Hydrogen for transport
The case & status for Denmark

October 2012
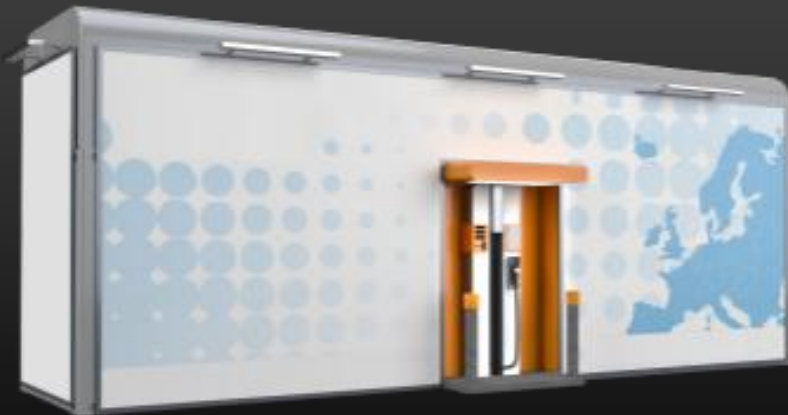
About H2 Logic A/S

- **Established 2003 | 38 employees**

- **Ownership by four founders (~85%) and board of directors (~15%)**

- **R&D & manufacturing of two focused products within hydrogen & fuel cells**

- **Accumulated positive profit since 2003 – all profit spent on continued growth**

- **+30% annual growth in turnover – continued annual target**

H2Station®
Hydrogen refueling for vehicles

H2Drive®
Fuel cell power for Material Handling

THE CHALLENGE
## Gasoline does a good job...for now!

Gasoline 3 min. 30 times a year = freedom

- **Challenge:**   Gasoline does a good job – as long as there is enough

- **Alternatives:**   Have to match gasoline to achive a high market share

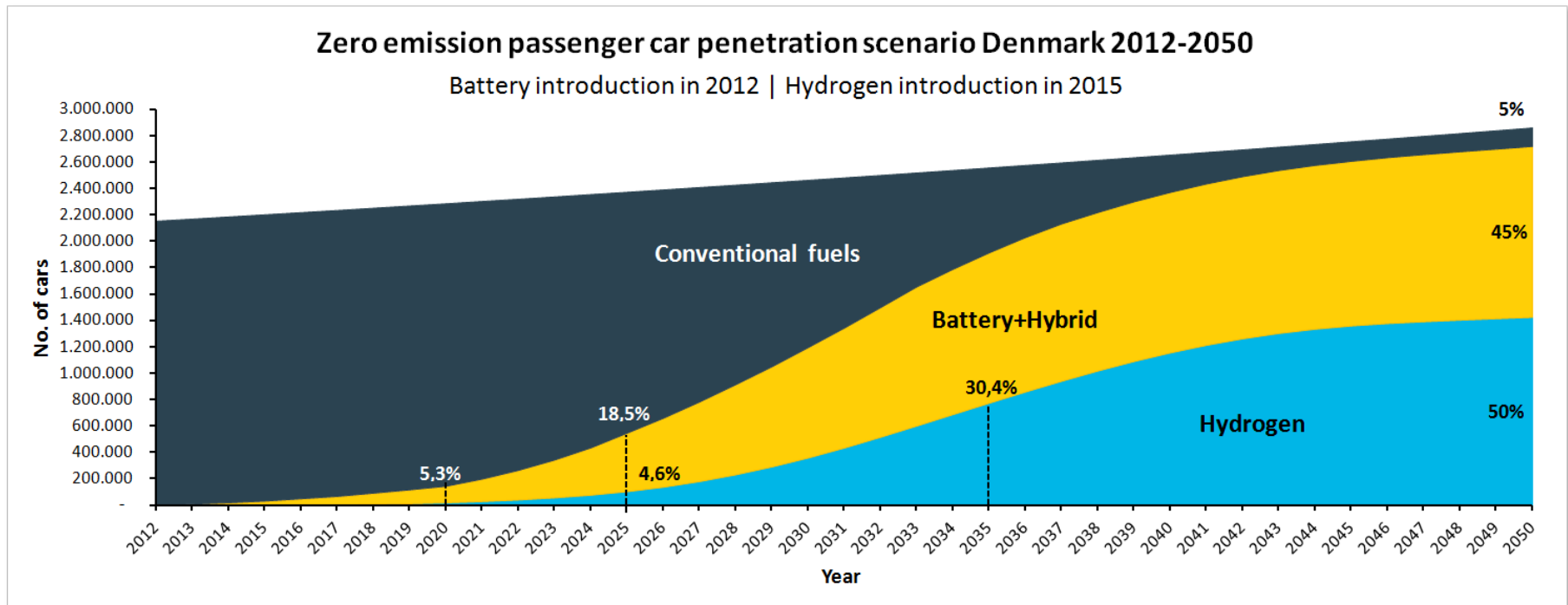- **Requirements:**   Fast refueling, everywhere & long range in all weather

