

## Part 4:

# Implementing green hydrogen supply for fuel cell buses in the Nordic countries

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nel.   
Number one by nature

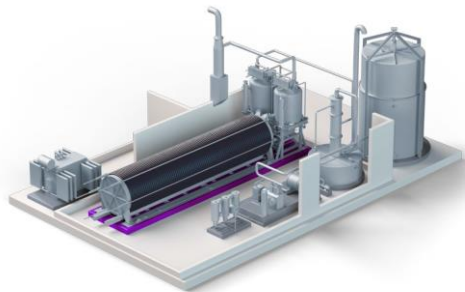
- World's largest pure-play hydrogen company with a market cap of more than \$250 million.
- 200 employees in Denmark, Norway and USA with world-class experience and skills.
- Offering hydrogen technology and solutions for industrial, energy and transport applications.
- More than 3500 hydrogen solutions delivered in 80 countries world wide since 1927.
- World #1 on hydrogen electrolyzers and hydrogen fueling – unrivalled performance and track-record.



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**ALKALINE ELECTROLYSERS**

Dates back to 1927



**PROTON**  
ON SITE

**PEM ELECTROLYSERS**

Acquired in 2017



**H<sub>2</sub> Logic**  
Hydrogen Fuel Cell Motive Power Solutions

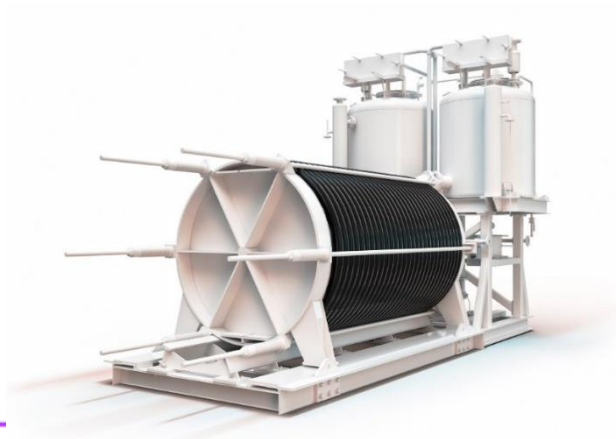
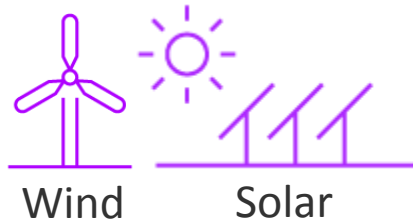
**HYDROGEN FUELING**

Acquired in 2015



# Nel Hydrogen: Zero emission – Zero compromise

- Nel Hydrogen provides solutions for renewable production and fast fueling of hydrogen with long driving range.
- Enables zero emission transport based on renewable energy with the same convenience and performance as gasoline.



**Electrolysers**  
Hydrogen production



**H2Station®**  
Hydrogen fueling



**Fuel Cell Bus**  
<10 min. fueling 400+km range  
20-40 kg per fill



**Fuel Cell Car**  
<5 min. fueling 500+km range  
4-7 kg per fill

# Large scale hydrogen electrolyzers since 1927



Delivered the world's largest electrolyser  
in 1950s on 135 MW / 30,000 Nm<sup>3</sup>/h

# H2Station<sup>®</sup> hydrogen fueling solution

Turn-key standardized hydrogen fuelling station with dispensers for cars, busses, trucks and forklifts.

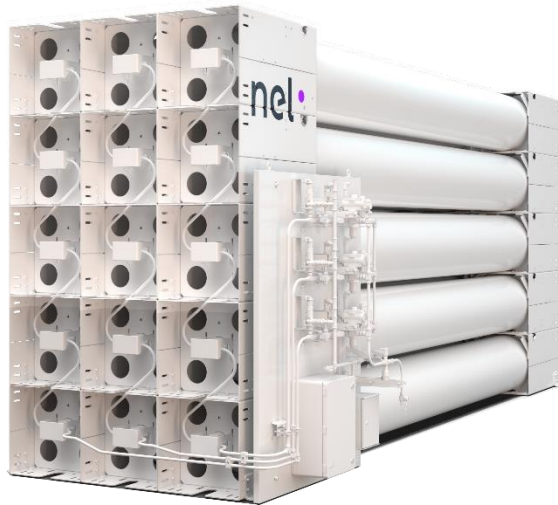
200kg per day at 70MPa or up to 600kg/day for 35MPa – all fast fuelling in accordance with SAE J2601.

Flexible configuration of hydrogen storage and fuelling capacity – very compact total footprint.

Can connect to various hydrogen supply sources e.g. onsite production or trucked-in delivery.



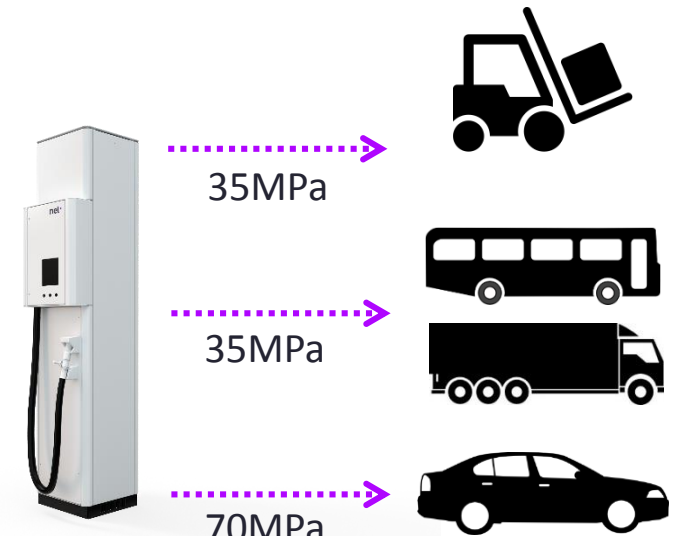
Supply Cabinet



Supply & Fueling Storage



Station Module



Dispensers

# New H2Station<sup>®</sup> manufacturing facility in Denmark



H2Station<sup>®</sup> manufactured  
at world's largest factory

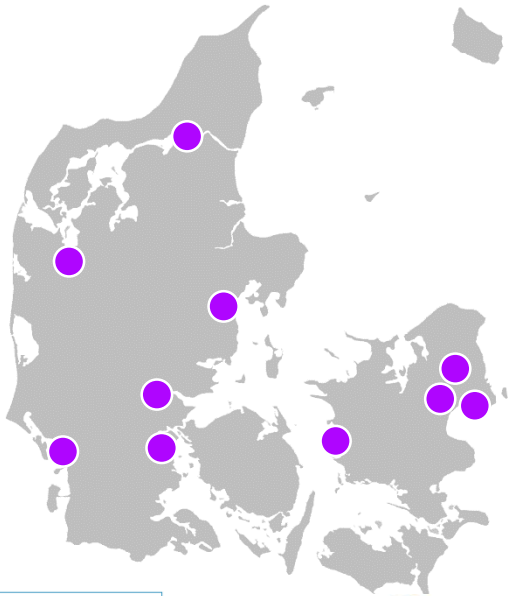
300 H2Station<sup>®</sup> per year – sufficient for  
fueling 200.000 new FCEVs annually.  
€9 million initial investment.



Nel Hydrogen has delivered more than 30% of 70MPa hydrogen fueling stations in Europe since 2011 and is now entering CA. In Denmark and Norway and Iceland entire countrywide networks are deployed in collaboration with oil and gas companies.

