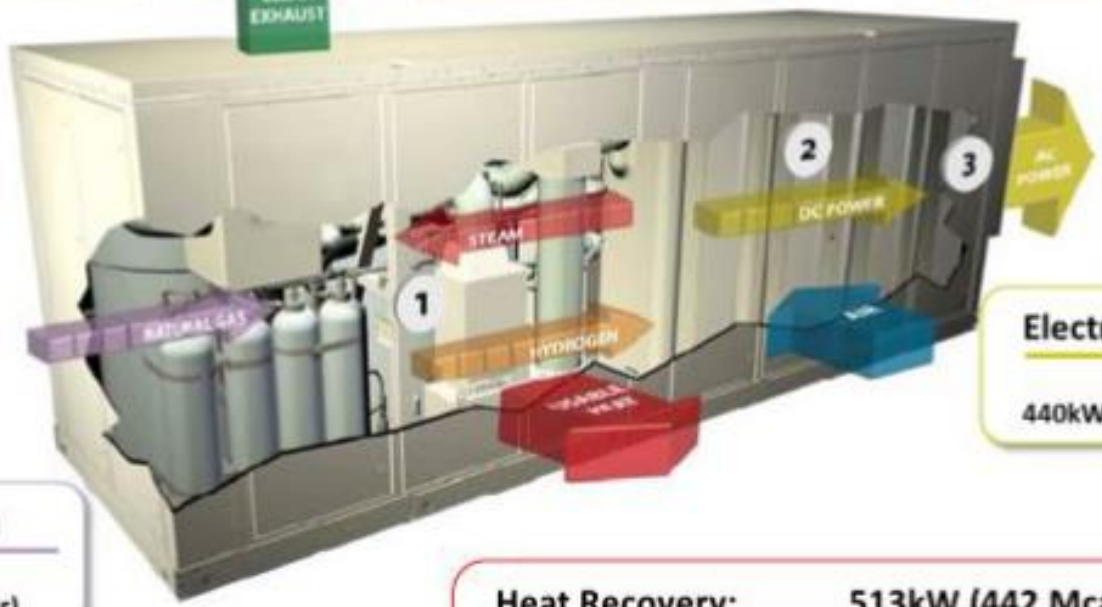
PAFC-Doosan

PURECELL® MODEL 400 PROCESS OVERVIEW

1 Fuel Processor
Converts natural gas fuel to hydrogen

2 Fuel Cell Stack
Generates DC power from hydrogen and air

3 Power Conditioner
Converts DC power to high-quality AC power



Overall System Efficiency 90%

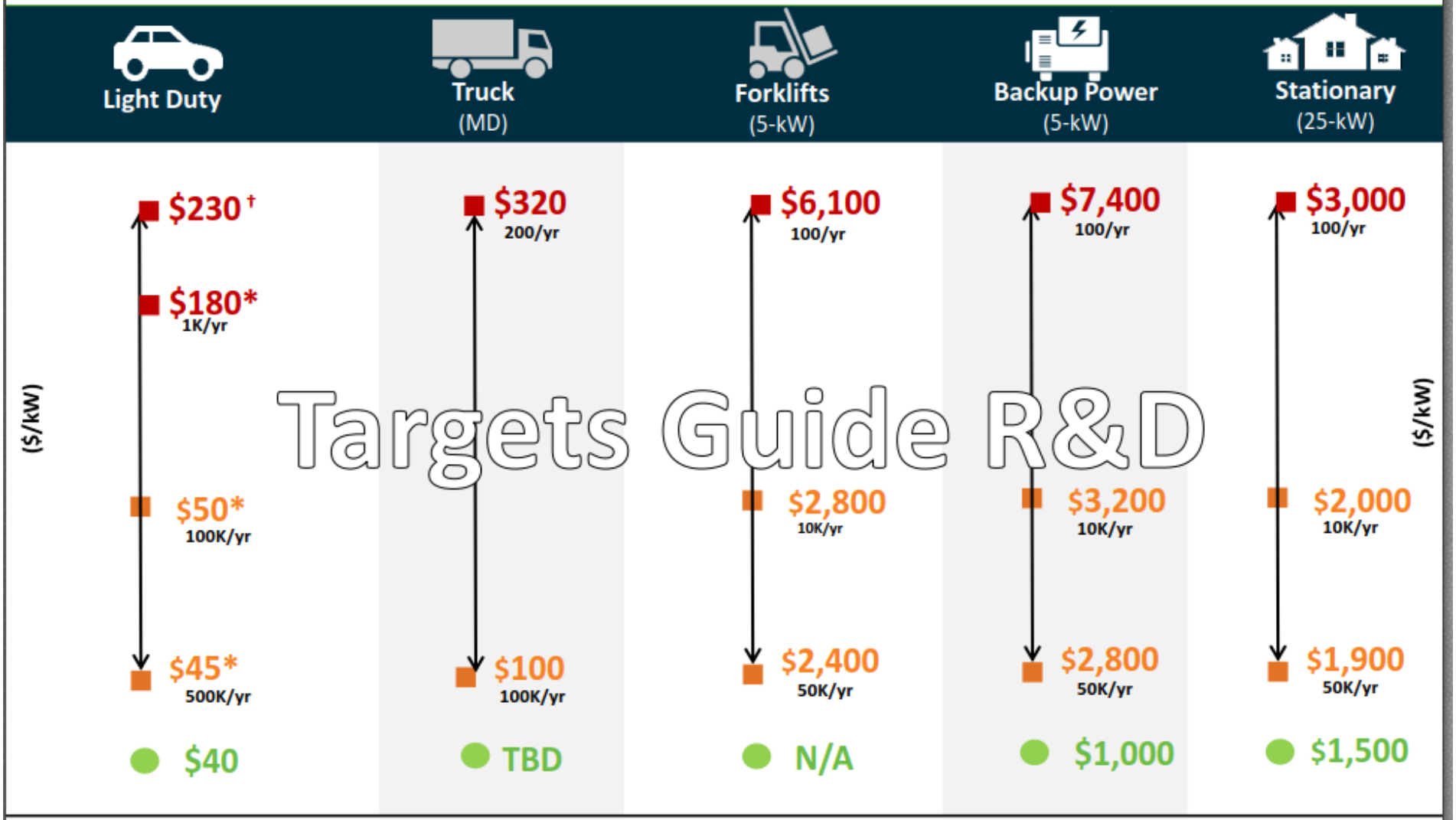
Electric Output: 41%
440kW, 480V, 50/60Hz

Fuel Input (LHV)
Natural gas
1071 kW (921 Mcal/hr)

Heat Recovery: 513kW (442 Mcal/hr)

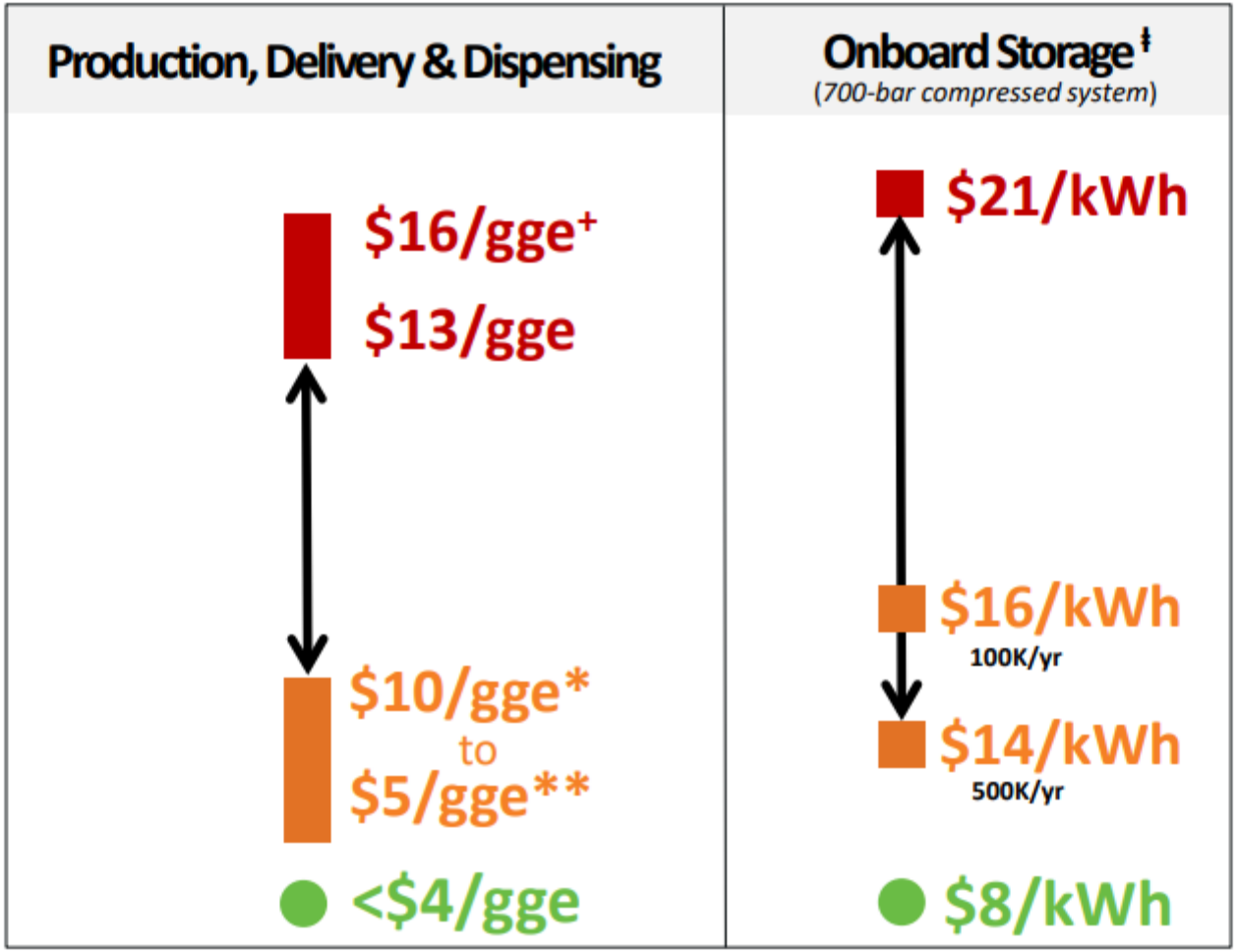
High-Grade up to 120℃	223kW (192 Mcal/hr)
Low-Grade up to 60℃	290kW (250 Mcal/hr)

DOE fuel cell system cost vs. targets



†Based on commercially available FCEVs *Based on state of the art technology Note: Graphs not drawn to scale and are for illustration purposes only.

Cost Targets and Status



† Range assumes current production from NG and delivery and dispensing
* Highest possible cost at high vol., assumes H2 from electrolysis at $5/gge and delivery via pipelines and liquid tankers at $5/gge
** Lowest possible cost at high vol., assumes H2 from SMR at $2/gge and delivery via tube trailer at $3/gge
ǂ Storage costs based on preliminary 2019 storage cost record

Ultimate Targets | High-Volume Projection | Low-Volume Estimate

Notes: Graphs not drawn to scale and are for illustration purposes only. gge: gallon of gasoline equivalent

Program Mission and Strategies

Early Stage R&D

Fuel Cells	Hydrogen Fuel	Infrastructure R&D
• PGM - free catalysts • Durable MEAs • Electrode performance	• Production Pathways • Advanced materials for storage	• Safety • Manufacturing • Delivery components • Others

PGM = Platinum group metals

MEA = Membrane Electrode Assembly

Mission

Applied research, development, and innovation in hydrogen and fuel cell technologies leading to:

- Energy security
- Energy resiliency
- Strong economy

Program Mission and Strategy

Early R&D Focus

Applied research, development and innovation in hydrogen and fuel cell technologies leading to:

- Energy security
- Energy resiliency
- Strong domestic economy

Key R&D Sub-Programs in Budget Request

Fuel Cells

- Cost, durability
- Components - catalysts, electrodes, etc
- Increase focus beyond LDVs

Hydrogen Fuel

- Cost of production across pathways
- Cost and capacity of storage, including bulk/ energy storage

Infrastructure R&D

- Cost and reliability of infrastructure
- Delivery components, supply chain
- Safety

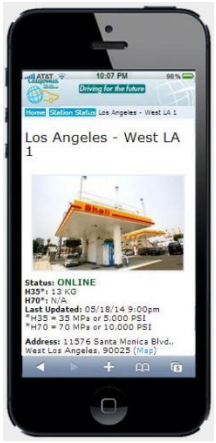
New in FY19 Budget Request

Enabling

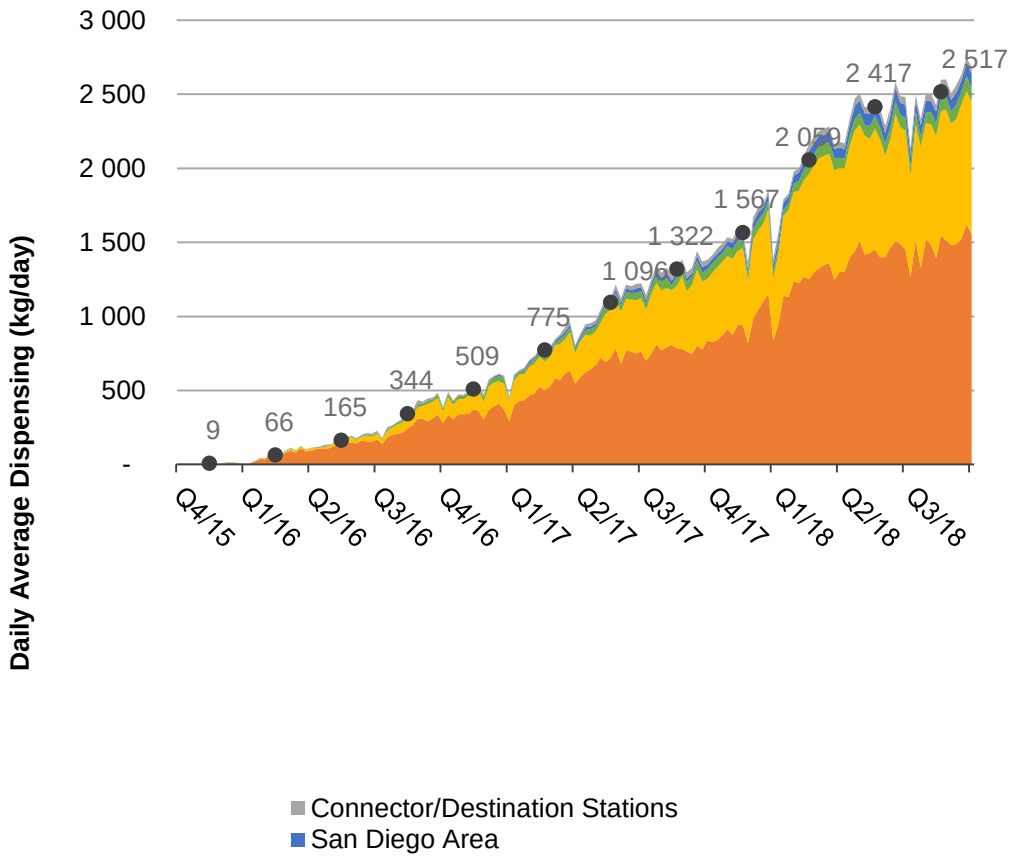
H2@Scale
U.S. Department of Energy

California's Experience – Customer Focus!

- The technology works – customers are coming!
- Need to know where, when and if HRS are available
- Quarterly CaFCP webinars for customers and stakeholders



http://m.cafcp.org

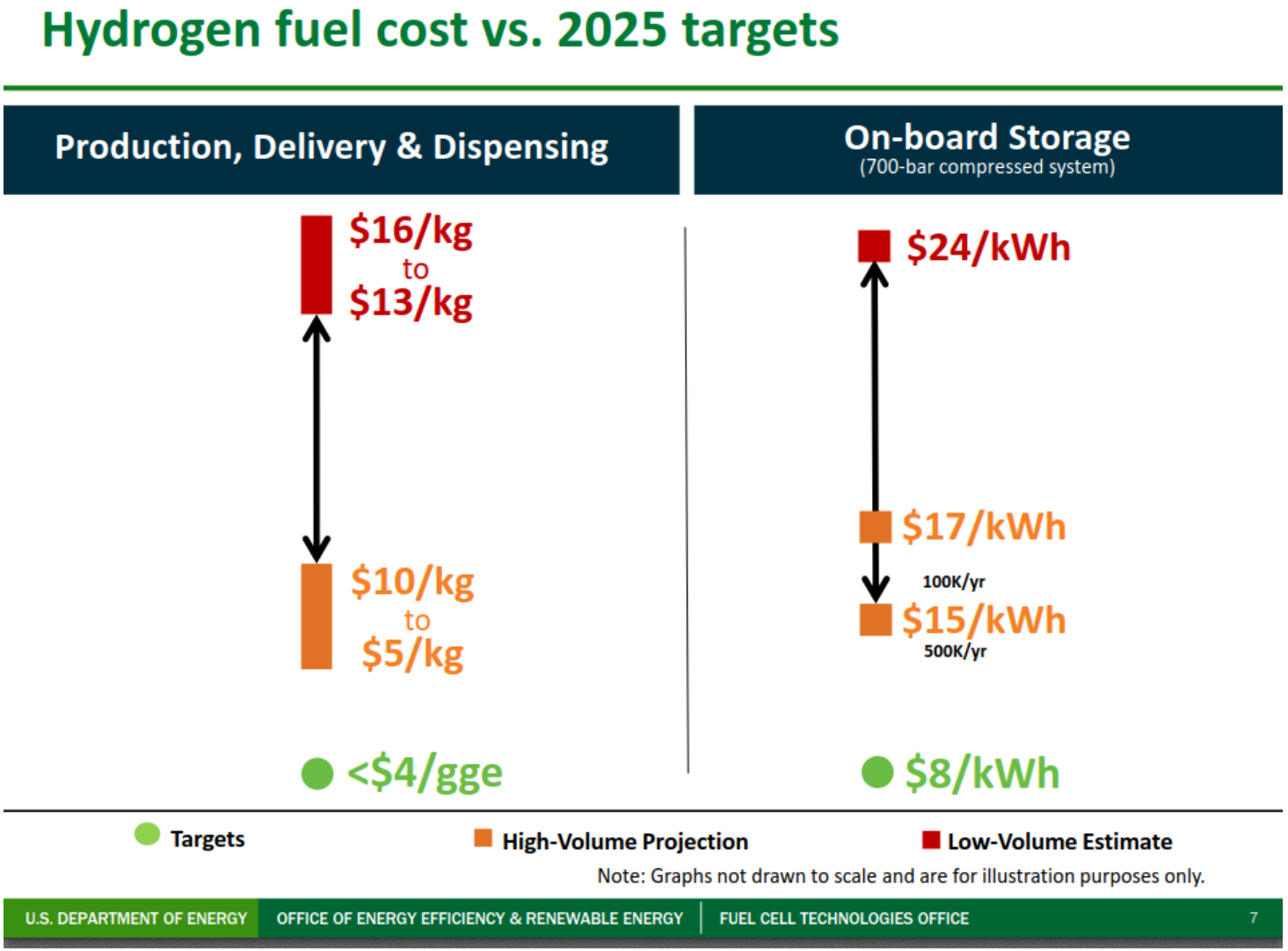


Megawatts by region of adoption					
Megawatts	**2014**	**2015**	**2016**	**2017**	**2018f**
Europe	9.9	27.7	27.4	38.9	43.4
N America	69.8	108.4	213.6	331.8	415.0
Asia	104.5	159.7	273.8	285.8	343.3
RoW	1.2	2.3	1.7	2.1	1.4
Total	**185.4**	**298.1**	**516.5**	**658.6**	**803.1**

Megawatts by fuel cell type					
Megawatts	**2014**	**2015**	**2016**	**2017**	**2018f**
PEMFC	72.7	151.8	341.0	466.7	589.1
DMFC	0.2	0.2	0.2	0.3	0.4
PAFC	3.8	24.0	56.2	81.0	97.3
SOFC	38.2	53.3	62.9	85.2	91.0
MCFC	70.5	68.6	55.7	24.7	25.2
AFC	0.0	0.2	0.5	0.6	0.1
Total	**185.4**	**298.1**	**516.5**	**658.6**	**803.1**

In California is the price at the gas station 16 USD per kg.

On-board storage is still expensive it is the carbon fibre that is the problem



The near future fuel cells ?!

- Air quality, local environment is a growing issue as well as GHG emissions
- Fuel cells are rapidly improving performance and lower cost is on its way
- More fleets of FCV taxi etc Paris 100 today and bus fleet
- Range extenders Renault Kangoo expanding now a new model 40 kW
- Hydrogen as fuel for stationary fuel cells has increased and especially by-product hydrogen as fuel is an expanding market
- Emergency power for telecom and data centres are growing important markets
- The developers from Japan Panasonic, Toshiba and AISIN have started export and high volume production
- Stack developers are supplying system builders ex Ballard, Kyocera, Powercell

- The overall market is still fragile as it depends heavily on subsidies
- The European market is slow and is still in the demonstration phase
- Several important Governmental programme are under discussion
  - the US tax credit program 3000 USD/kWe ended 2016 and the US Hydrogen program will in 2018 be less than half of 2017
  - In Japan the Ene-Farm is still expanding but the subsidies are decreasing
- The utilities are under pressure and they have difficulties to invest in fuel cell projects