Mercedes B 180 - Gasoline

- **2.000 stations**
- **2,1 million cars**
- **1.000 cars/station**

Tank content:	**50 liter**
NEDC consumption:	**16,5 km/liter**
NEDC Range on full tank:	**825 km**
Refueling time:	**<3 min.**
Km/year (average):	**15.000**
No. of 30 liter refueling's pr. year:	**30 units**

NB: Consumption is higher than NEDC in real life, thus range is less and more refueling's are need per year.
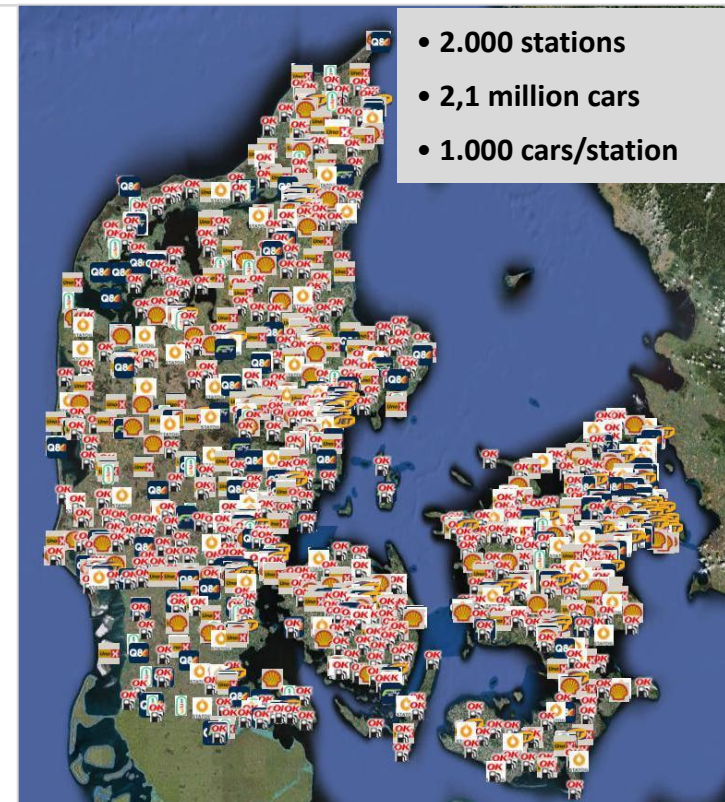
100% zero emission vehicles by 2050 in DK

- Danish political goal to reach 100% fossil independence by 2050

- Requires entire car fleet by 2050 to become zero emission

- Biofuels prioritized for heavy duty transport – leaving only electricity for cars

- Battery vehicles limited to smaller cars with short range (~50% of car fleet)

- Fuel cells provides long range for normal sized cars (~50% of car fleet)

Zero emission passenger car penetration scenario Denmark 2012-2050
Battery introduction in 2012 | Hydrogen introduction in 2015

THE SOLUTIONS & HOW?
Among others hydrogen… it takes a bottle of wine!

Hydrogen almost matches gasoline today

- **Hydrogen provides same performance as gasoline & almost same range**

- **Fuel economy almost twice as good – pure water as exhaust**

- **Price reduction through volume production is next necessary step**

Fuel	HYDROGEN	GASOLINE
Model	iX35 FCEV	iX35 2.0 Aut. Premium
Power (kW/Nm)	124kW / 300Nm	120kW / 194Nm
Performance (top/acc.)	160 km/h / 14,0 sec.	182 km/h / 10,6 sec.
Transmission	Automatic	Automatic
Range (NEDC)	525 km	725 km
Fuel economy (NEDC – Gasoline Equivalent)	25,5 km/liter GE	12,5 km/liter gasoline
Pric / production	Too expensive – prototype	Affordable? – mass production

The technology works – also in cold weather

- **55.000 km since May 2011 in two Hyundai fuel cell vehicles in Denmark**

- **Cross country driving without stop or refueling – aprox. 350 km on highway**

- **Fuel economy ranges from 20-30 km/liter gasoline equivalent**

- **No problem with start or operation in cold weather – limited impact on range**

- **Long time parking in below minus 20 degrees – operation down to minus 41,5 degrees**

Same fast refueling & range as today

- **Global established standards for nozzle & refueling** (SAE J2600, J2601 & J2799)