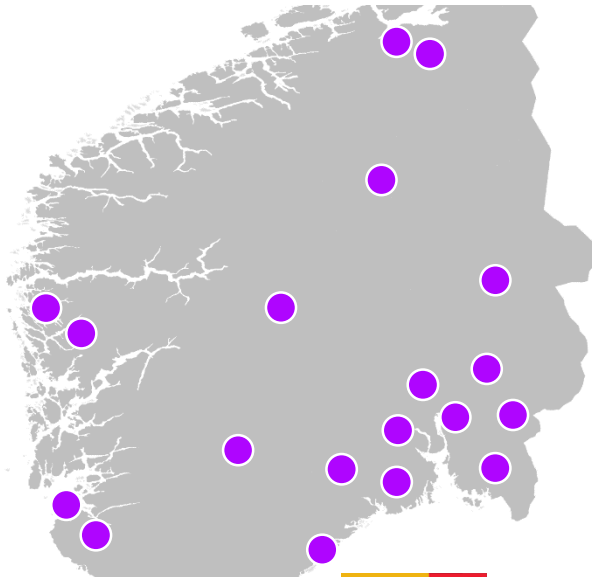
## DENMARK 2011-2016

10 H2Station<sup>®</sup> and  
Hydrogen production



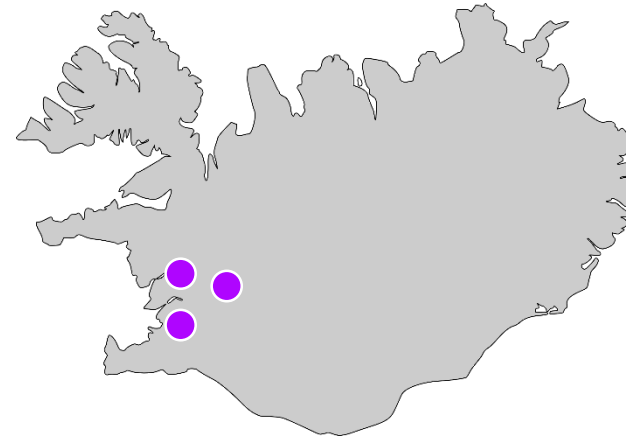
## NORWAY 2016-2020

Up to 20 H2Station<sup>®</sup> and  
Hydrogen production



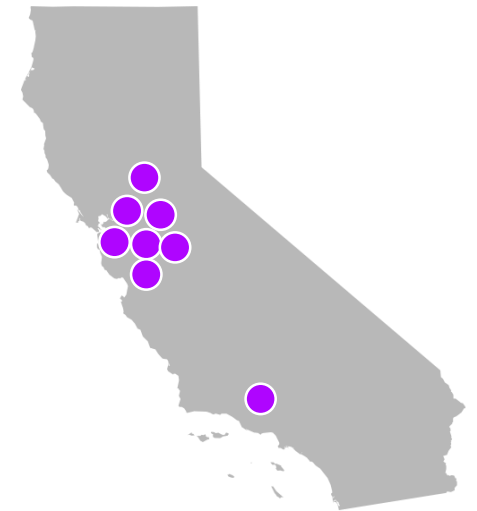
## ICELAND 2017-2020

3 H2Station<sup>®</sup> and  
Hydrogen production



## CALIFORNIA 2017-2018

Multiple H2Station<sup>®</sup> in San  
Francisco and Los Angeles



# First H2Station<sup>®</sup> for busses (2013)

- Customer:** Solvay, Antwerp, Belgium.
- Capacity:** 400kg/day – prepared for upgrade to 800 kg/day.
- Supply:** Pipeline from nearby industrial surplus hydrogen production.
- Fuelling:** 35MPa – up to 40kg/fuelling in 10 minutes @ 25°C.
- Protocol:** Patented fuelling protocol ensuring 10-15 min. fuelling and high State-of-Charge.
- Operation:** Since Dec. 2013 – more than 13.799kg / 823 fuelings by June 2017

**We are currently building new bus fueling stations in Riga and on Island**

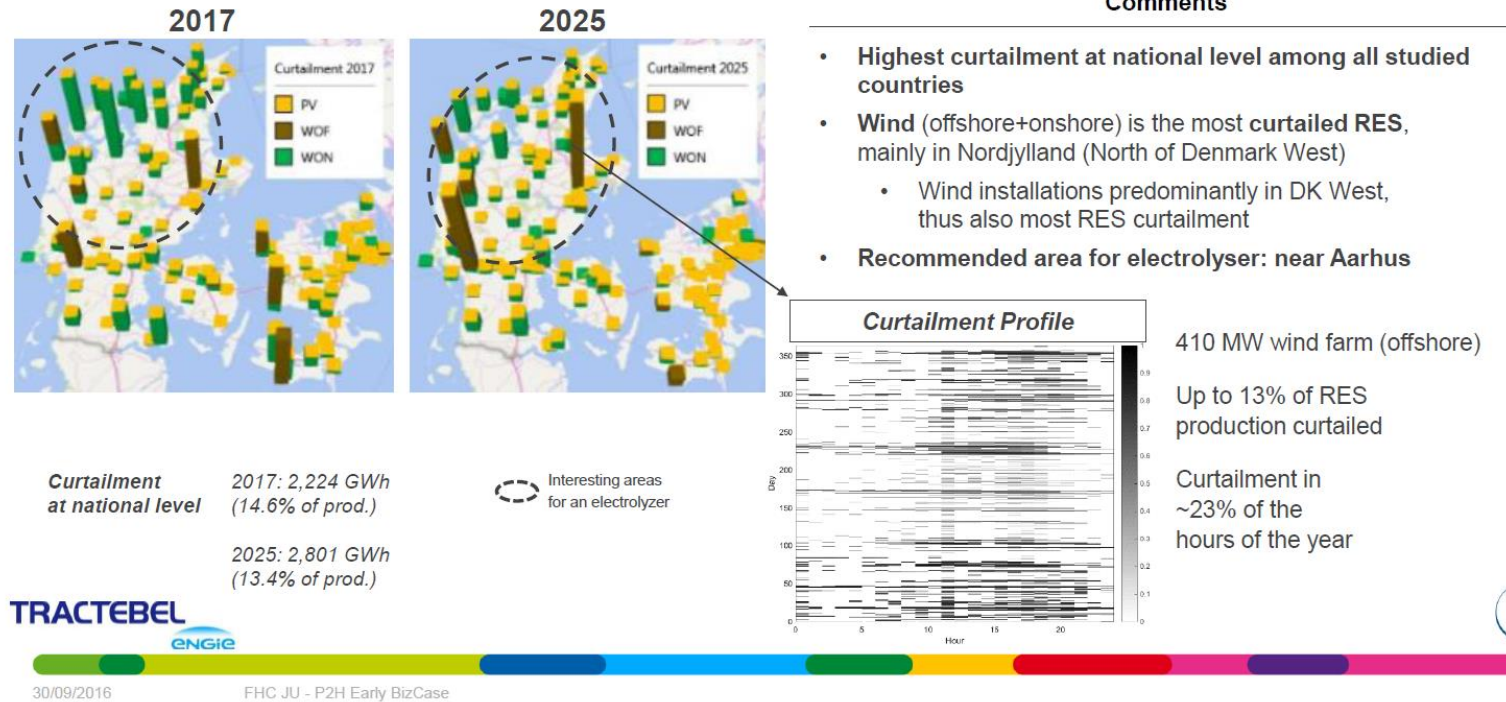




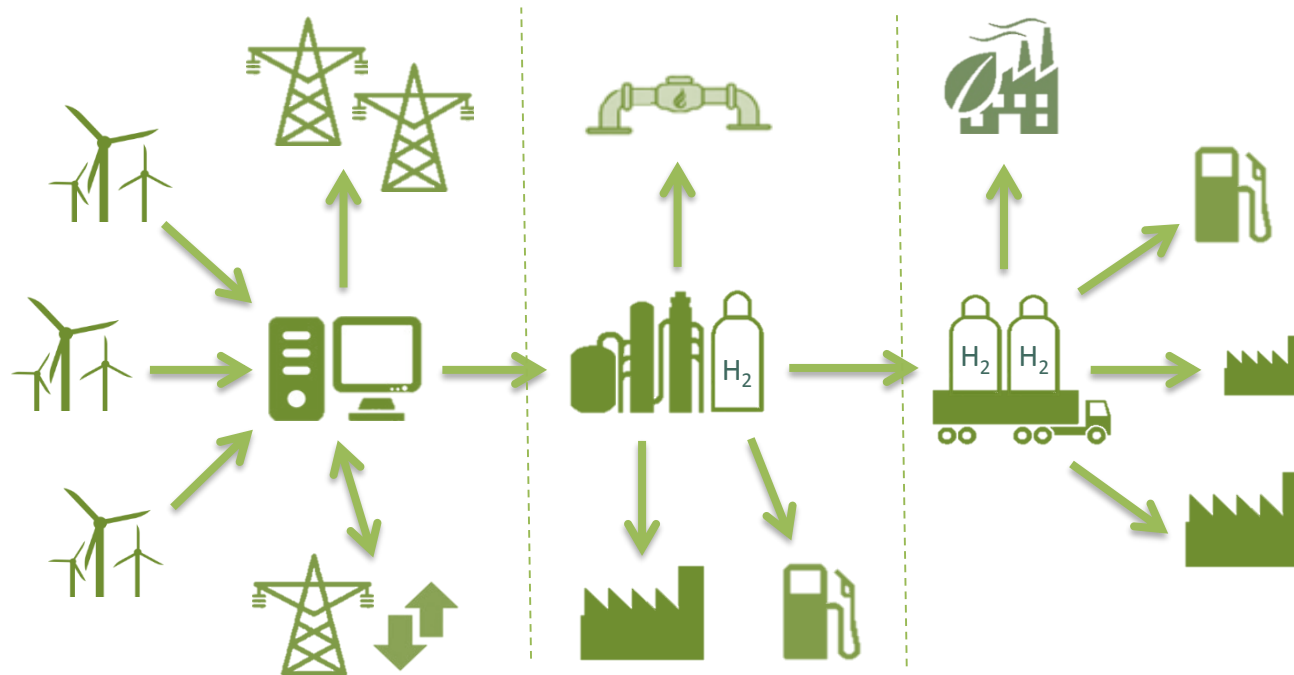
2017: 2.2 TWh curtailment in DK to avoid negative spot price.

- Electrolysis provide the needed flexibility. Conversion of wind overproduction to a valuable hydrogen fuel.
- Hydrogen can be easily stored
  - High pressure vessels
  - Or Salt caverns
- Transportation fuels are high value

## Danish system showing East-West split with high RES curtailment in Western part



- Via electrolysis, excess Wind Energy is converted to hydrogen and utilized in several sectors
  - Enables access to a cheap 100% green alternative for transportation and in numerous industrial applications
  - Sustains RE-business cases *and* drives the vital sector coupling - benefitting all participants



## Hydrogen today:

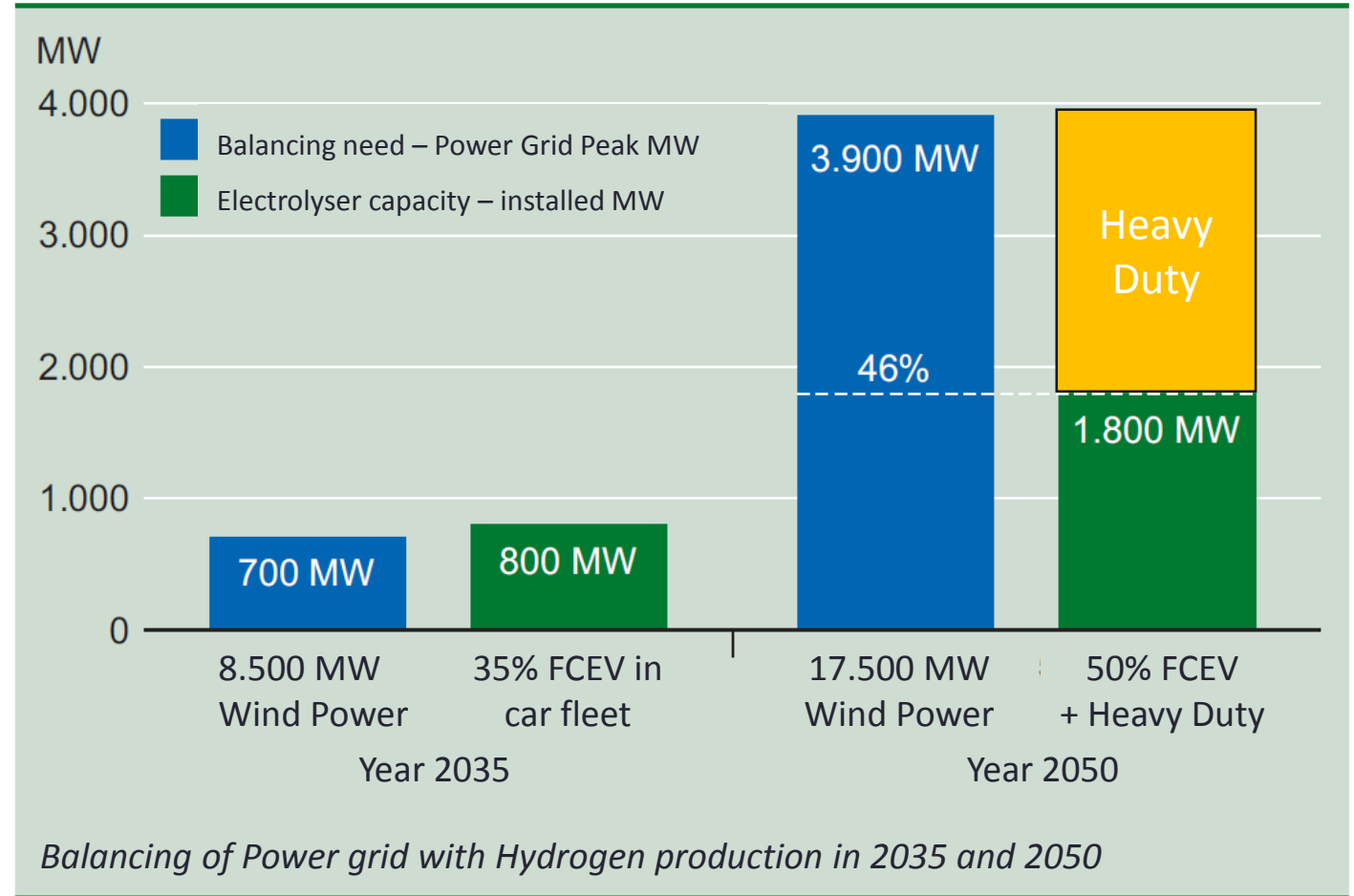
- 100 B€ industry
- Ammonia
- Refineries
- Steel
- Food
- Chemicals
- Power2gas
- Transportation