- **Refueling of 500+ km range in 3 minutes**

- **Hydrogen production onsite from renewable energy or trucked-in**

- <u>**Hydrogen pump price competitive today on a cost per driven km basis**</u>

H2Station® i Oslo, Norge

Hydrogen pump price – same as gasoline

- Hydrogen pump to price match gasoline on fuel cost per/km

- Hydrogen price should reflect today's Willingness To Pay (WTP) per driven km

- Gasoline will be the dominating fuel ➔ 2050 – thus hydrogen to be priced against this

- Hydrogen pricing should therefore take into account the higher fuel efficiency of FCEV's

WTP Hydrogen price in Denmark - July 2012 (Willingness to Pay)			
	Fuel sales price *Incl. tax & profit*	**NEDC Consumption** *km/L or kg/100 km*	**Price/km** *€/km*
GASOLINE	**€1,76/liter*** ⟶	**15,15 km/liter**** ⟶	**€0,12/km**
HYDROGEN	**€1,16/100 gram** *8,66 DKK/100 gram*	**1 kg/100 km*** ** ⟵ 27 km/Gasoline Equivalent (GE)	**€0,12/km**

* Average 95 octane gasoline price @ dispenser in Denmark past 12 months – The Danish Petroleum Association www.eof.dk

** Average NEDC fuel efficiency for Danish car fleet – calculated on data from Statistics Denmark - www.dst.dk

*** Actual NEDC fuel efficiency for latest FCEV generations in operation – Daimler, Hyundai, Toyota & GM

FCEV's & BEV's supplements each other

- BEV's are ideal for short trips and smaller cars where slow charging is acceptable

- FCEV's are ideal for longer trips and <u>larger cars</u> where fast refueling is required

Car model & type	Nissan Leaf - BEV	Hyundai iX35 - FCEV
Power	109kW / 280Nm	124kW / 300Nm
Top speed & acceleration (0-100km/h)	145 km/h / 11,9 sec.	160 km/h / 14 sec.
Vehicle weight (running order)	1.525 kg	1.920 kg
Recharging / Refueling time	0,5-7,5 hours	3 minutes
Range (lowest & NEDC)	80-175 km	600 km
Cold weather & cabin heating impact on range	Yes: >30%	ed: 5-10% less
Fuel economy (NEDC - Gasoline Equivalent / Wh)	52 km/lite (173 W	5km/liter GE (353 Wh/km)
Fuel cost per driven km (15.000 km/year)	0,74 DKK/km	0,92 DKK/km
Total fuel cost per year (NEDC)	€1.486	€1.844
Fuel provider	Clever A/S	@ DK H2 stations

Fast refueling & long range Only €350/year

Car manufacturers aim for hydrogen by 2015

o All major car manufacturers aim for market introduction of fuel cell vehicles beyond 2015

o Since a major car manufacturer MoU in 2009, several initiatives have been launched

GLOBAL:	*2009: Car manufacturer MoU on 2015 market introduction*
GERMANY:	*2009: Government/company MoU on German hydrogen infrastructure*
JAPAN:	*2011: Energy/car company MoU on Japanese hydrogen infrastructure*
SCANDINAVIA:	*2011: Market collaboration MoU with Hyundai/KIA*
DENMARK:	*2011: Car manufacturer support letter for Everfuel A/S*
	2012: Car manufacturer support letter to Danish Government
UK:	*2011: Government/company MoU on UK hydrogen market analysis*