Using green hydrogen will have a major impact on CO2 emissions

## Hydrogen production can cover large parts of the balancing needed in DK to integrate renewable energy in the system by 2035 and 2050

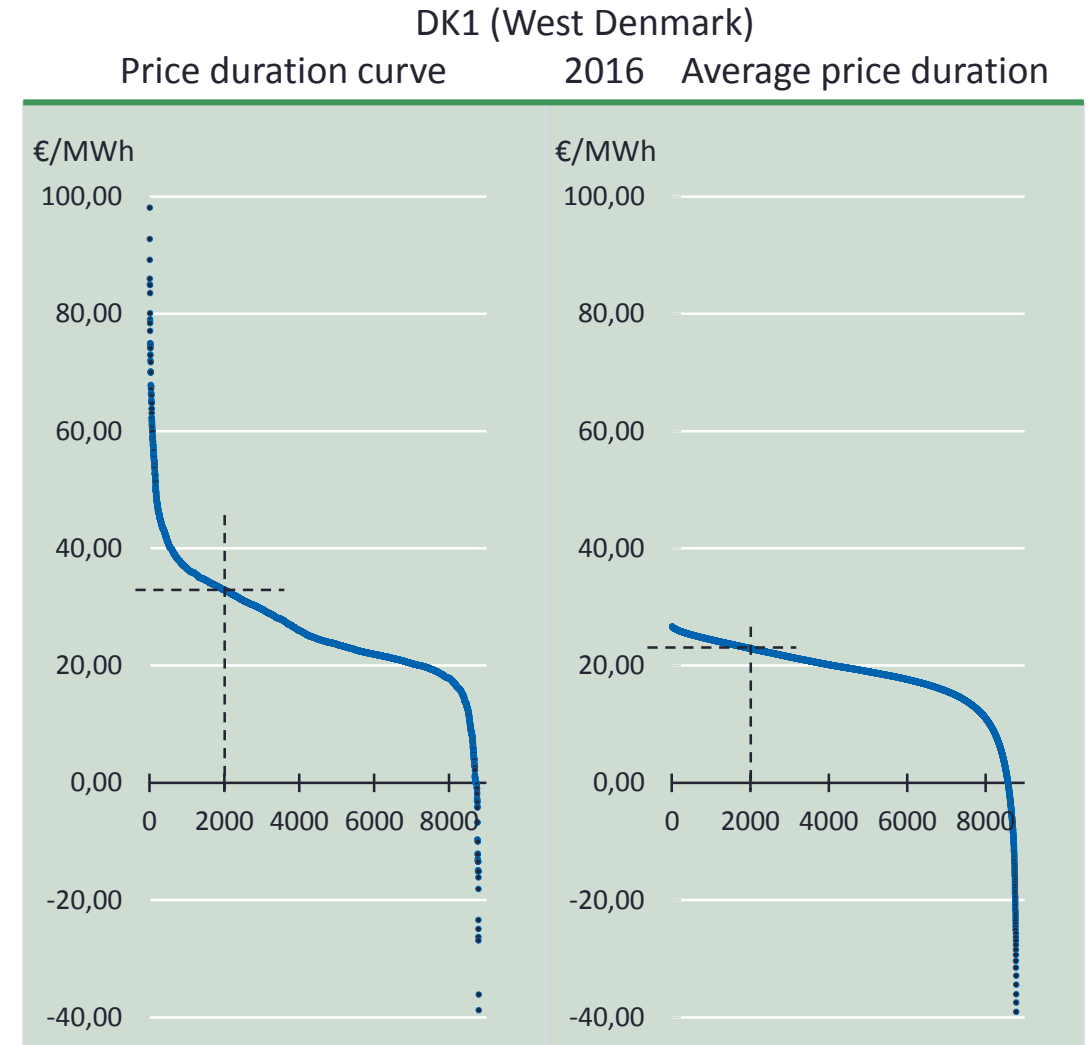
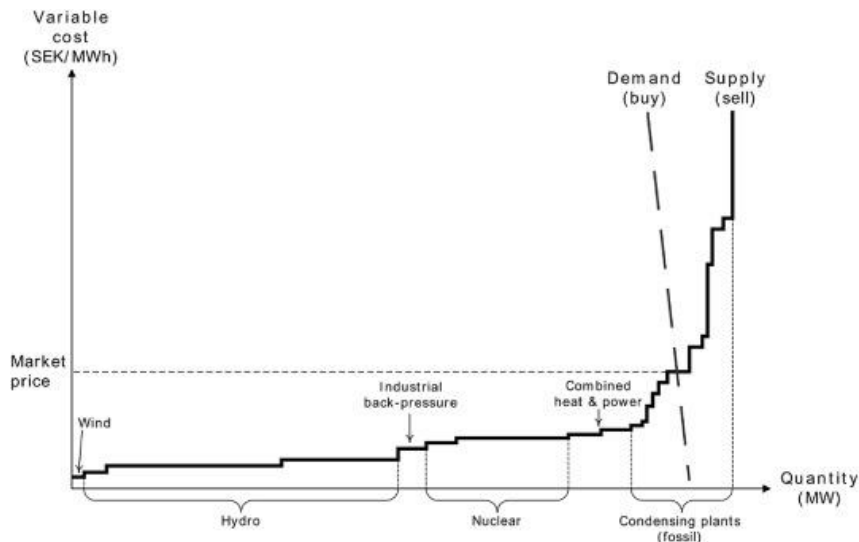
- 2035: 35% FCEV in car fleet cover the Danish balancing needs
- 2050: 50% FCEV in the car fleet and Heavy duty cover 100% of the balancing needs

Source: MegaBalance project



# Renewable energy is the key to cheap green hydrogen

- Electrolyser operation support the stability of the power system.
- Operation is highly flexible and can be aligned with the availability of excess electricity.
- Wind, Solar and Hydro have very low marginal cost and shift the spot price curves lower when production exceed demand.



# H2 supply chain for Heavy Duty vehicles

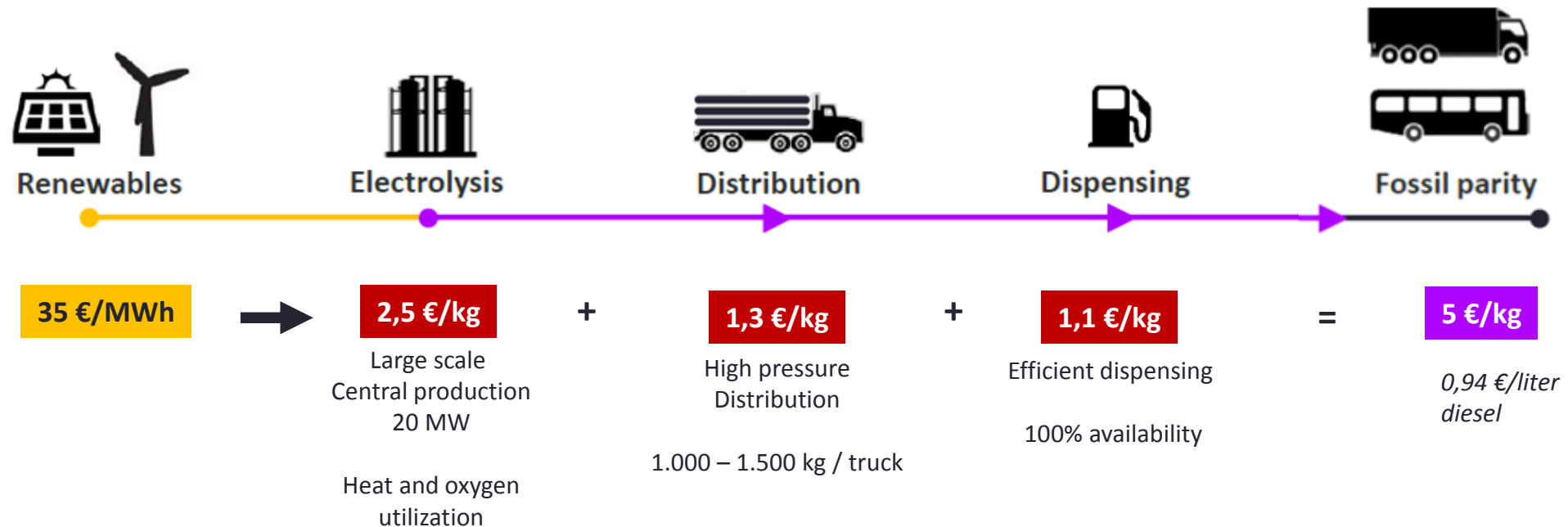
- Optimized hydrogen supply chain
- Cheap renewable electricity is converted to hydrogen
- Distributed by truck, and dispensed competitively

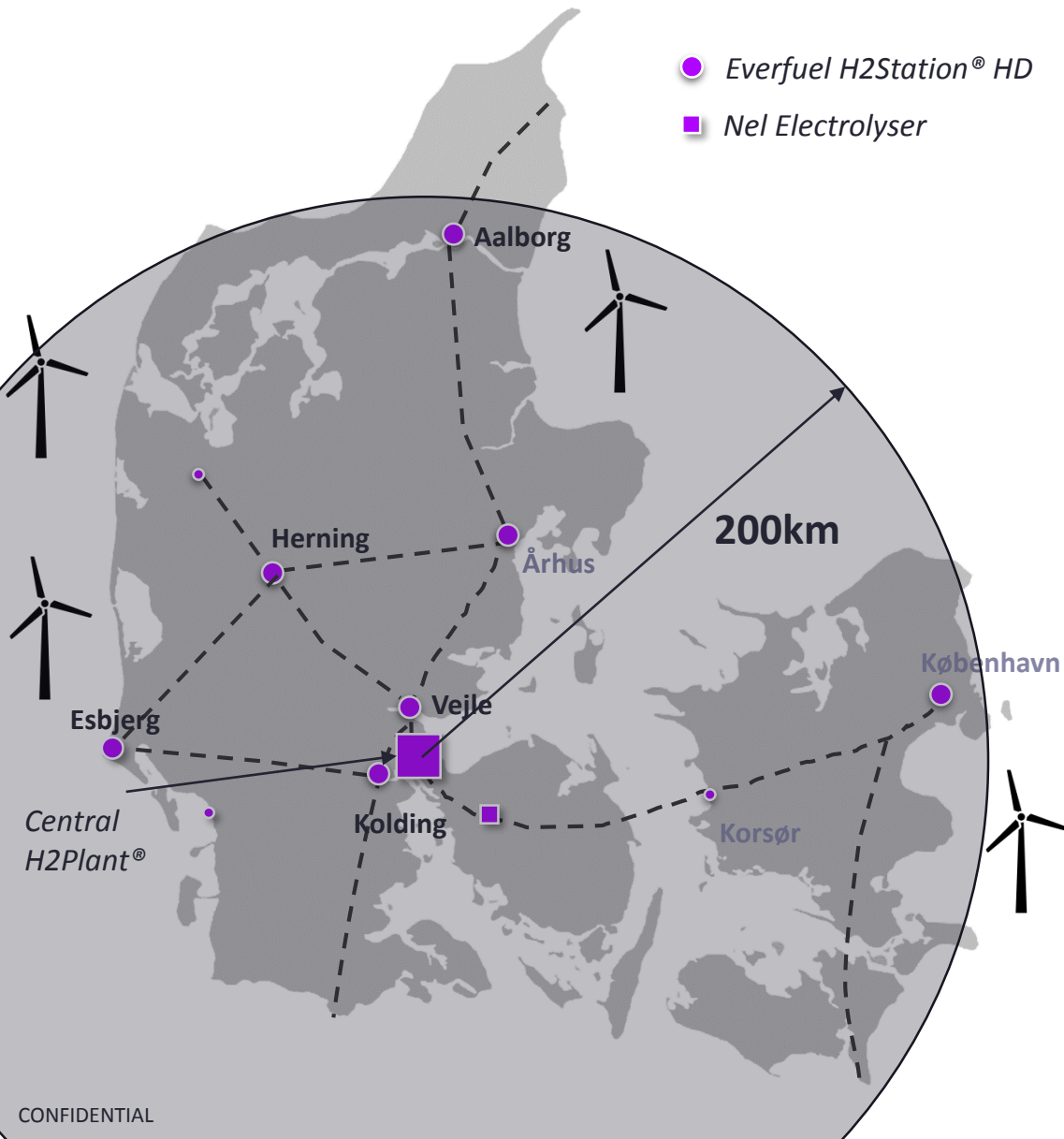
**H2 Supply contracts available for public transport sector:**

**8-10 year hydrogen contract at 5€ / kg**

Fueling infrastructure can be provided as part of the supply contract.

*500kg/day, 10 year depreciation, <200km distribution:*





## Central production, distribution, fueling, services

### Competitive green hydrogen production in central location:

- Potential co-location with high demand customer
- Utilization of heat and oxygen byproducts

### Efficient Hydrogen distribution:

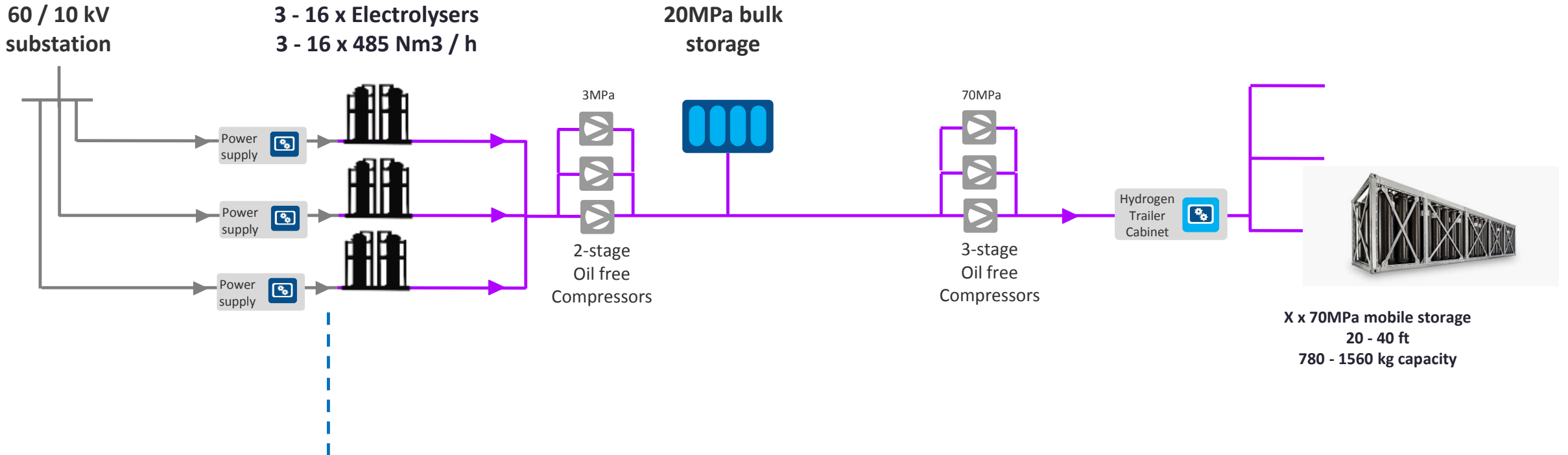
- 1500kg pr. truck
- Swap of container or Dump-off