DAIMLER Ford GM OPEL HONDA HYUNDAI KIA RENAULT NISSAN TOYOTA Shell TOTAL VATTENFALL
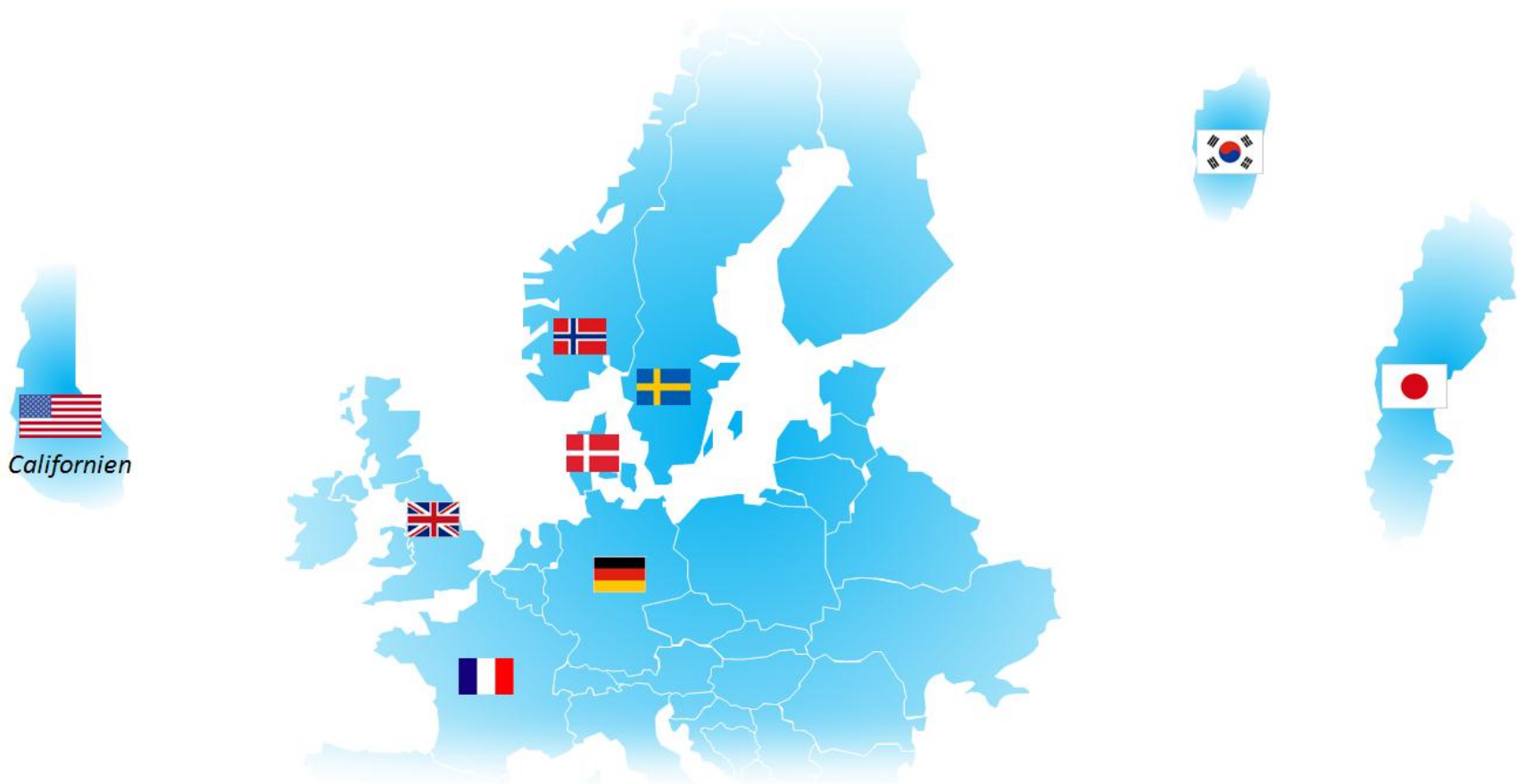
Planning of 2015+ market introduction

Global partnerships plan the roll-out of vehicles & infrastructure

Roll-out of hydrogen refueling in Denmark

- A staged roll-out - ensuring availability of refueling to the growing fuel cell vehicle fleet

- Appropriate public market support mechanisms to ensure attractive investment case

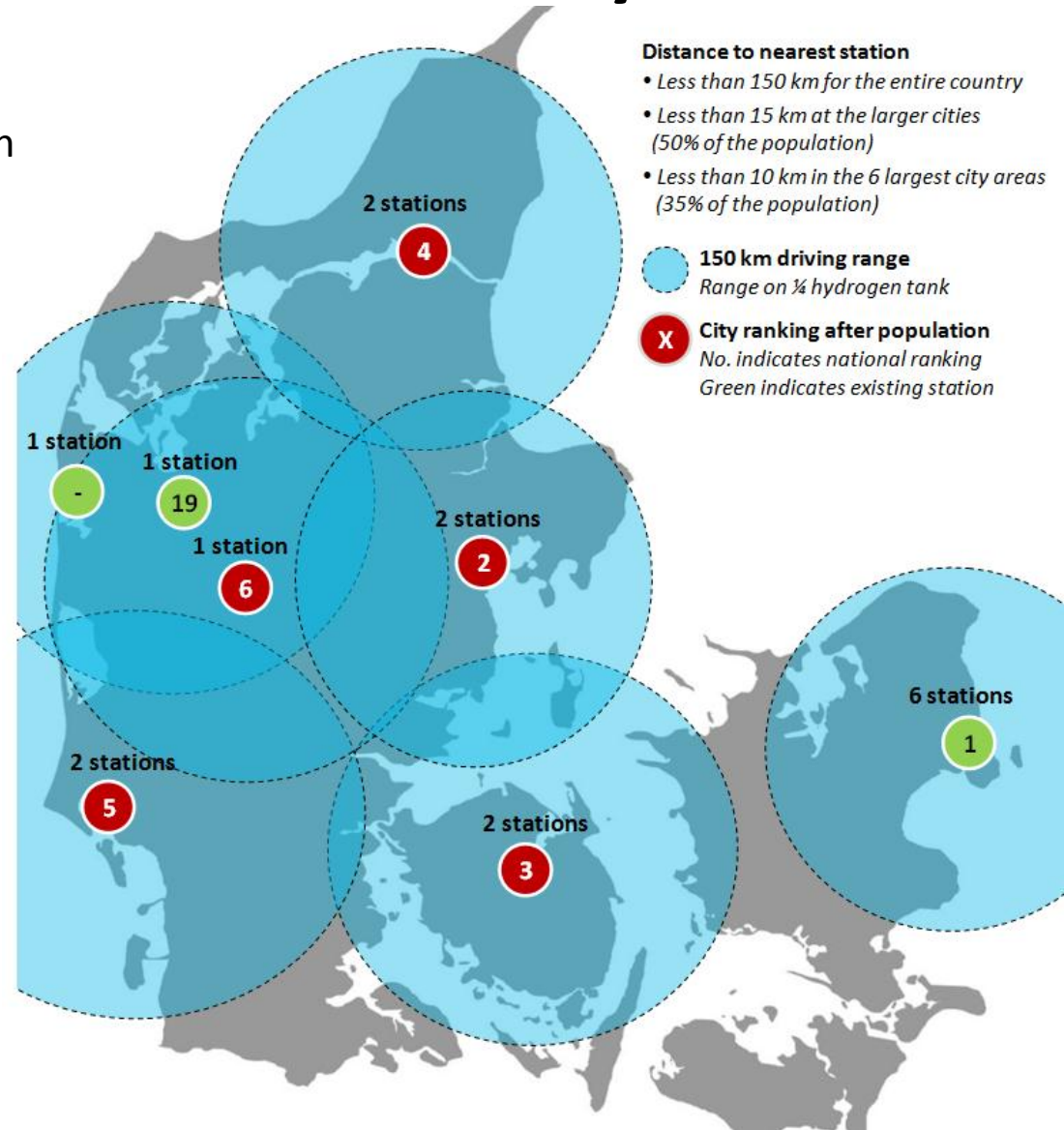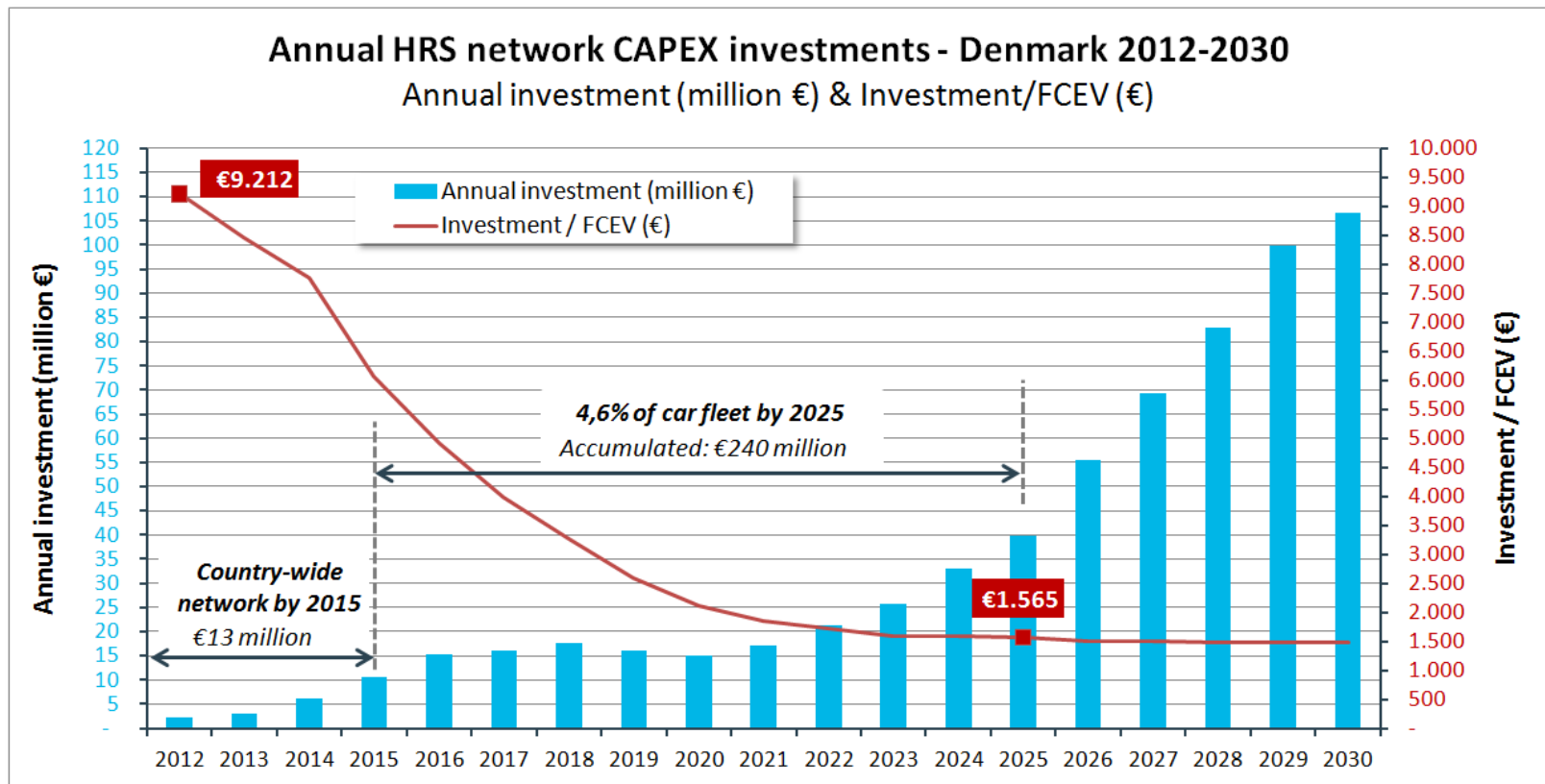| 2012-2015 Country-wide network	2015-2025 Build-up of critical volume	2025-2050 Commercial deployment