### Scalable solution

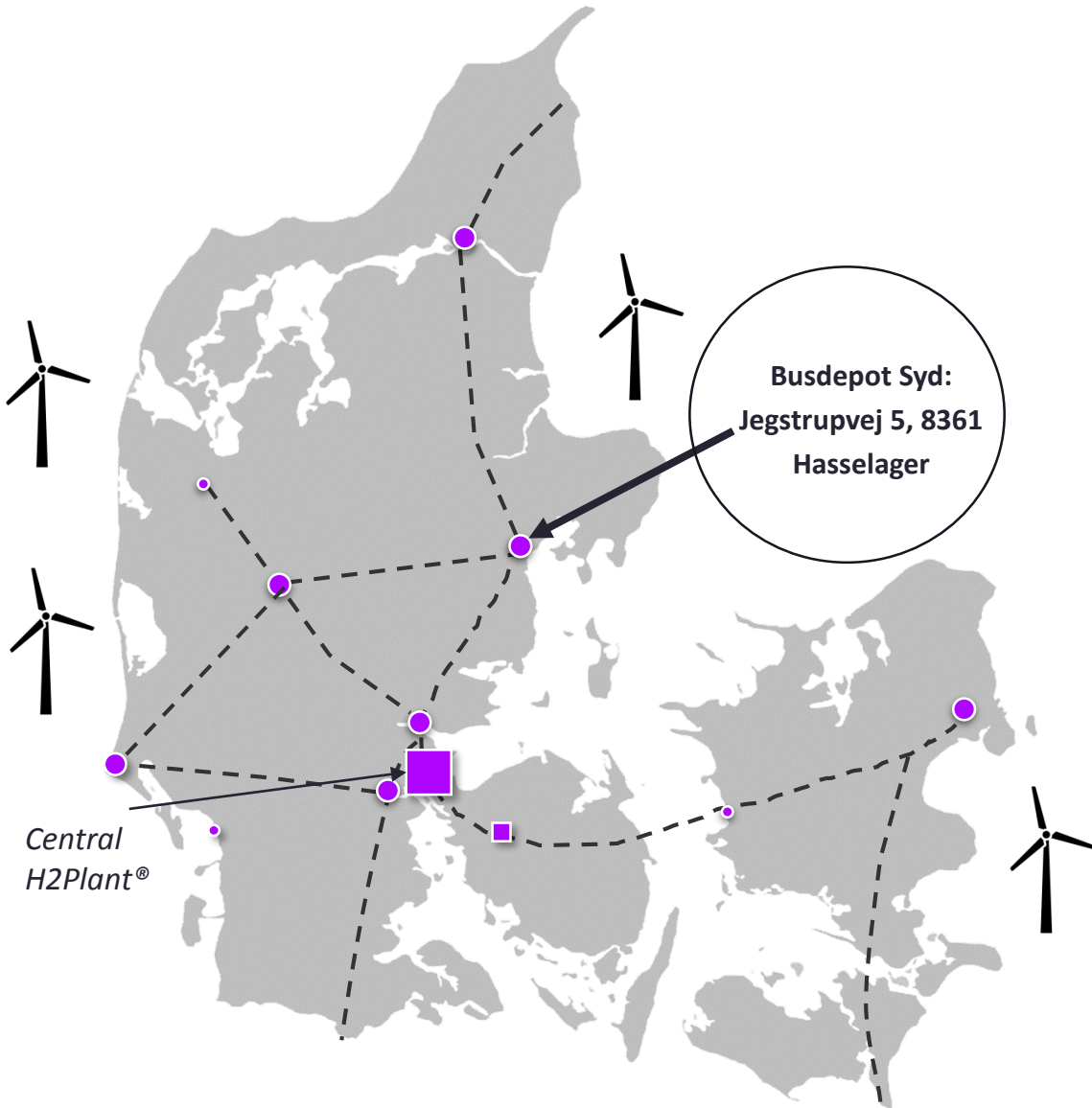
- Bus depot capacity can be easily added or extended
- Production centers will be located throughout Scandinavia within proximity of 20 largest cities

# Central Hydrogen Production plant

Plant Capacity: 2 – 100 T / day



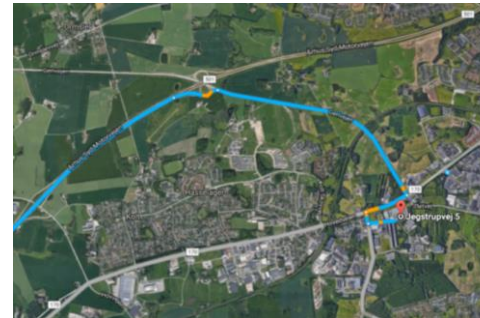
# Hydrogen Bus setup – case Hasselager



Centrally produced hydrogen



Trucked-in in pressurized tanks



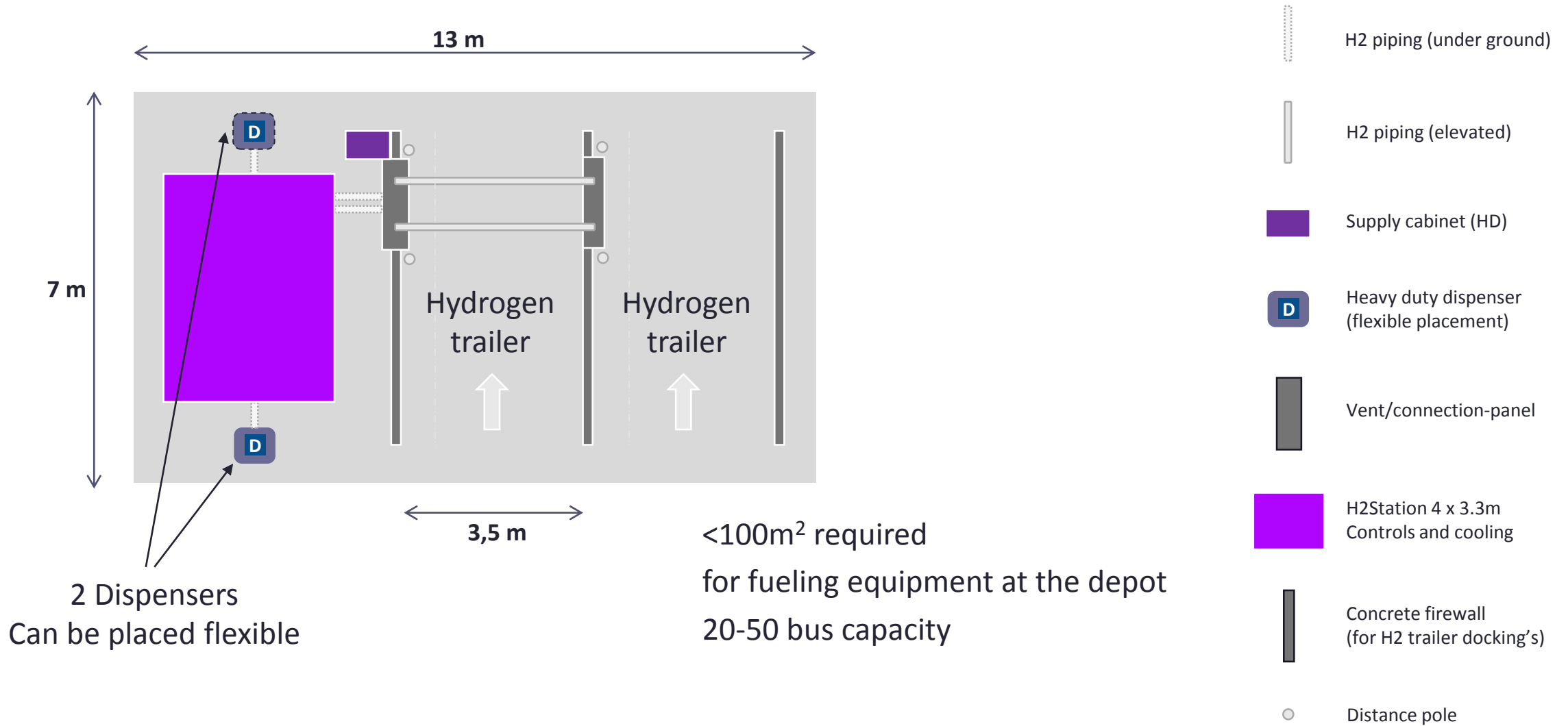
From high way to busdepot



Busdepot Syd: Jegstrupvej 5, 8361 Hasselager



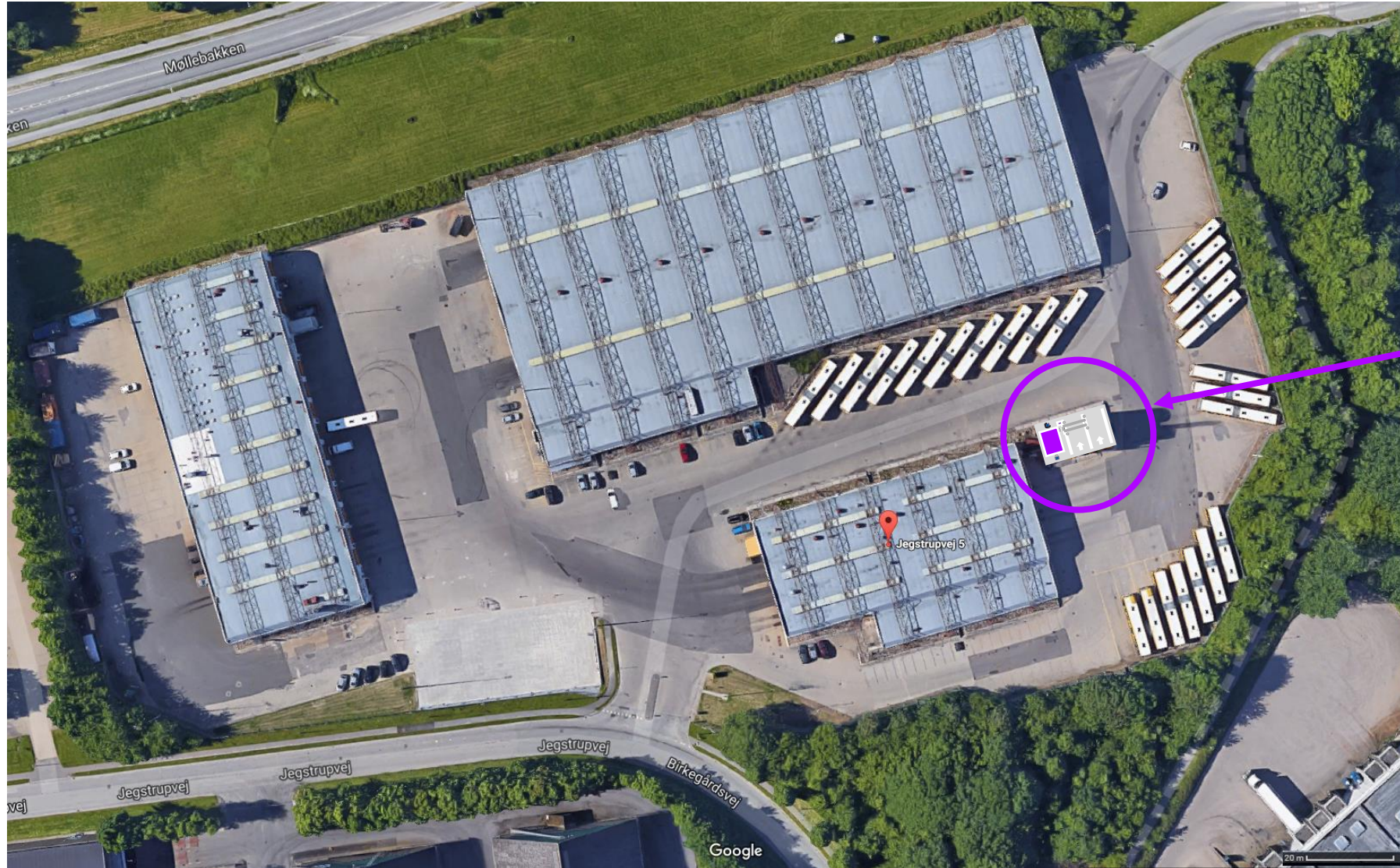
# HD bus station footprint (standard – drive thru)



2 Dispensers  
Can be placed flexible

<100m<sup>2</sup> required  
for fueling equipment at the depot  
20-50 bus capacity

# Station siting example - Hasselager



Footprint of compact  
H2Station<sup>®</sup> HD  
Up to 1000 kg /day  
~ 20 - 50 FC busses

## TCO of Fuel Cell busses will become equal to diesel!

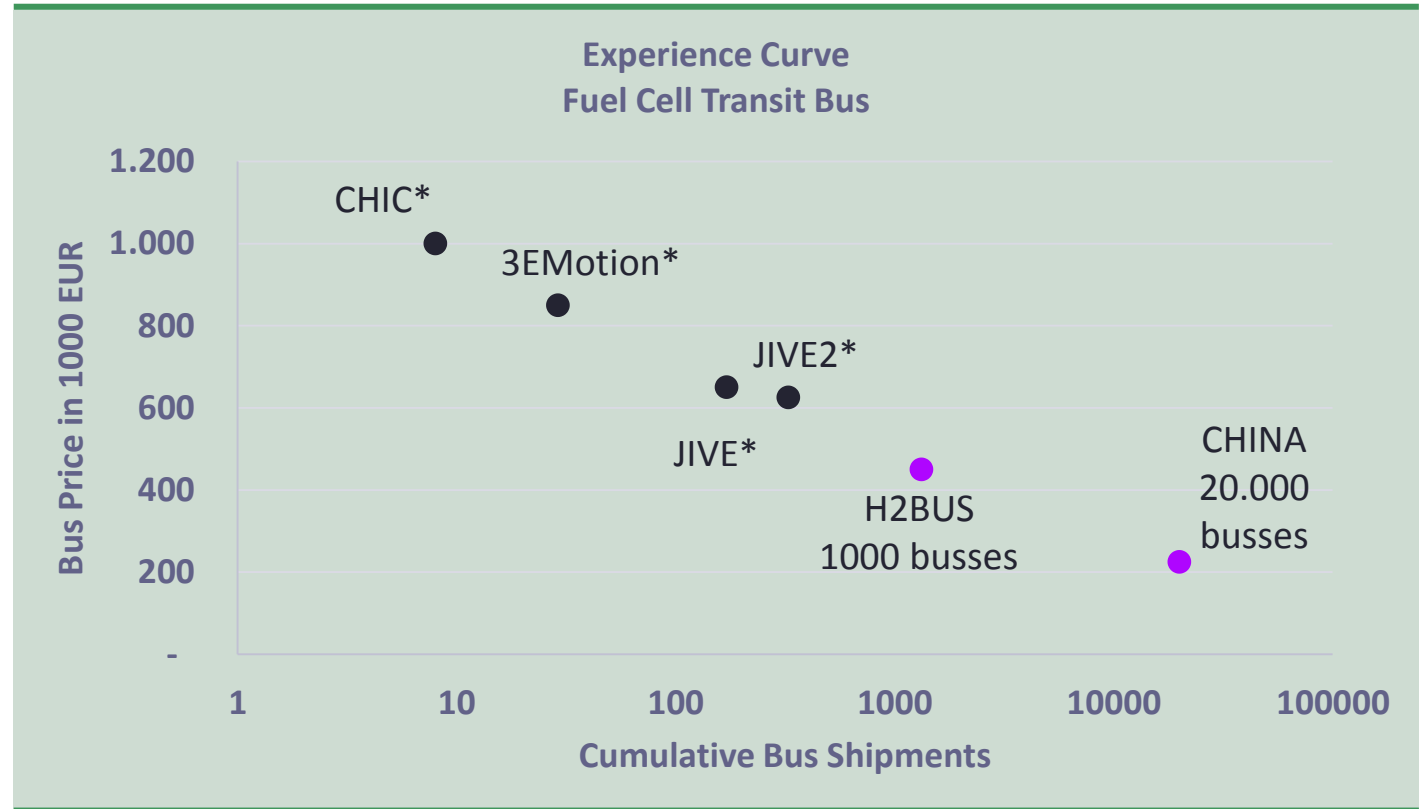
### Hydrogen supply and operation

- Cost of hydrogen dispensed 5€/kg
- **Fossil Parity** - (Hydrogen competitive with diesel)

### Total BUS economy

- Hydrogen cost is linked to cost of wind and solar (Will show further declining cost trend over the next 10 year period)
- Risk of ban on diesel in the contract period, Pollution limits exceeded etc
- FC Bus with Green Hydrogen → CO2 reduction pr. bus over 10 years = 850 ton CO2 reduction

- From the first projects the price has come down with every new demonstration project
- ~15% cost reduction from every doubling of accumulated shipment (learning curve)
- Volume will drive down cost further.
- 1.000 busses needed to make Fuel Cell bus a competitive zero emission vehicle
- At 20.000 busses FCV will compete with current diesel bus cost



- \*CHIC: <http://chic-project.eu/>
- \*3Emotion: <http://www.3emotion.eu/>
- \*JIVE: <http://www.fch.europa.eu/project/joint-initiative-hydrogen-vehicles-across-europe>
- \*JIVE2: Upcomming

# 7% CO2 reduction of total Municipality emissions

	Diesel	H2 electrolysis from Renewable
Average consumption	39 l/100km	8kg/100km
Fuel consumption ( 1.000.000 km/year)	389.000 l/y	80.000 kg/y
CO <sub>2</sub> emission (@2,66 kg / L)	1.034 tCO <sub>2</sub> /y	0
Herning Kommune footprint 2015	15.415 tCO <sub>2</sub> /y	
City emission reduction with 10 Fuel Cell busses		~7%
Reduction of CO <sub>2</sub> emission in Bus fleet		100%

## Case Herning – can be applied in other municipalities

- City buses converted to Hydrogen – previously EURO4
- Implementing hydrogen buses saves **7%** of the total CO2 emissions in the entire municipality
- Savings in emissions: SO<sub>2</sub>, NO<sub>x</sub>, CO, HC, PM saves money and lives.

## CO<sub>2</sub> footprint of electricity is crucial

### CO<sub>2</sub> emissions of bus fuel (well-to-wheel) in 2015 [kg/100 km]

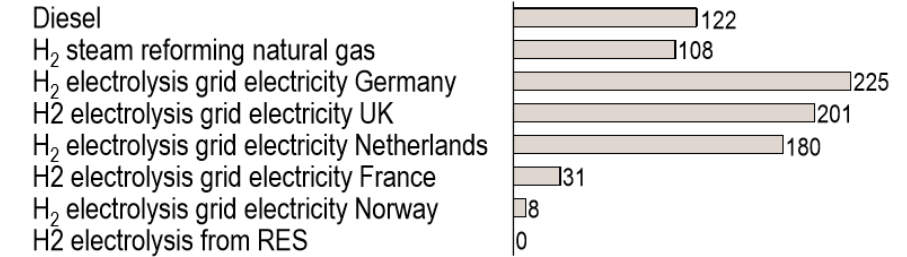


Figure 19: WTW CO<sub>2</sub> emissions of diesel and hydrogen in 2015 [kg/100 km]

## Fuel Cell Electric Buses – Potential for Sustainable Public Transport in Europe

A Study for the Fuel Cells and Hydrogen Joint Undertaking



## Implement Hydrogen Fuel Cell city Busses in Scandinavia at competitive TCO

### How?

- Gathering of significant demand (1000 Fuel Cell Buses through 2022)
- Develop infrastructure at scale
- Start by signing a non-binding LOI that we can present to OEM's – Volume production is what is needed to bring down the bus and hydrogen cost

### Hydrogen Infrastructure ?

- Hydrogen will be provided in the contract period at fixed price – safe, green and reliable
- Easy installation of fueling infrastructure at the depot – no interference in townscape

### Choosing a solution

- In the tenders choose the best solution for **your** Municipality based on **your** criteria

## Fuel Cell busses are 1 : 1 substitution for diesel buses

- Range of the buses can service the existing routes - no on-route infrastructure
- Refueling is done at depot once a day (takes 10 minutes)

## No expensive investment in fueling / charging infrastructure is needed

- Supplier of hydrogen provides the refueling infrastructure
- The refueling is done at the depot – no interference with traffic / problem for the city during setup and operation.

## Total Cost of Ownership will become equal to Diesel!

- Hydrogen supplied at fixed price for 10 year period.

## Environmental benefits

- 100% renewable electricity = save 85t CO<sub>2</sub>/ year pr. bus at 85.000km
- Zero Emissions: SO<sub>2</sub>, NO<sub>x</sub>, CO, HC, PM reduce cost to society and saves lives.
- Low Noise Level (Stress, property value, operability)

# What we ask of you:

Reach out to us for more information or for help to assess your **fuel cell bus** potential

Send clear “market signal” that fuel cell busses are a desired zero emission solution

- By including Fuel Cell busses in your next bus tender
- Non-binding FCB – Letter of Intent (LOI) this fall

**Green Hydrogen and Fuel Cell busses are ready for action - We are here to help you**



**Help us to bring 1000 fuel cell busses on the roads in Scandinavia by 2022**



End of presentation

**Thank you for  
your attention**

**Questions?**

[www.nelhydrogen.com](http://www.nelhydrogen.com)

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