15 stations / €13 million	185 stations / €240 million	450-1.000 stations
50% public CAPEX support	30% public CAPEX + fuel support	Commercial market terms
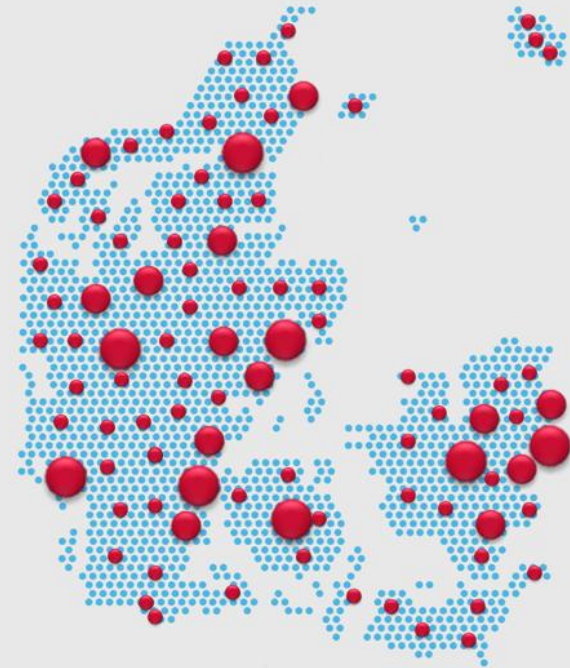
Danish country-wide HRS network by 2015

- A country-wide network of 15 HRS can enable FCEV market introduction

- The network will ensure less than 150 km to nearest station – equivalent to ¼ tank of hydrogen

- 50% of population will have less than 15km to nearest station & 35% less than 10 km (largest cities)

- The large cities holds the majority share of car sales, thus also where market introduction will commence

- 2 HRS to be build in larger cities to ensure a dense network

Distance to nearest station
- Less than 150 km for the entire country
- Less than 15 km at the larger cities (50% of the population)
- Less than 10 km in the 6 largest city areas (35% of the population)

150 km driving range
Range on ¼ hydrogen tank

X City ranking after population
No. indicates national ranking
Green indicates existing station

2 stations — 4

1 station — -
1 station — 19
1 station — 6
2 stations — 2
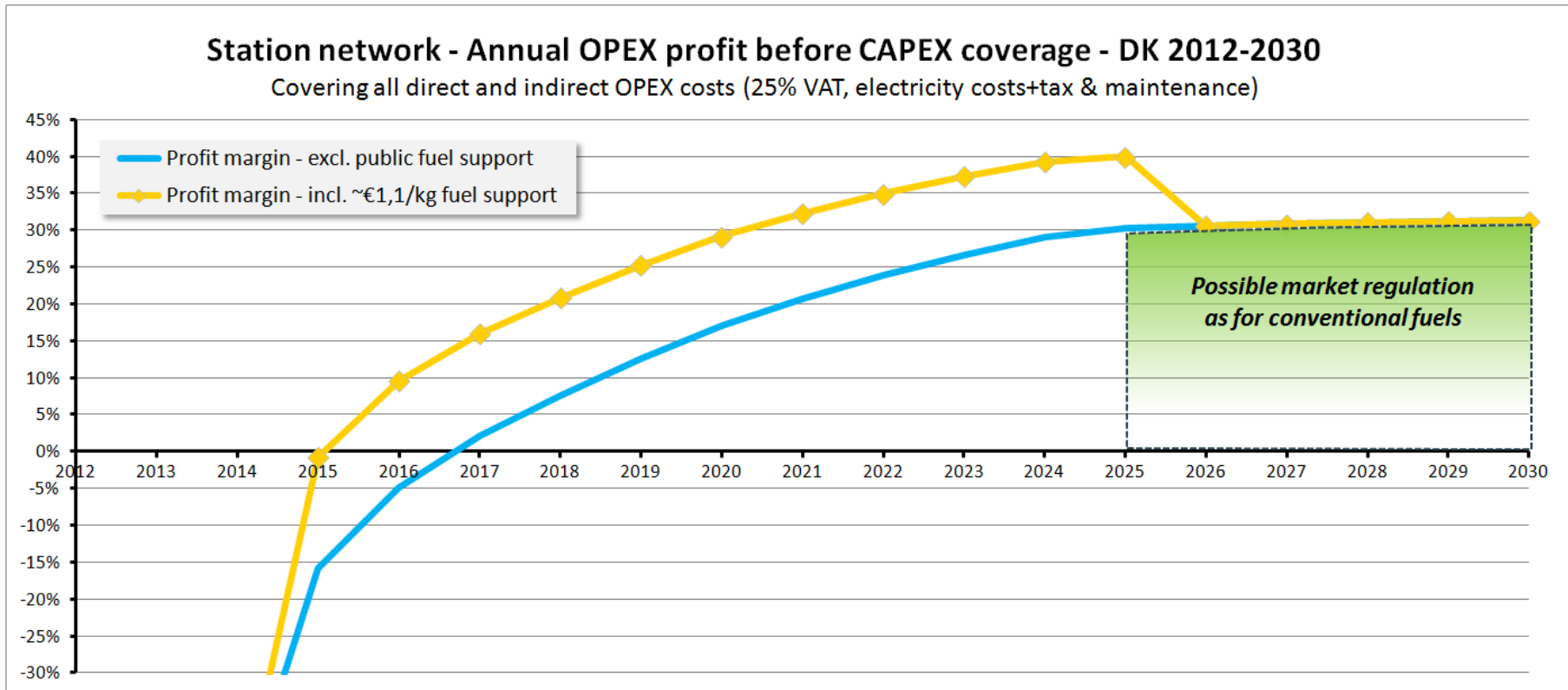2 stations — 5
2 stations — 3
6 stations — 1

Danish HRS network investment ➔ 2030

- A country-wide network of HRS's will require €13 million investments

- A network sufficient for 4,6% FCEV share of DK car fleet by 2025 will require additional €240 million

- During the years, size of HRS's are increased and cost of technology reduced

- Infrastructure investment per FCEV is therefore reduced from €9.212 (2010) to €1.565 (2025)

Annual HRS network CAPEX investments - Denmark 2012-2030
Annual investment (million €) & Investment/FCEV (€)

Legend:
- Annual investment (million €)
- Investment / FCEV (€)

€9.212

4,6% of car fleet by 2025
Accumulated: €240 million

Country-wide network by 2015
€13 million
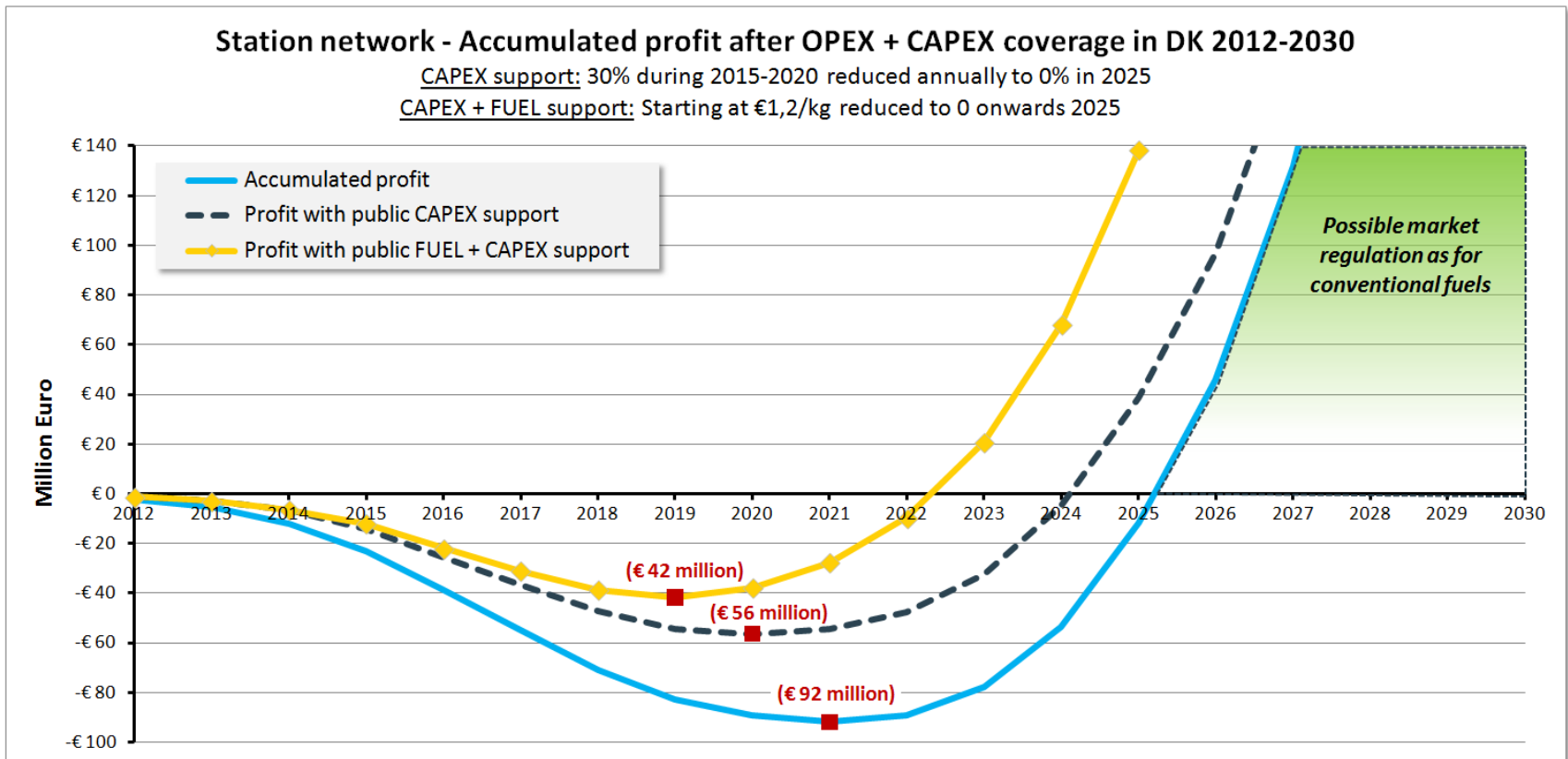
€1.565

Hydrogen Station network profit margin

- Network operation profit increase with growing utilization as FCEV fleet grows

- Hydrogen pump price competitive with gasoline – all applicable taxes are paid

- Profitable operation is reached during 2016 – without public fuel support

- Beyond 2025 hydrogen & profit margin may be regulated as conventional fuels

Station network - Annual OPEX profit before CAPEX coverage - DK 2012-2030
Covering all direct and indirect OPEX costs (25% VAT, electricity costs+tax & maintenance)

Legend:
— Profit margin - excl. public fuel support
— Profit margin - incl. ~€1,1/kg fuel support

Possible market regulation as for conventional fuels

Hydrogen Station network pay-back period

- No public support: break-even in **2025** – cash draw **~€92 million** in 2021

- With public CAPEX support: break-even in **2024** – cash draw **~€56 million** in 2020

- With public CAPEX+FUEL support: break-even in **2022** – cash draw **~€42 million** in 2019

- **CAPEX & FUEL support are exactly the same as given for biogas fuel today**

Station network - Accumulated profit after OPEX + CAPEX coverage in DK 2012-2030
CAPEX support: 30% during 2015-2020 reduced annually to 0% in 2025
CAPEX + FUEL support: Starting at €1,2/kg reduced to 0 onwards 2025

Public investment of 1 bottle of red wine

Danish public investments in support schemes 2015-2025

Vehicle tax exemption/reduction: *€200 million*

Hydrogen infrastructure CAPEX support: *€45 million*

Hydrogen fuel support: *€100 million*

TOTAL: **€345 million**

Equals 1 bottle of wine for every Dane per year, from 2015-2025

Questions.....

Danish hydrogen infrastructure analysis support by: