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"Experience from operating a 70 MPa hydrogen refuelling station in Oslo"

PUBLIC PROJECT END-REPORT
TOWARDS DANISH EUDP PROGRAM

February 2013 | For publication

EUDP Project no.: 64009-0297

Project manager:

H2 Logic
Hydrogen Fuel Cell Motive Power Solutions

Supported by:

New Energy World JTI
fuel cells & hydrogen for sustainability

EUDP
Energiteknologisk udvikling og demonstration

transnova

Executive summary

As part of the H2MOVES Scandinavia project H2 Logic were to construct a large scale hydrogen refuelling station (HRS) in Oslo providing hydrogen for FCEV's from Daimler and Hyundai in the project.

The effort has provided extensive results and lessons learned across the entire process from site selection, HRS design and manufacturing to the final installation and operation.

An extensive site screening of more than 30 sites in Oslo was firstly conducted to identify the most optimal location for the HRS. A suitable site was identified at the research organisation SINTEF in Gaustad in the western part of Oslo. The location was strategically well located with regards to the other HRS's in the city ensuring good refuelling coverage in Oslo.

The HRS was manufactured, installed and operated by H2 Logic based on the company's H2Station® technology. The HRS provides 70MPa refuelling in accordance with the SAE J2601, and operation results have confirmed refuelling times consistently below four minutes for a full tank. The HRS includes onsite electrolysis production providing a 20kg/day base load supply, with potentially additional trucking-in of hydrogen up to a total capacity of 200kg/day.

The installation of the HRS took in total 10 days, from arrival at site, until first refuelling was conducted. This included local inspection by third parties and authorities as well as several days of hydrogen production and compression to reach the necessary refuelling pressure. Before opening a refuelling recommendation process was successfully conducted by Daimler.

The HRS opened on 21st November 2011 and has been operated for 13,5 months during the remainder project period (ending December 2012). The HRS is expected to continue operation beyond the project. Below are shown the major operation results from the HRS during the project:

- 701 kg dispensed
- 313 refueling's conducted
- Average availability of 97% during first half of 2012
- 53% of all down-time situations solved within ½ hour and 82% within 1 day
- All refueling's consistently below 4 minutes in accordance with the SAE J2601

The HRS demonstration was supported by the FCH-JU (EU), Transnova (NO) and EUDP (DK) programs. This report functions as the internal project end report towards the EUDP program and is confidential, thus not intended for publication.

Dansk sammendrag

Som en del af H2MOVES Scandinavia projektet har H2 Logic etableret en stor-skala brint tankstation i Oslo som har leveret brint optankning til brintbiler fra Hyundai og Daimler i projektet.

Aktiviteterne har bidraget med omfattende resultater og erfaringer dækkende over hele processen fra valg af placering, design og fremstilling af tankstationen og endelig installation og drift i Oslo.

Første skridt i projektet var en omfattende analyse af mere end 30 lokationer i Oslo med henblik på at vælge den mest optimale placering for tankstationen. En egnet placering blev valgt ved forskningsinstitutionen SINTEF i den vestlige del af Oslo. Placeringen var også strategisk optimal i forhold til de andre brint tankstationer i Oslo, så at der sikres et dækkende netværk af tankstationer i hele byen.

Brint tankstationen blev fremstillet, installeret og driftet af H2 Logic A/S baseret på virksomhedens H2Station® teknologi. Tankstationen leverer 70MPa påfyldning i henhold til SAE J2601, og driftsresultaterne har vist stabile optankningstider på under fire minutter for en fuld tank. Brint forsyningen er baseret på et 20kg/dag elektrolyse anlæg som leverer basisforsyningen. Yderligere brint op til 200kg/dag kan leveres til tankstationen med lastbil i takt med at forbruget stiger på sigt.

Installationen af tankstationen tog samlet 10 dage fra ankomst ved sitet og indtil først optankning var foretaget. Dette inkluderer inspektioner af myndigheder og tredjeparts organisationer samt adskillige dages brint produktion og kompression for at kunne foretage første optankning. Før idriftsættelsen gennemførte Daimler succesfuldt en række optankningstest og godkendte dermed brug af stationen.

Tankstationen åbnede den 21. november 2011 og har været i drift i hele projektperioden indtil udgangen af 2012 (13,5 måneder). Driften af stationen forventes at forsætte efter projektets afslutning. Nedenfor er gengivet de væsentlige opnåede driftsresultater:

- 701 kg optanket
- 313 optankninger
- Tilgængelig på 97% (første halvår 2012)
- 53% af alle driftsforstyrrelser blev løst indenfor ½ time og 82% indenfor same dag.
- Alle optankninger var under fire minutters varighed og i henhold til SAE J2601

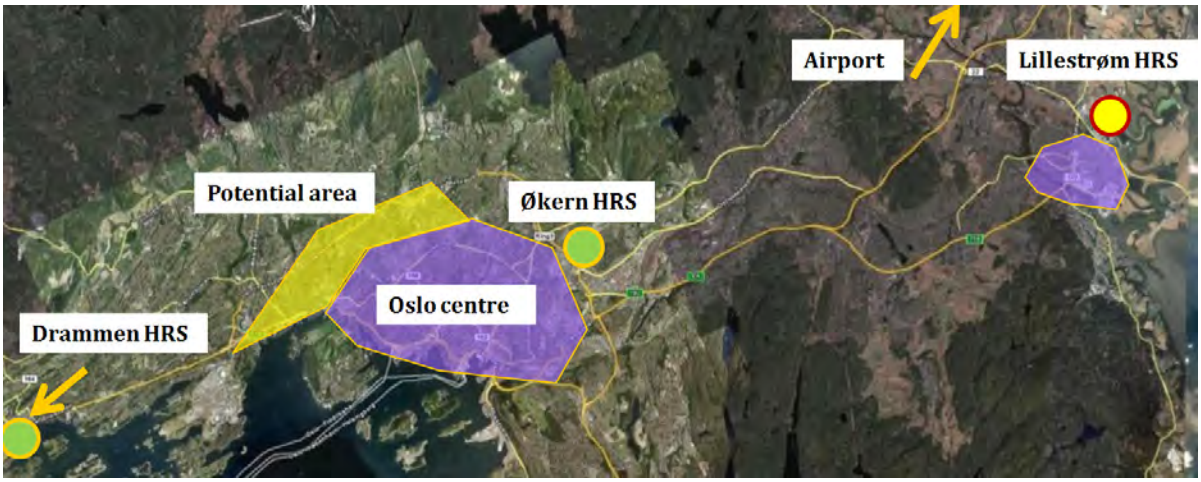
Demonstrationen af brint tankstationen var støttet af FCH-JU (EU), Transnova (NO) og EUDP (DK) programmerne. Denne rapport fungerer som den interne rapportering overfor EUDP programmet og er fortroligt og derfor ikke tiltænkt offentliggørelse.

Table of content

1. Site screening & selection in Oslo

One of the first activities was the conducting of an extensive site screening and selection process with the aim to find a suitable location for the HRS in Oslo. Besides providing sufficient space for the HRS the placement also had to take into account the distance to the existing and planned HRS's to ensure a placement that could give optimal network coverage of the city.

The picture below shows the location of the existing (green) and planned (yellow) HRS's in Oslo.



Obvious areas for a new HRS could be pointed out from the map of existing and planned HRS's, namely the downtown area as well as on the west side of the city along the highway.

Despite these obvious locations, the site process in Oslo was not fixed from the beginning. Thus the analysis covered the greater area of Oslo both to the south, north, east and west. The reason for this broad scope was the general conditions in Oslo for placement of a HRS. Oslo is characterised with limited space inside the city due to hills and high land value, so only very few gasoline stations exists in the downtown area. Outside the city centre, e.g. around the city highway, sites have more room, but number of sites are also limited as HRS ideally should be placed close to highways & major roads.

The picture to the left shows as an example one of the few downtown gasoline stations were room at the site is very limited and makes integration of an HRS challenging.

1.2 Overall site selection & placement criteria

Before commencing the site analysis process a set of criteria for the selection and placement were formulated. With the criteria several sites could be screened and only the most promising ones selected for a more detailed analysis.

The set of selection criteria are shown below and cover the main aspects to take into consideration in the initial site screening process.

Overall location

- Central location – visible, near major roads, high use frequency, if highway both directions should have access to site with exit ramp
- Visible location (increasing exposure of HRS)
- Sufficient/large site – easier HRS integration
- Site owner identification & evaluation (any initial limitations on potential use)
- Within or in close proximity to Oslo city centre or the greater Oslo area
- Located strategically within the Oslo HRS network
- Located in city centre or along west side of the city centre (e.g. along highway

Placement at site

- Ensure necessary distance to adjoining property
- Avoid/reduce need for removal of existing installations (fence, oil vents/pipes etc.)
- Enable easy access for vehicles from both ends of HRS
- Reduce impact on existing driving lanes/parking at the site
- Ensure optimal visual & symmetric placement of HRS in relation to surroundings
- Space available at site for potential HRS placement
- Space around HRS for future capacity upgrade
- Potentially enable access for hydrogen delivery trucks and parking of tube-trailer
- Onsite infrastructure available & ease of access (plumbing & power connections)
- Ensure necessary distance to adjoining property & critical elements in the surroundings
- Sufficient space at site to comply with international safety distance (EIHP2, EIGA, ISO20100, NFPA55, NFPA 52 etc.).

1.2 Initial site screening & selection of potential candidates

An initial site screening was conducted across the greater Oslo area, identifying more than 30 potential sites. Various types of sites were identified e.g. parking lots, shops, existing gasoline stations, open land and others. The identified sites are shown on the map below.

Based on the selection criteria the identified sites were narrow down to only 8 candidates, as shown on the map below. Generally many of sites not selected were due to limited space at site and their location too far away from major roads. Also some sites were placed too close to existing HRS's or planned ones.

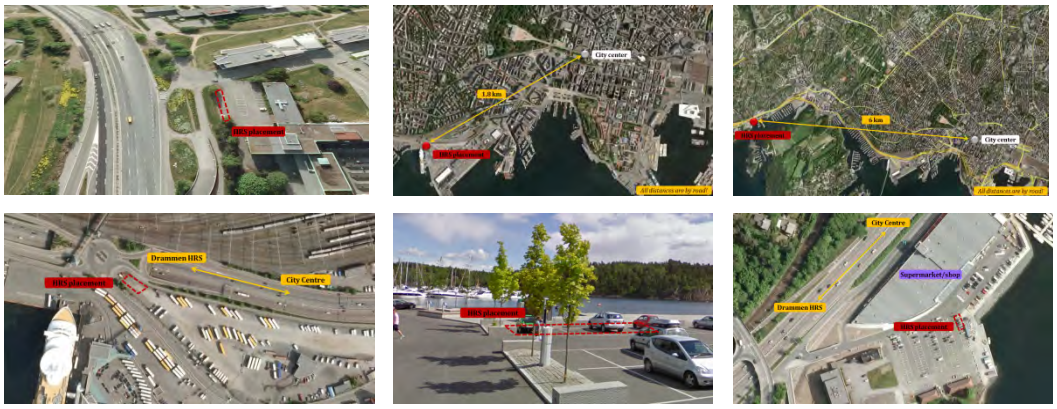
All of the 8 candidate sites were placed around the city centre thus within the area that were prioritized from the beginning. Also taken into consideration where the distance to the FCEV workshop of Daimler, to enable easy access to refueling during vehicle maintenance.

1.3 Detailed analysis of candidate sites & selection of final

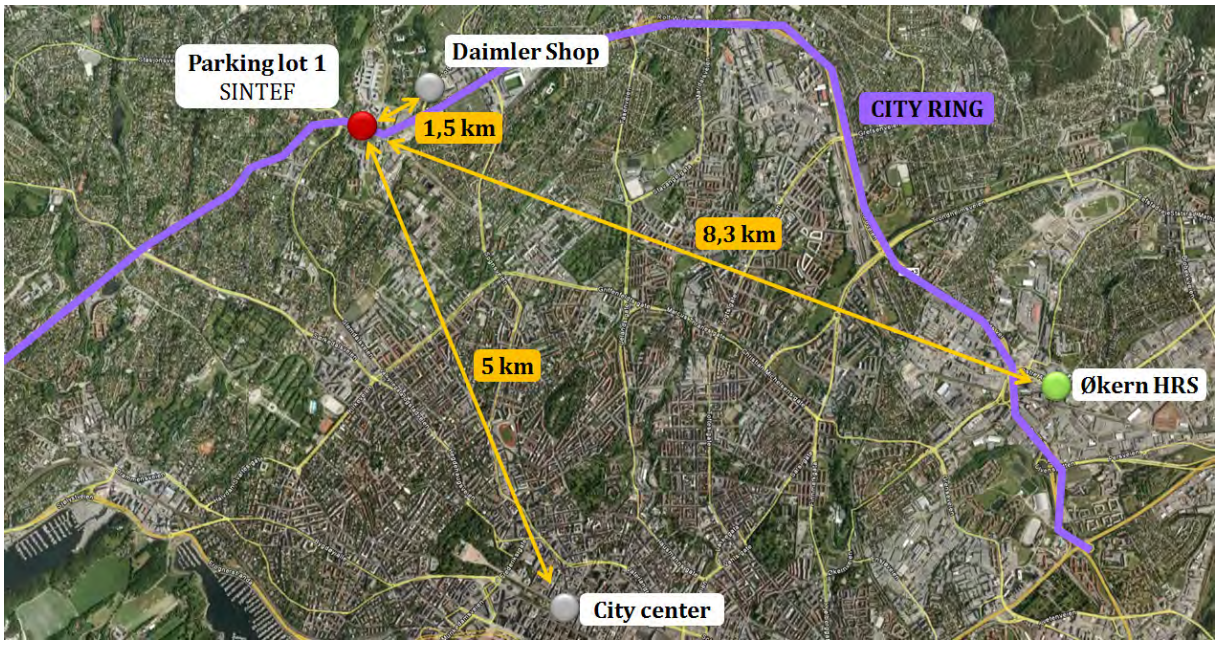
Each of the 8 candidate sites were analysed in detail, still using the overall selection criteria, but now also looking into details of e.g. potential placement of the HRS at the site.

In particular sites were analysed for their ability to enable a convenient placement of the HRS whilst taking into consideration the safety distances. This proved to be a challenge at many sites as an ideal placement of the HRS with regards to easy vehicle access often required space, which again was limited and thus compliance with safety distances became difficult.

Also considerations on distance to city centre and existing HRS's were analyzed for each site as well as their location with respected too easy access from major roads.



Of the 8 candidates a location at the parking lot of the Norwegian Research Organization SINTEF proved to be most suitable location. The site is only 1,5 km from the FCEV Daimler shop and with 8,3 km to the next HRS and only 5 km to the city center. Also the station is located ideally next to the highway around the city and on the west side. The SINTEF location is shown on the map below.



1.4 Placement at site

At the selected SINTEF site, four potential placements for the HRS were analysed. This included detailed indicative placement of the HRS and in-depth analysis of in particular, safety distances, to ensure that the selected site would pass the following building permitting process.

Based on the analyses the site A (shown in picture above) was selected and it is also where the new HRS is located today, as shown in the pictures below.

2. HRS Specification, manufacturing & installation

2.1 Initial & realised technical specifications

The table below shows the initial technical specifications for the HRS from the H2MOVES project Description of Work (DoW) and the actual realised performance on the new HRS in Oslo.

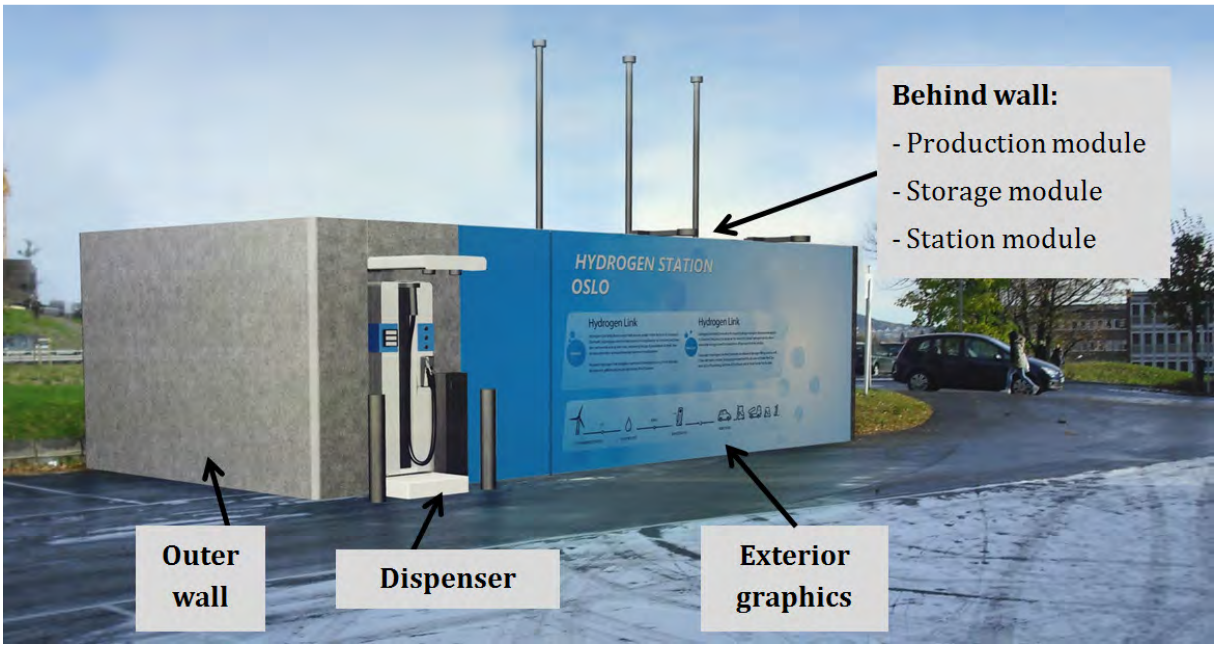
Moveable HRS – Technical specifications		
Specification parameter	**Data according to DoW**	**Actual performance realised**
Refuelling pressure	70MPa	70MPa
Control & refuelling	SAE J2601	SAE J2601
IR communication	Not specified	Yes (SAE J2799)
SAE refuelling level	Not specified	A-level (minus 40 degrees)
Refuelling time	<5 min.	3 min.
Daily refuelling capacity (24hour)	200 kg / 50 vehicles	200 kg
1 hour refuelling capacity	20 kg / 5 vehicles	20 kg
Fuel quality & composition	SAE J2719	SAE J2719
Hydrogen supply	20 kg/day onsite 180 kg/day trucked-in	20 kg/day onsite 180 kg/day trucked-in
Refueling station siting	100m2	100m2

All specifications from the DoW have been fulfilled. Concerning refueling time the actual HRS performance supersedes the initial specifications with a refueling time of 3 min. as in accordance with the SAE J2601, where the DoW anticipated less than 5 min.

Methodology for the performance specifications of the HRS is based on the requirements in the FCH-JU call text of 2008, thus it may differ from new methodologies in use today.

2.2 HRS Design

The Oslo HRS has been designed with easy installation and small foot-print in mind, as outlined in the graphical figure below.

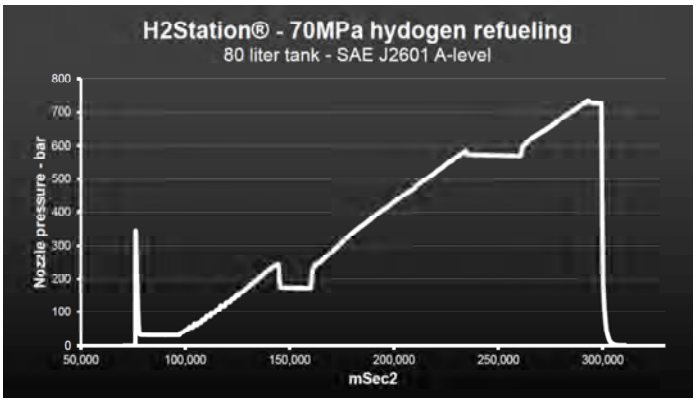


The HRS consists of four main modules surrounded by an outer wall:

- Production module - electrolyser with integrated water and hydrogen purification
- Storage module – for trucked-in hydrogen
- Station module – all refuelling equipment (compressor, storage & cooling)
- Dispenser with activation module

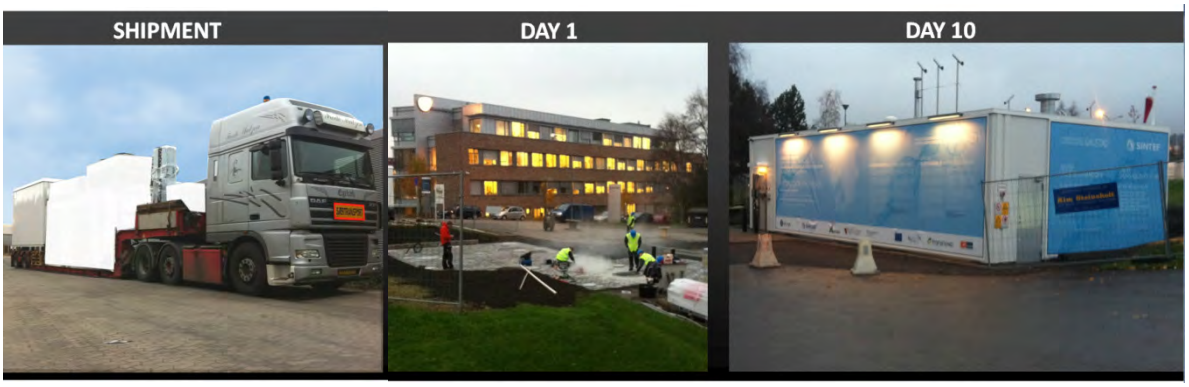
This modular approach was used to both ensure manufacutering of all major components at factory and an easy transport and installation. Also it has enabled a compact footprint which was required in order to integrate the HRS at the designated site.

Signifigant efforts have been spent on ensuring refueling in accordance with the specifications in the SAE J2601, and thus ensuring a fast refueling within only 3 minutes. The graphs shows an example of a 70MPa refueling at A-Level in accordance with the SAE J2601, conducted with the H2Station® technology from H2 Logic, which is used in the Oslo HRS.



2.3 HRS installation & opening

After manufacturing of the HRS modules they were shipped by truck from Denmark to Oslo in Norway. The compact design allowed for transport of all modules on one truck, except for the storage module.



In parallel with the manufacturing of the HRS modules, local works were conducted in Oslo, covering:

- Preparing of site including foundations
- Establishment of power connection
- Establishment of water connection & plumbing (for electrolyser)
- Underground pipe channels (for connection between station module & dispenser)

The installation of the HRS modules took in total 10 days, from arrival at site, until first refuelling was conducted. This included local inspection by third parties and authorities as well as several days of hydrogen production and compression to reach the necessary refuelling pressure.

Before opening of the HRS, a refuelling recommendation process was successfully conducted by Daimler, to evaluate if refuelling of Daimler FCEV's would be acceptable.

The HRS opened on 21st November 2011. The picture below shows the finalised station in Oslo.

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3. H2MOVES Technical reporting of operation results

5th and last reporting period

1/2013
SLIDE SELECTION
CLASSIFICATION: PUBLIC

Partners
Coordinator: ludwig bölkow systemtechnik
Vehicles and infrastructure: H2 Logic, DAIMLER, HYUNDAI
Communication: Hydrogen Link, Hydrogen Sweden
Safety: SP, TÜV
CO-Funded by: transnova, New Energy World JU, eUDP, European Commission
Local partners: SINTEF, HYNOR
Scandinavian Hydrogen Highway Partnership
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Aim of this document

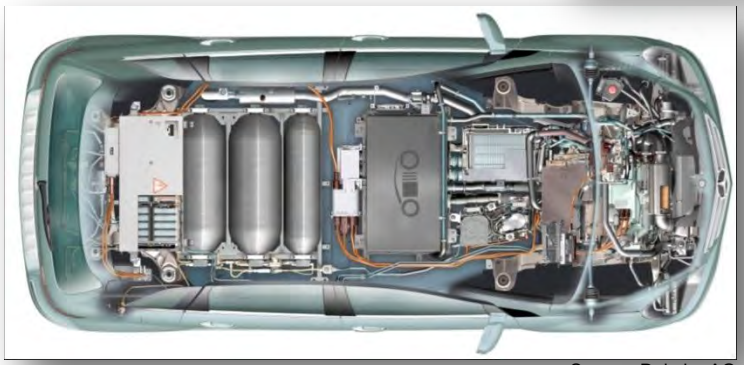
- These slides are classified as public and can be distributed.
- The individual slides and graphs can be used for presentations at conferences, posters, publications, etc.
- When presenting individual slides or graphs, please state this as reference: „H2moves Scandinavia, 2013, www.scandinavianhydrogen.org/h2moves“
- Please send a copy of your document to info@h2moves.eu.

H2mS at a glance

Period covered in this report	11/2011 – 12/2012
Number of vehicles	19 (10 Daimler + 4 Hyundai + 5 Th!nk)
Location of FCEVs	17 in Oslo, Norway + 2 in Denmark
km driven	213,641 km
Hydrogen refuelled	2,334 kg
Number of refuellings of FCEVs	1,170
Number of HRS	1 (in Oslo) + 1 moveable refueller
Hydrogen dispensed at station	701 kg plus 51 kg for moveable refueller
Number of refuellings at station	313 plus 26 for moveable refueller

Content

Source: Hyundai Motor Europe



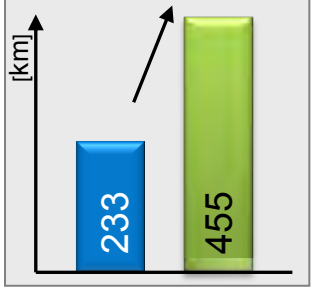
Source: Daimler AG

Source: H2 Logic A/S

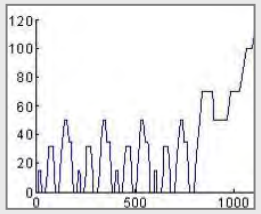
Technical advancement: FCEVs

Range

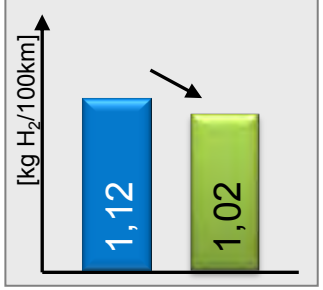
+96 %



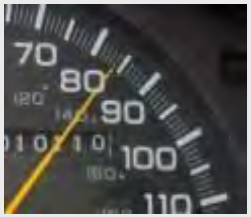
Consumption



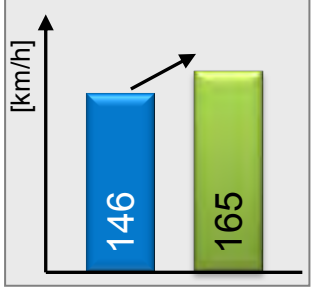
- 9 %



Top Speed

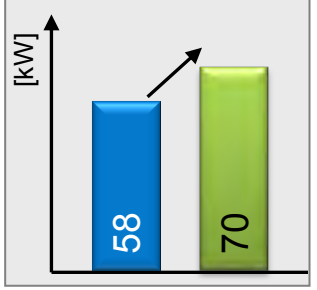


+13 %

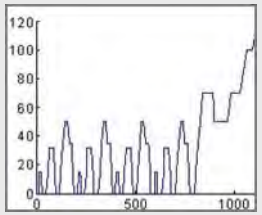


Power

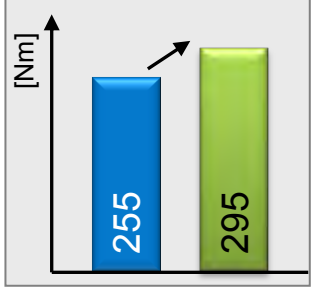
+22 %



Max Torque



+16 %



Last generation FCEVs

H2mS FCEVs 2012

Technical Advancements of TH!NK FCEV Range Extender

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- A standard BEV city car from TH!NK retrofitted with fuel cell system & H_2 storage
- Capable of operating on battery alone (plug-in) or range extension with fuel cell
- A 1st generation FC city car was developed & tested in 2008
- An optimized 2nd generation developed for H2moves Scandinavia
    - Increase of pressure to 70 MPa – increase of range to 250 km
    - Use of excess heat from fuel cell system for cabin heating
    - Noise reduction due to floating fuel cell operation depending on vehicle speed

TH!NK FCEV Range Extender Performance indicator	Unit	Specification
Maximum speed	Km/h	100
Acceleration	Sec	0-50 km/h @ 6.5 sec 0-80 km/h @ 16 sec
Total driving range	km	250
Range on battery	km	110
Range on fuel cell/hydrogen	km	140
Passengers	No.	2
Hydrogen storage capacity	kg	~1,7
Hydrogen storage pressure	bar	700

Source: H2 Logic A/S

Technical Advancements of HRS Gaustad, Oslo

- HRS developed & operated by H2 Logic A/S
- Based on H2Station® 70MPa fast-fill technology
- Refueling in accordance with SAE J2601 (A level)
- Refueling time of ~3 minutes (-40 °C pre-cooling)
- Onsite hydrogen production (electrolysis)

H2MOVES - HRS Gaustad, Oslo Specification parameter	Performance
Refuelling pressure	70MPa
Control & refuelling	SAE J2601
IR communication	Yes (SAE J2799)
SAE refuelling level	A-level (minus 40 degrees)
Refuelling time	3 min.
Daily refuelling capacity (24hour)	200 kg
1 hour refuelling capacity	20 kg
Fuel quality & composition	SAE J2719
Hydrogen supply	20 kg/day onsite 180 kg/day trucked-in
Refueling station sitting	100m2

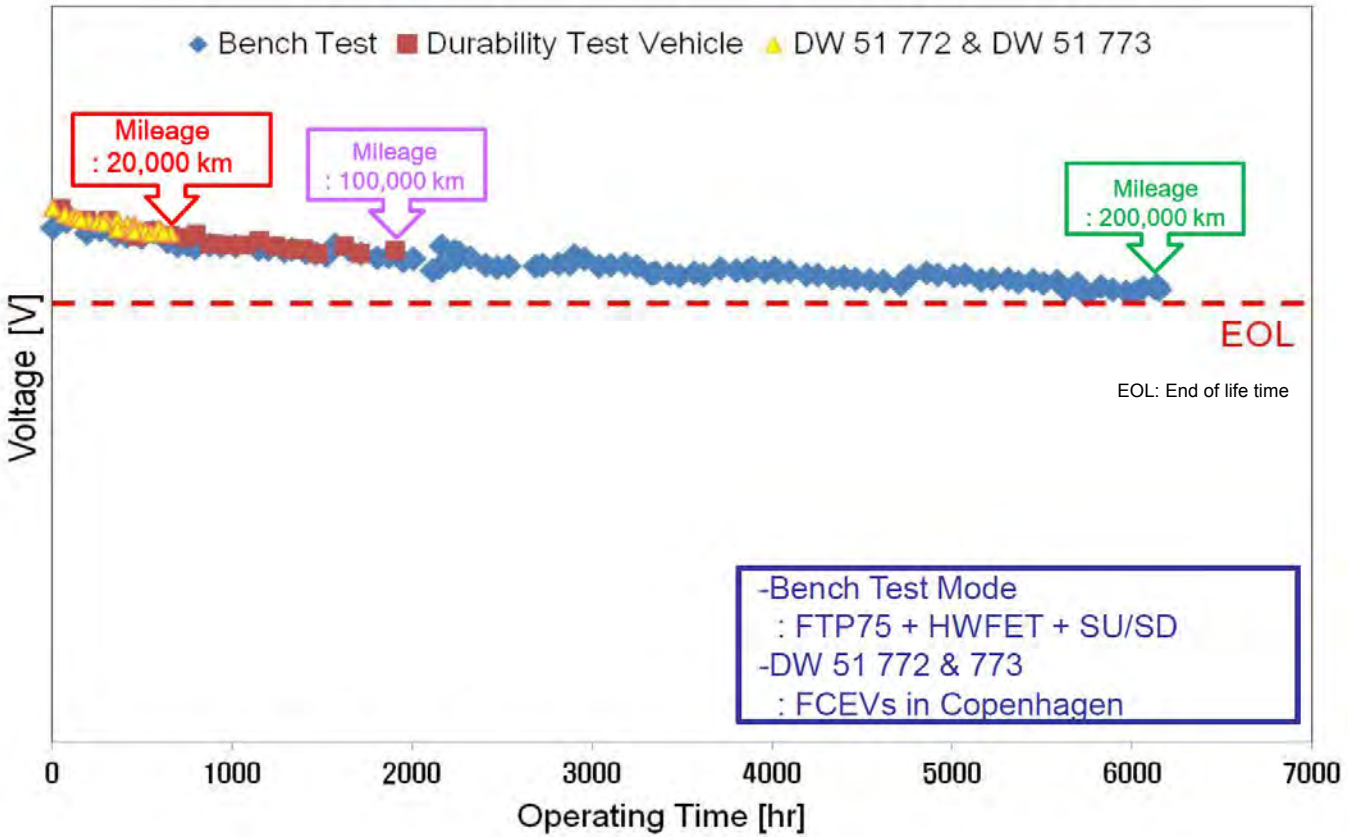
Source: H2 Logic A/S

Technical Advancements of Moveable Refueller

- HRS developed & operated by H2 Logic A/S
- Based on H2Station® 70MPa fast-fill technology
- Refuelling in accordance with SAE J2601 (A level)
- Refuelling time of ~3 minutes (-40 °C pre-cooling)

Moveable HRS – Technical specifications	
Specification parameter	**Actual performance realised**
Refuelling pressure	70MPa
Instant refuelling capacity	2x4 kg (back-to-back)
Daily refuelling capacity (24hour)	50 kg @ 2,5MPa inlet
Refuelling time	3 min. @ 70MPa (5,6 kg)
Refuelling nozzle	TK17 for 70MPa
Fuel quality & composition	According to car manufacturers requirement
Control & refuelling	SAE J2601
Mass flow metering	Yes (Coriolis)
Start/stop	Key card
Hydrogen supply	Trucked-in or available pipe/onsite
Minimum inlet pressure of H2 supply	0,6MPa (6 bar)
IR communication	Yes (SAE J2799)
SAE refuelling level	A-level (minus 40 degrees)

Source: H2 Logic A/S



- The two H2moves Scandinavia vehicles (marked in yellow) operating in Denmark for 1 year follow bench test durability curve
- No difference with test vehicles running in South Korea

Source: Hyundai Motor Europe

1. Technical Advancements
2. FCEV Performance Data
3. HRS Performance Data
4. Customer Survey
4. Outlook

Source: Daimler AG

Source: Hyundai Motor Europe

Source: H2 Logic A/S

FCEV Lab Data

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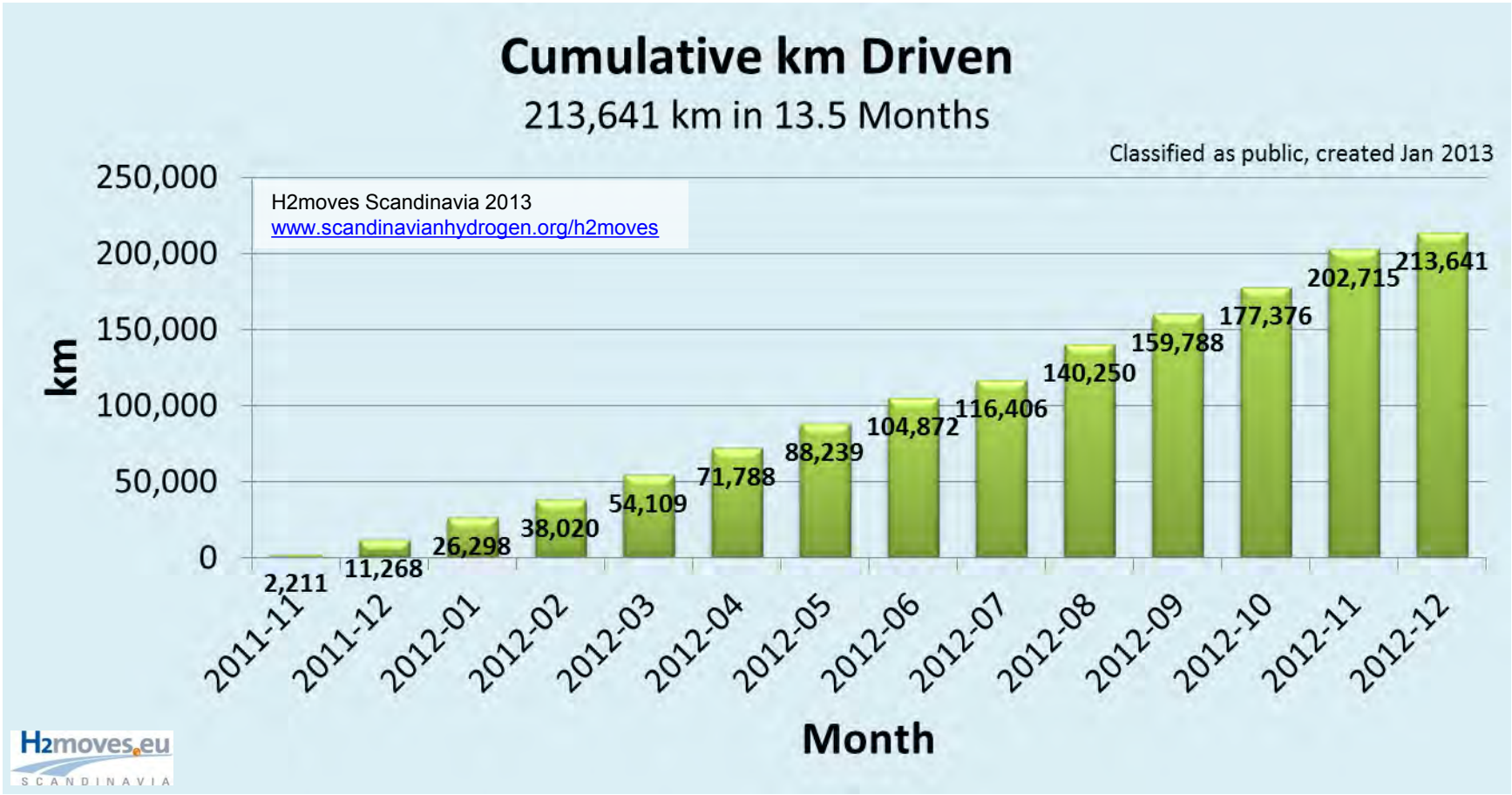
	H2moves Scandinavia fleet
Fuel consumption (NEDC) [kg H_2 / 100 km]	0.97 – 1.07
Maximum speed [km/h]	160-170 Th!nk: 100
Acceleration 0-100 km/h [s]	11.4 – 14.0 Th!nk 0-50 km/h: 6.5 s
Tank capacity [kg]	3.7-5.6 Th!nk: 1.5
Driving range [km]	250-525
Number of B-Class F-CELL	10
Number of ix35 FCEV	4
Number of Th!nk	5

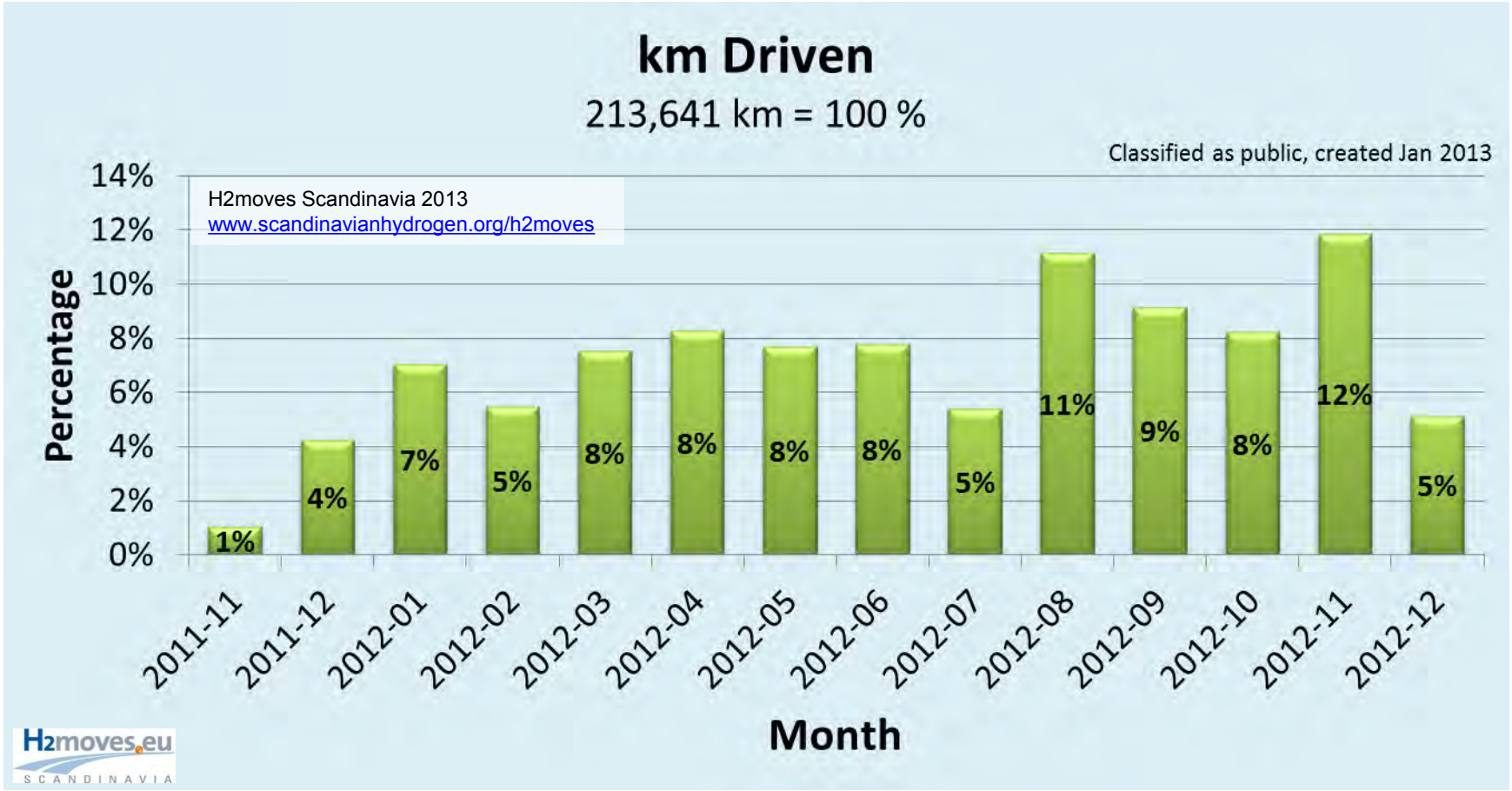
FCEV Performance Data



So far, our cars drove around the world more than five times.
Equivalent conventional cars would have emitted
24.5 tons CO_2 equivalent for this distance (well-to-wheel).

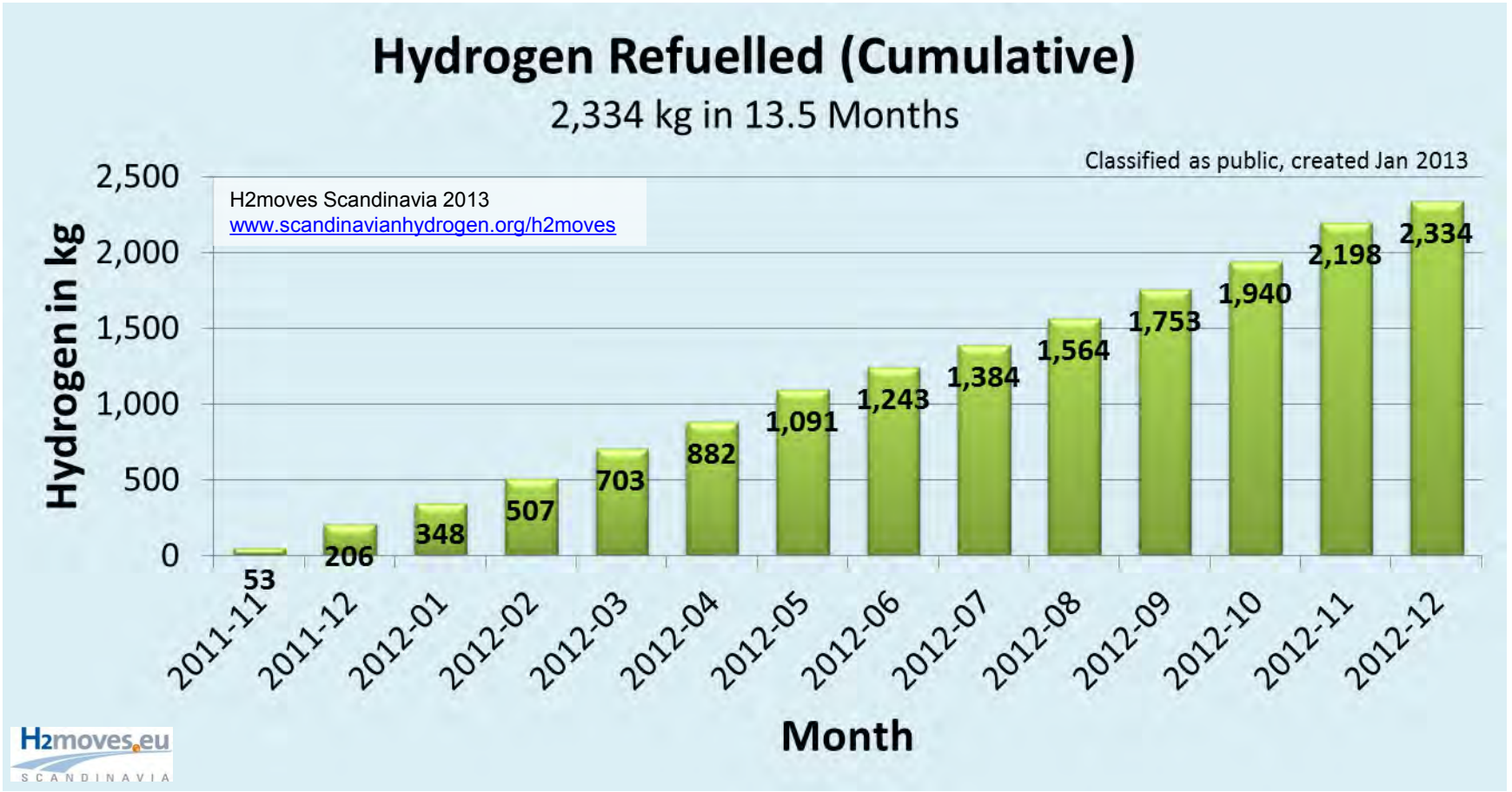
Sources: own calculations based on Hyundai 2012; Daimler AG 2012; JEC-Joint Research Centre-EUCAR-CONCAWE, Report EUR 24952 EN – 2011

FCEV Performance Data

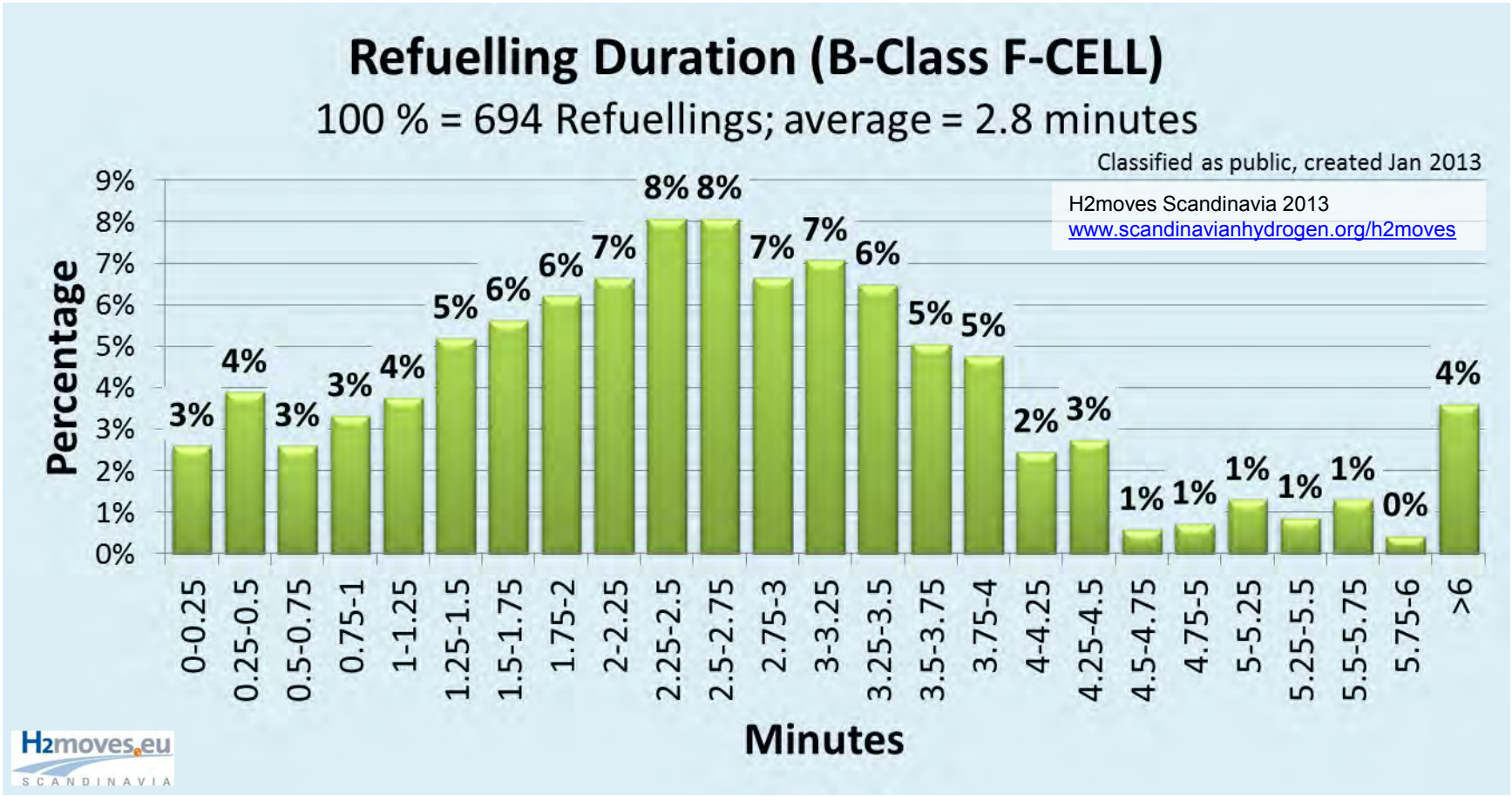


July and December are holiday seasons,
so people drive significantly less.

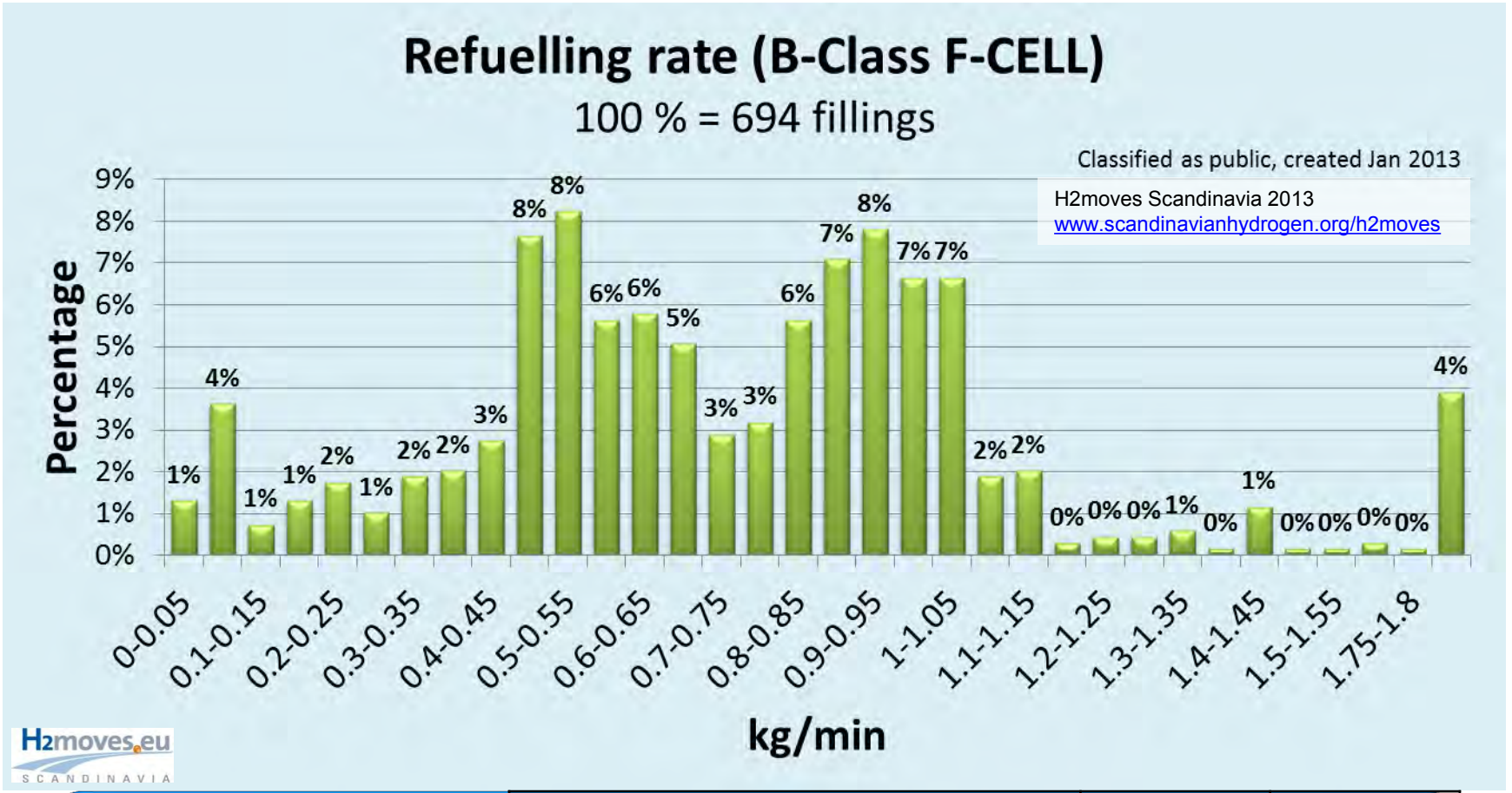
FCEV Performance Data



- All FCEVs refuel randomly at any available HRS in Oslo & Copenhagen
- The H2moves HRS in Oslo (Gaustad) delivered 701 kg (30%) out of the total 2,303 kg. These 701 kg are ca. 42% of the hydrogen refuelled in Oslo.



On average, refuelling a Daimler-Benz B-Class F-CELL takes 2.8 minutes

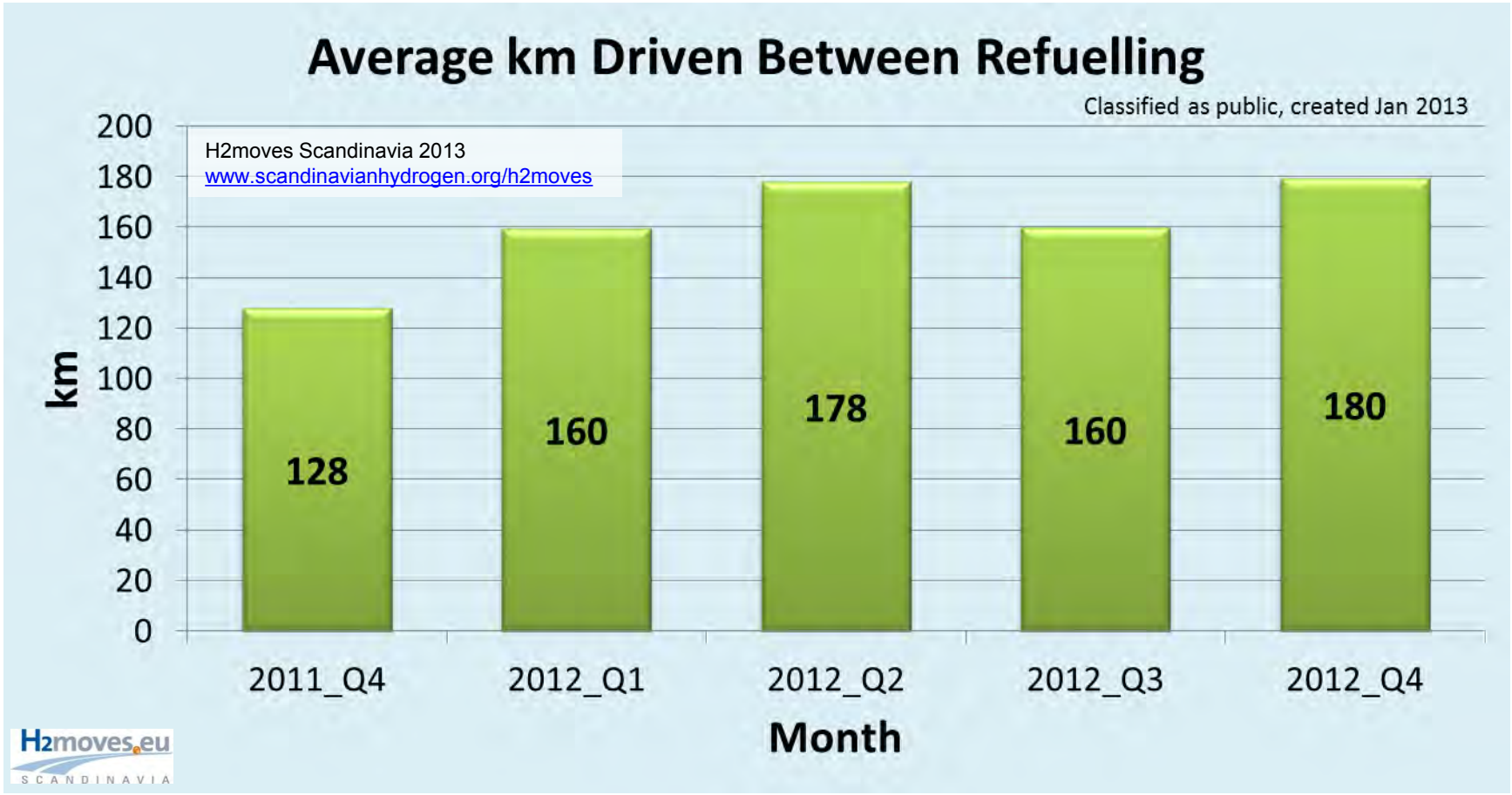


Data comparable to NREL:

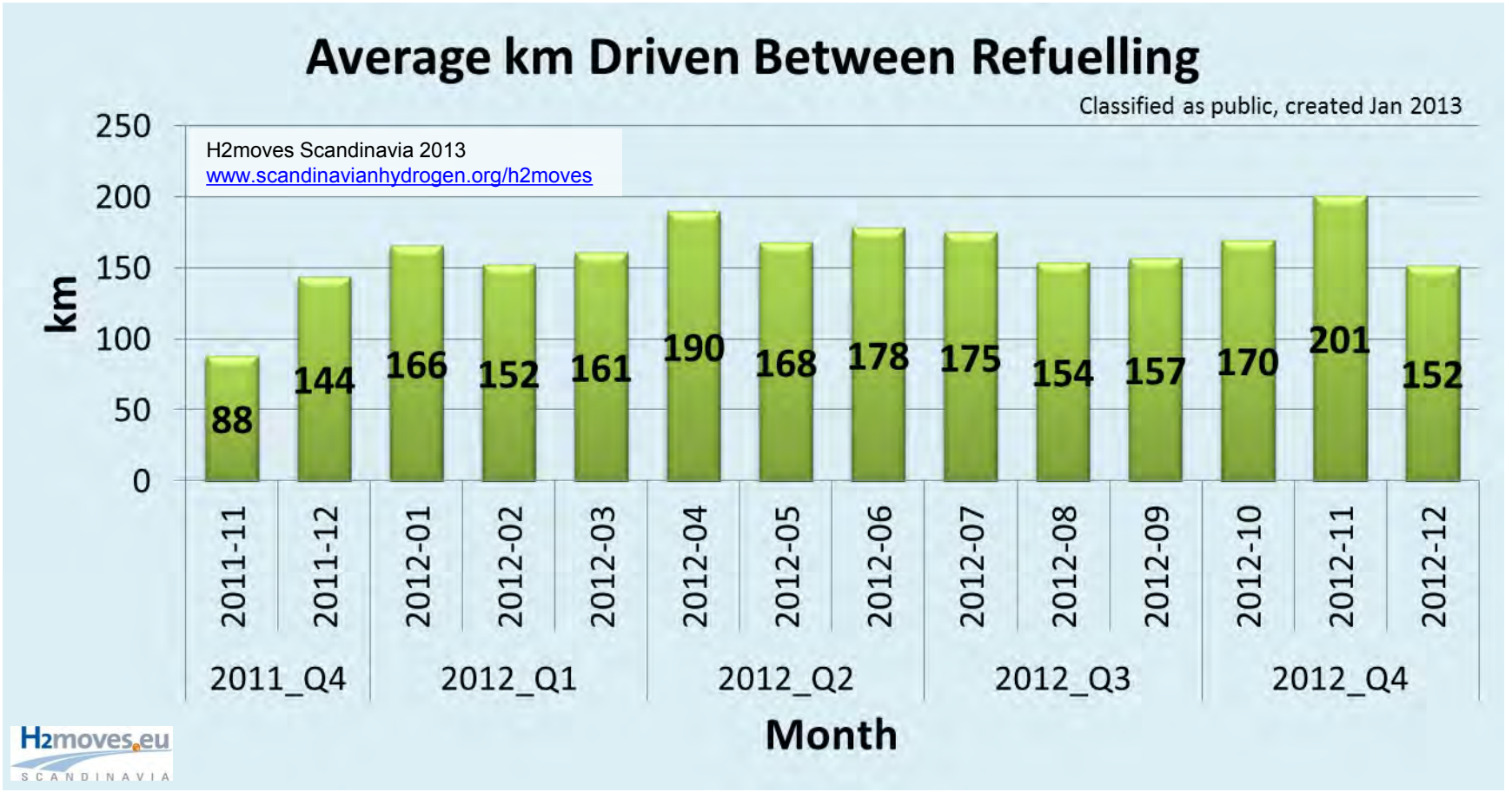
	H2mS	NREL
Percent of fillings with rate > 1 kg/min	18 %	20 %
Percent of fillings with rate > 1,67 kg / min	4,04 %	3 %
Average filling rate	0.8 kg/min	0.72 kg/min

http://www.nrel.gov/docs/fy13osti/56809.pdf

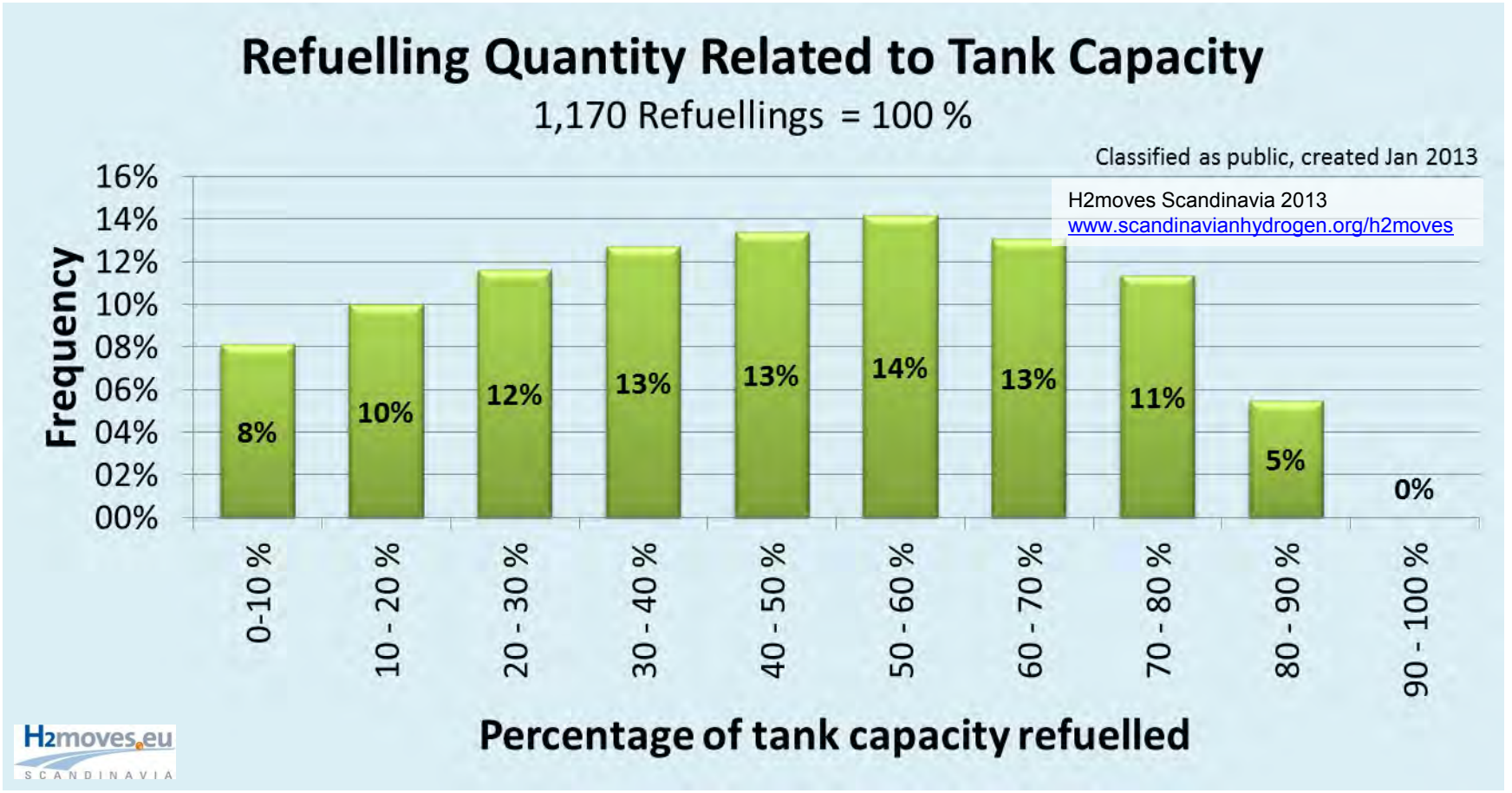
FCEV Performance Data



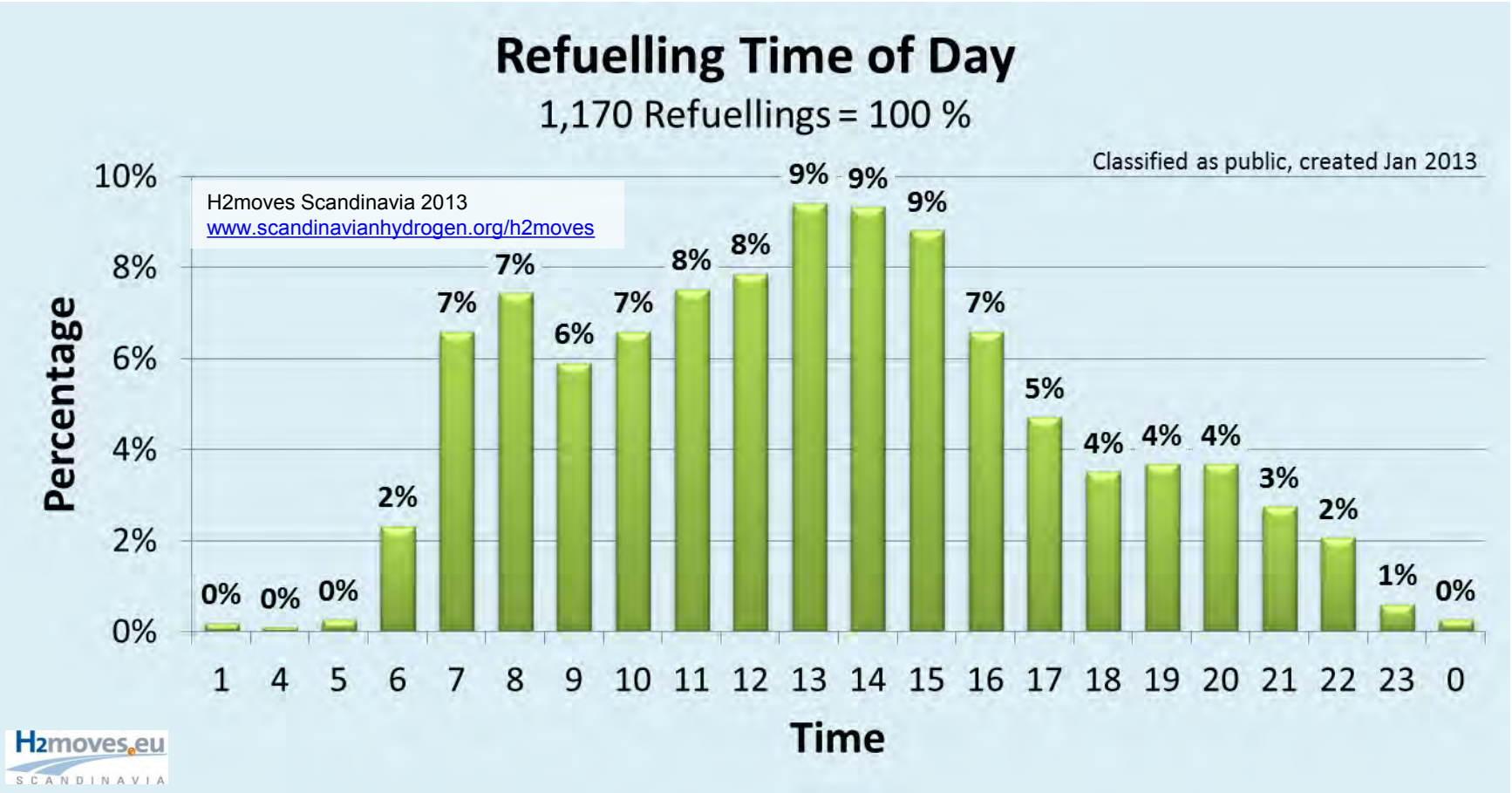
Decreasing range anxiety:
128 km ➔ 160-180 km



Distance driven was slightly reduced during down-time period of Gaustad HRS in August and September. When HRS resumed operation, driven distance quickly rose again to normal level.

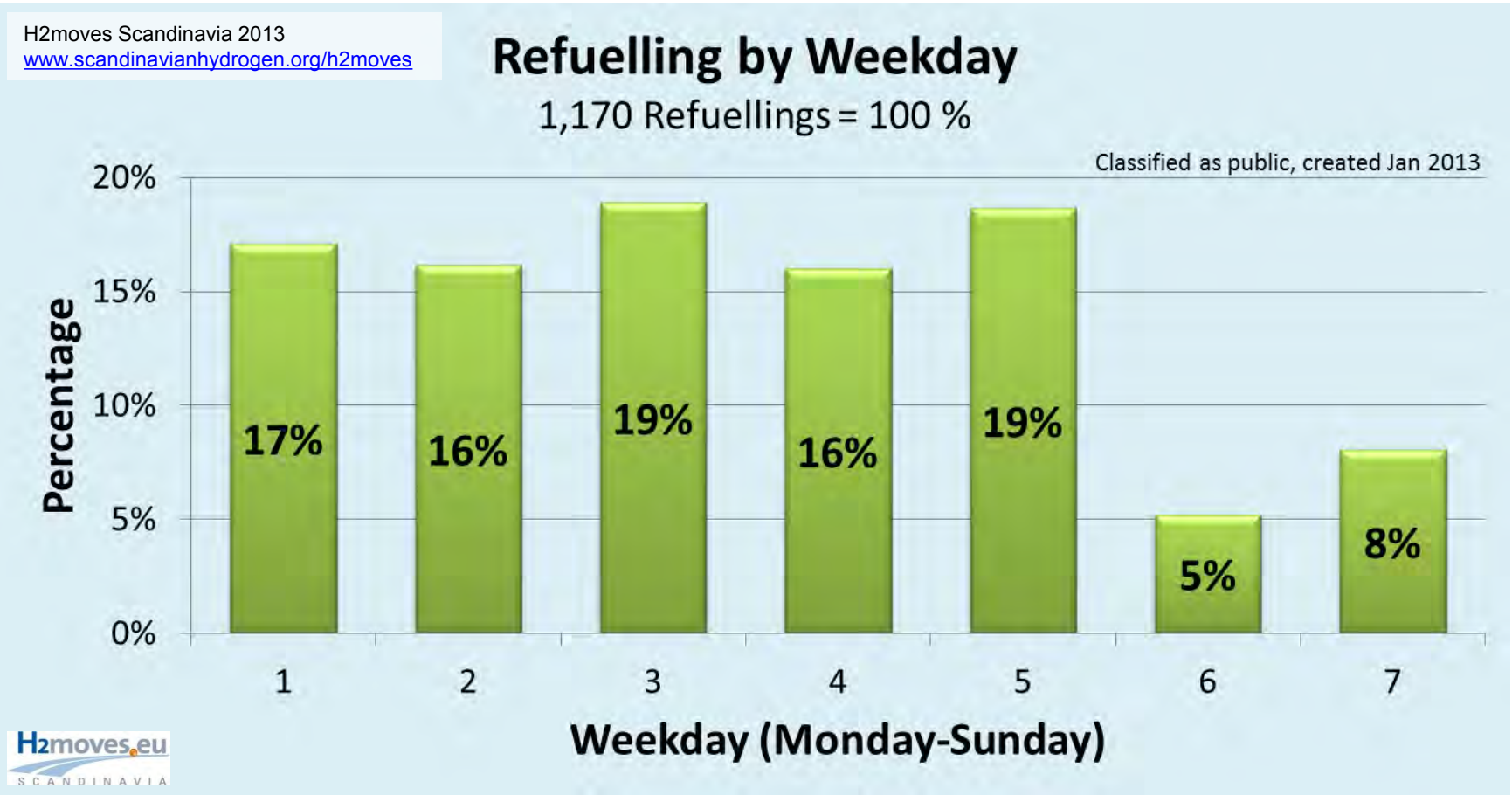


Refuelling quantity is driven by range anxiety



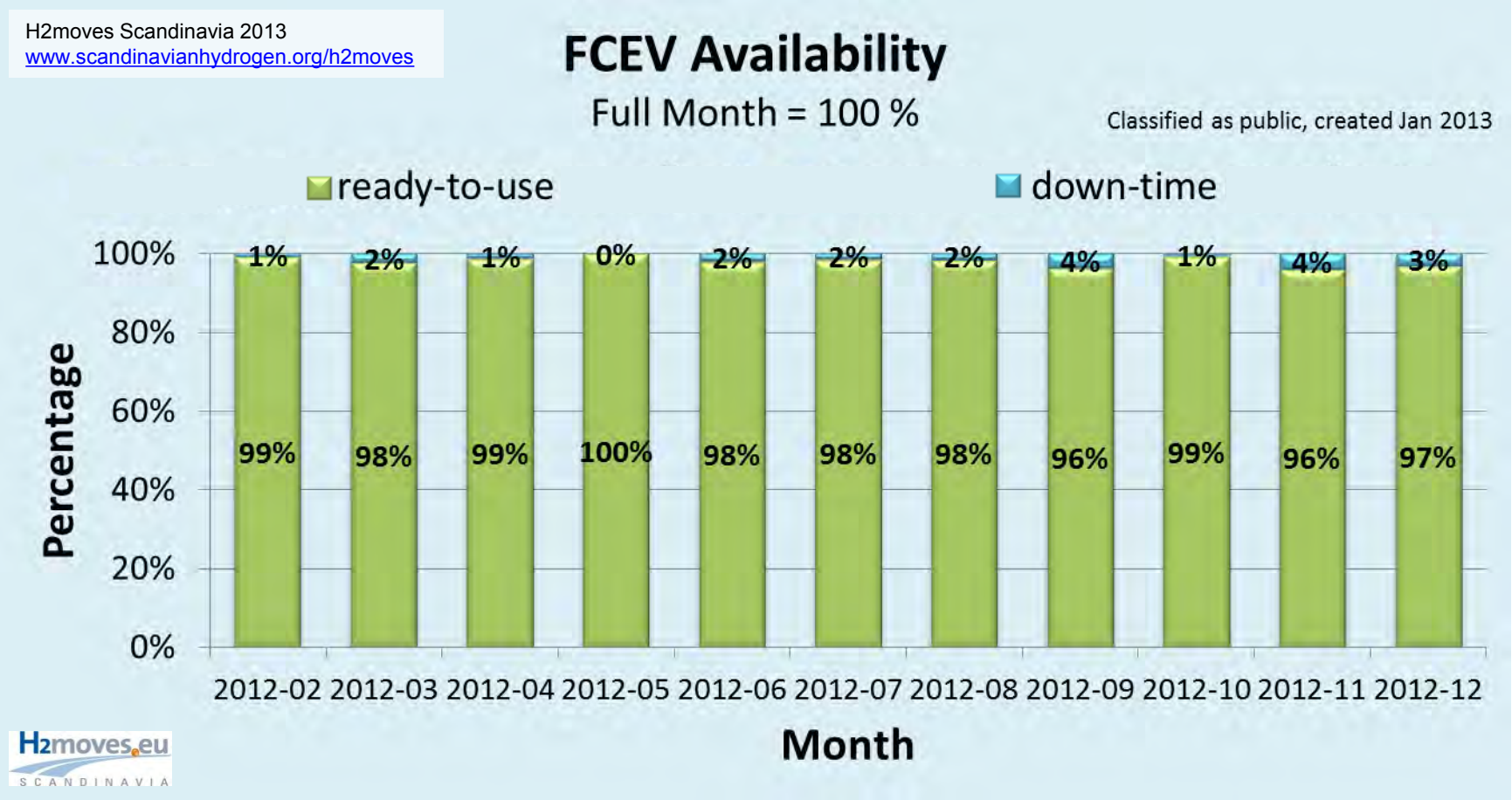
- no significant morning or evening peak
- back-to-back refuelling capacity of small HRSs not relevant

H2moves Scandinavia 2013
www.scandinavianhydrogen.org/h2moves



- no clear peak for single weekday
- back-to-back refuelling capacity of HRS not relevant

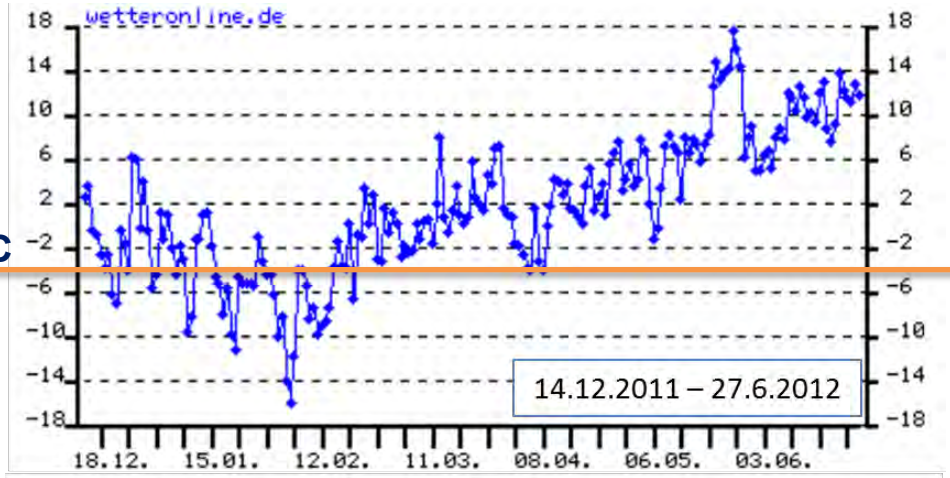
H2moves Scandinavia 2013
www.scandinavianhydrogen.org/h2moves



Expected ready-to-use time: 24/7
➔ Excellent performance: 98% overall availability

FCEV Performance Data

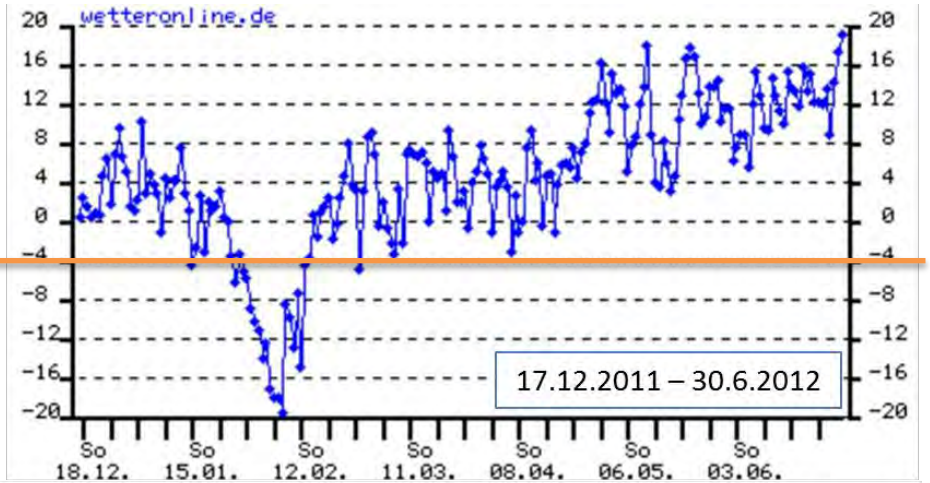
Oslo



Oslo/Blindern: lowest temperature at night in °C

- 4°C

Berlin



Berlin-Tegel: lowest temperature at night in °C

Hyundai winter test in northern Sweden in February 2012:

- outside temperature reached -41.5 °C
- no damage of parked fuel cell vehicle

- successful test of cold winter conditions
- no problems with cold starts

Sources: wetteronline.de, Hyundai Motor Europe

Comparing H2moves Scandinavia with NREL and CEP

H2moves.eu SCANDINAVIA

	H2mS (Norway, Denmark)	CEP (Germany)	NREL (USA)
Start of operational phase	2011	2005	2005
Total number of HRS incl. moveable refuellers	2	11 (+2)	25
Total number of FCEVs since project begin	19	139	183
Km driven per FCEV per 12 months	9,995 km	2012: 5,568 km	-
Average tank capacity	3.52 kg Without Th!nk: 4.24 kg	2012: 3.98 kg	-
Average refuelling amount	2.0 kg	2012: 1,96 kg	2.13 kg[A] 2.64 kg[B]
Percentage refuelled of average tank capacity	45% (without Th!nk)	2012: 49 %	-
Median on-road distance between refuellings	166 km	-	158 km[B]
Percentage of fills between 6 AM and 6 PM	83 %	-	88 %[B]
Percentage of fills between 7 AM and 10 PM	94 %	-	-
Percentage of fills on weekends	13 %	-	6.5 %[B]

All three projects yield comparable results

[A]: Through 2009 Q4
[B]: After 2009 Q4

Sources:
NREL final report July 2012;
CEP 01/2013

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2. FCEV Performance Data
3. HRS Performance Data
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Source: H2 Logic A/S

Four 70 MPa HRSs in Oslo - H2moves Gaustad, is one of them

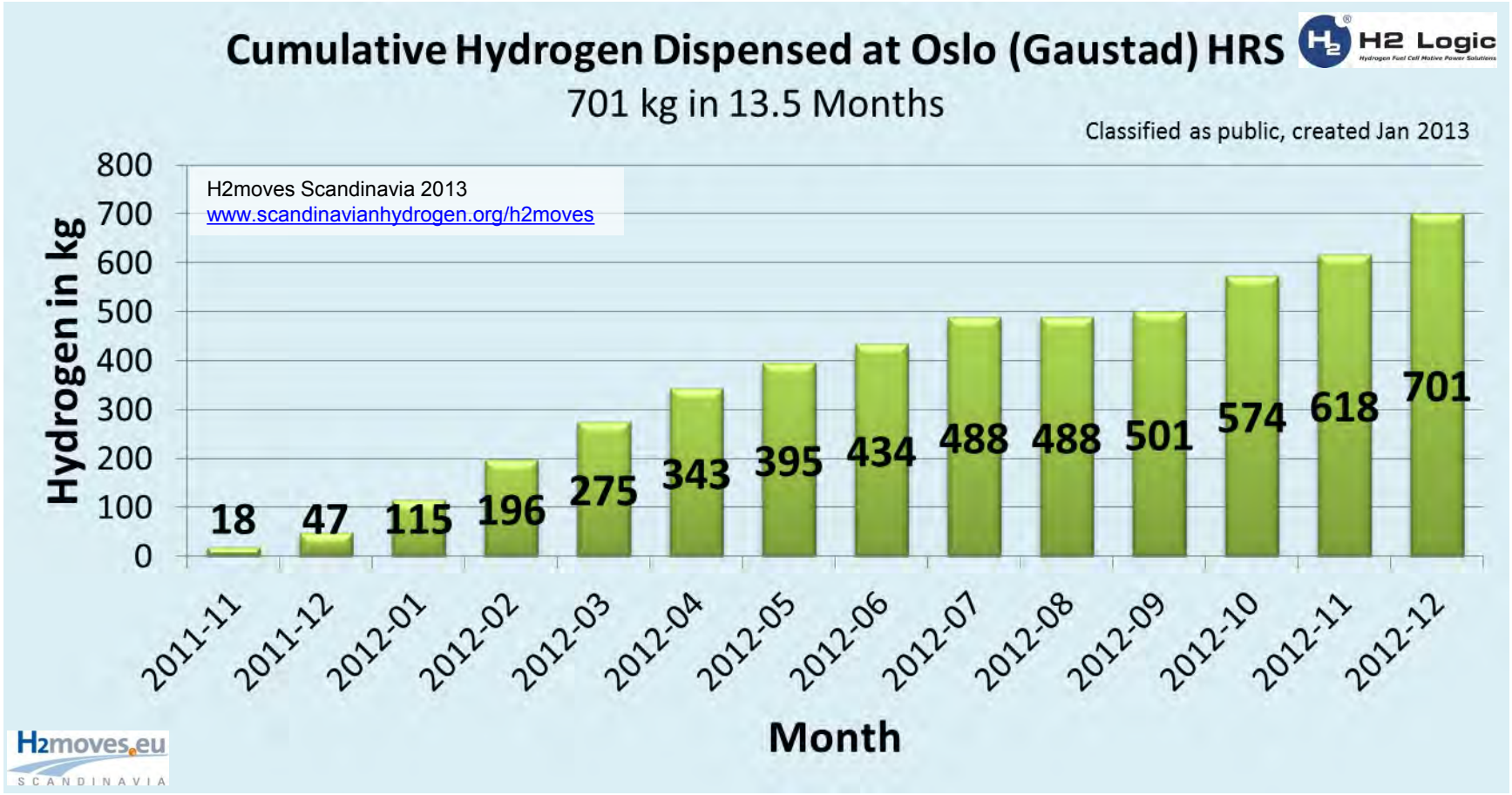
H2moves.eu SCANDINAVIA

Source: adopted from www.klimabiler.no/kart/

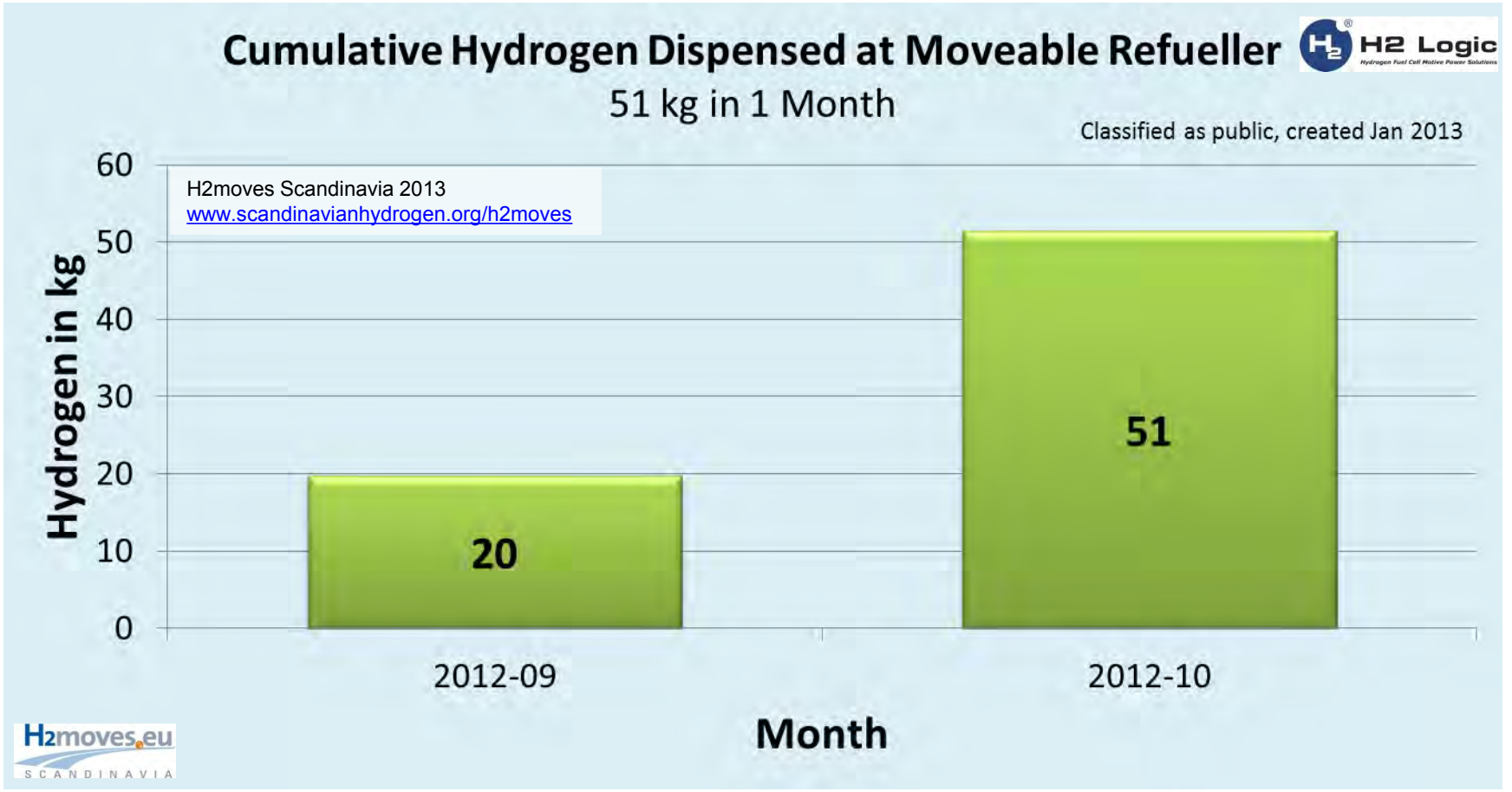
70MPa Car HRS *35MPa Bus HRS* * Opened in summer 2012

HRS Lab Data

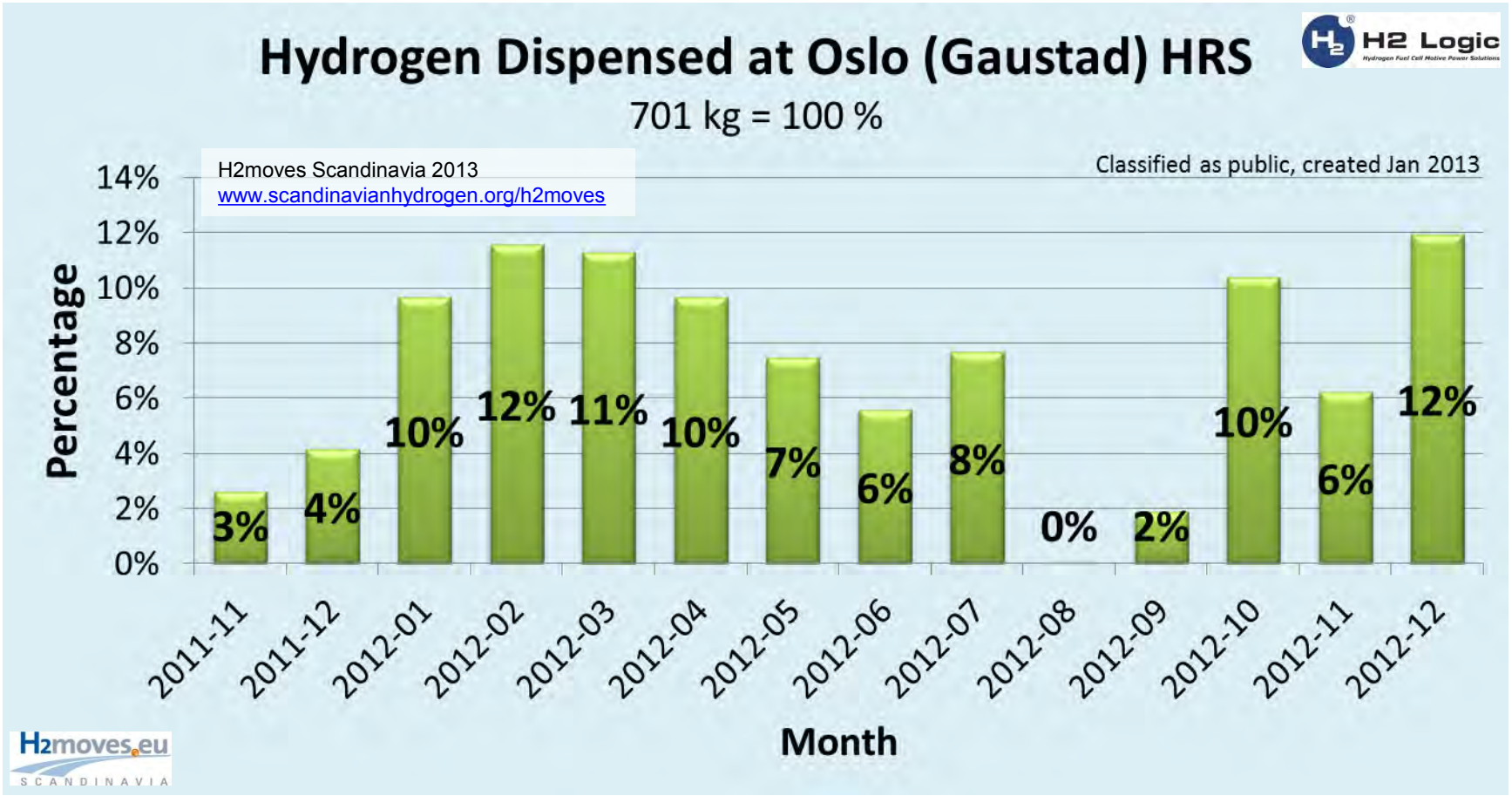
	Per hour	Per day	Per week
kg of hydrogen that can be provided	20	200	1,400
Max number of FCEV that can be fully refuelled	5	50	350



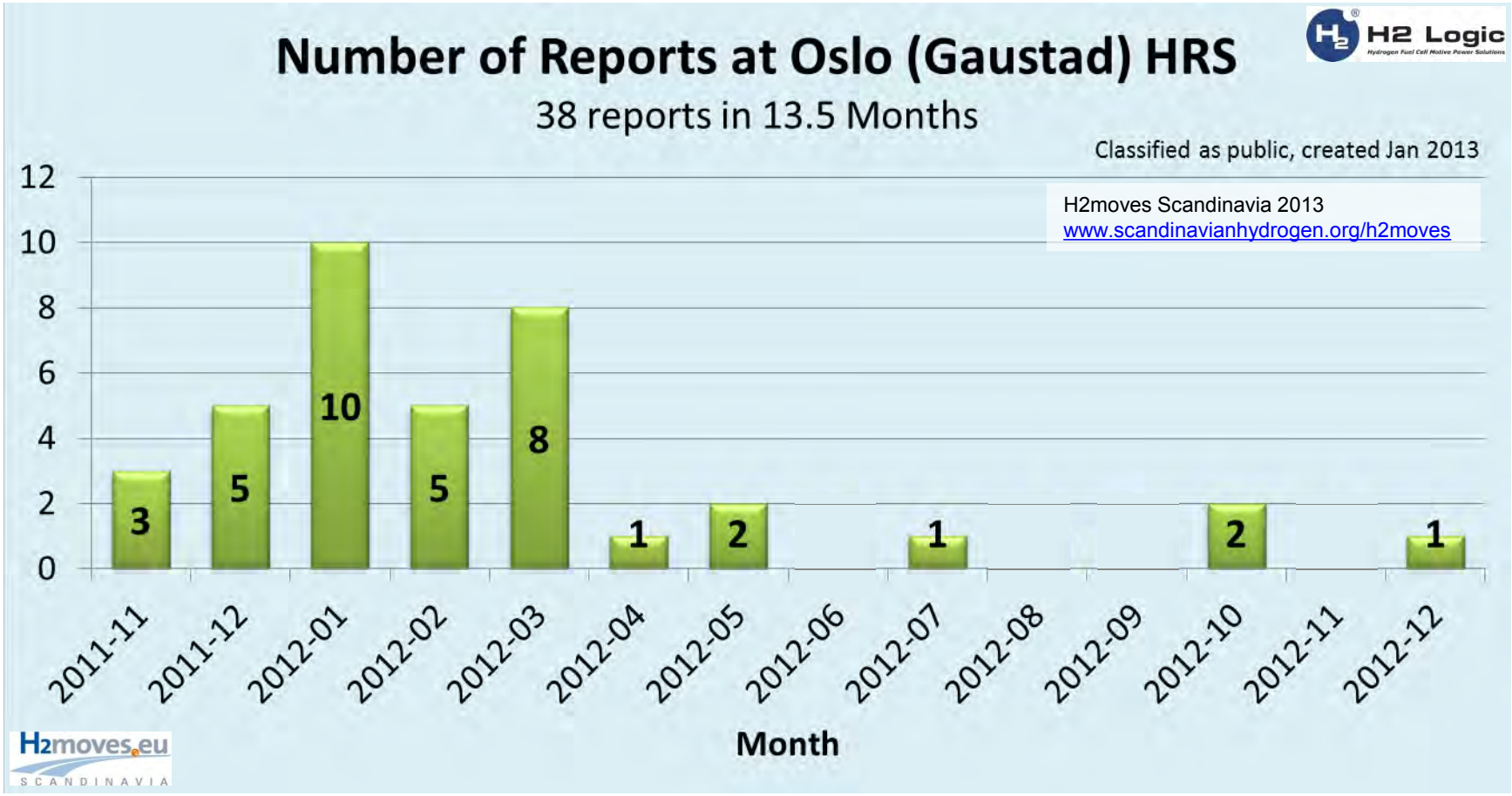
30% of hydrogen refuelled was dispensed at project HRS Gaustad in Oslo.



No problem experienced with the moveable refueller during Road Tour:
100% availability



After repair in late September, customers quickly returned to HRS.



Learning curve for technical reliability of HRS.
First months: several minor reports.
After 2012-03: Either no reports or a major component event (compressor & electrolyser).

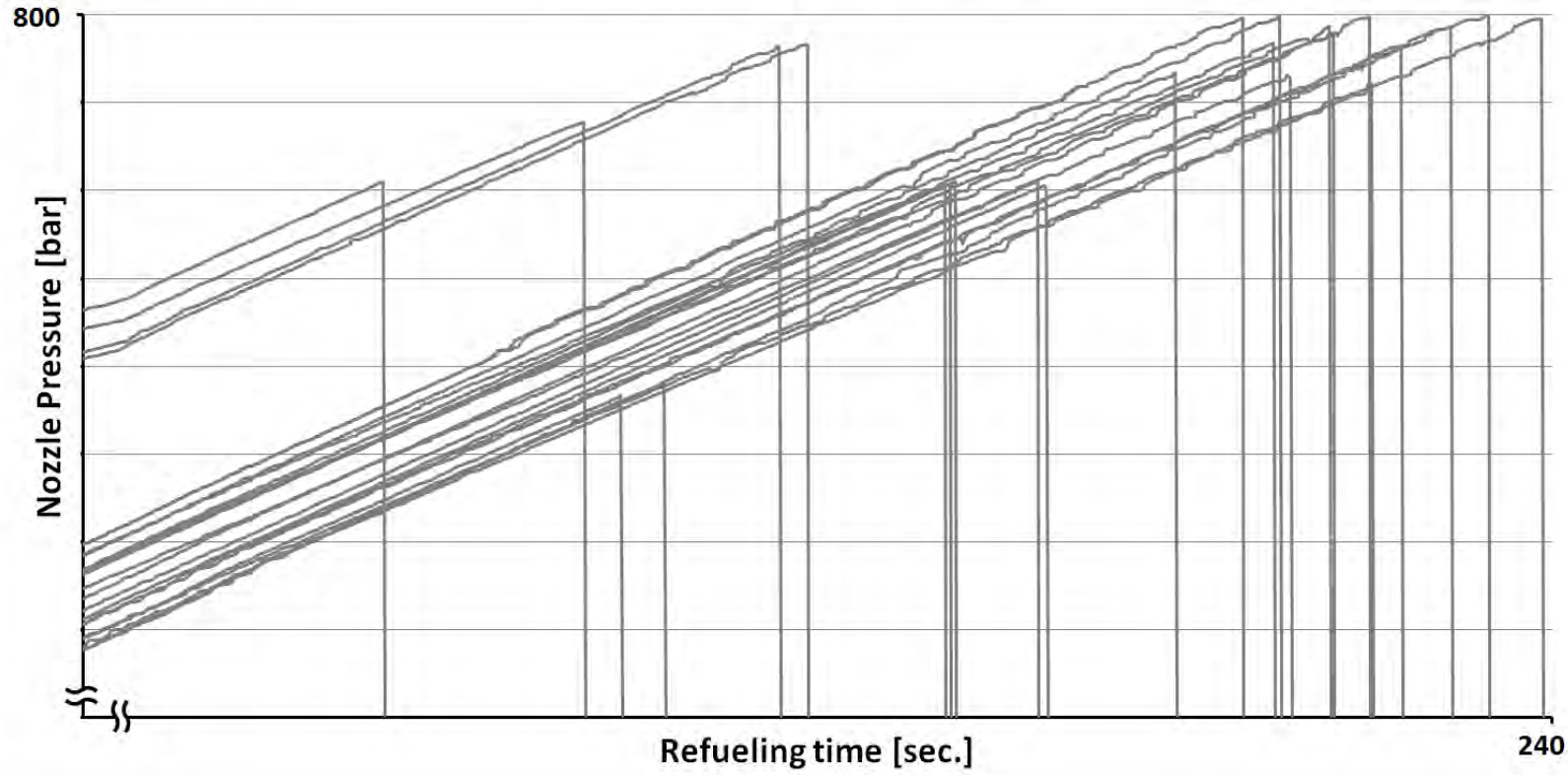
HRS Performance Data

H2moves.eu SCANDINAVIA

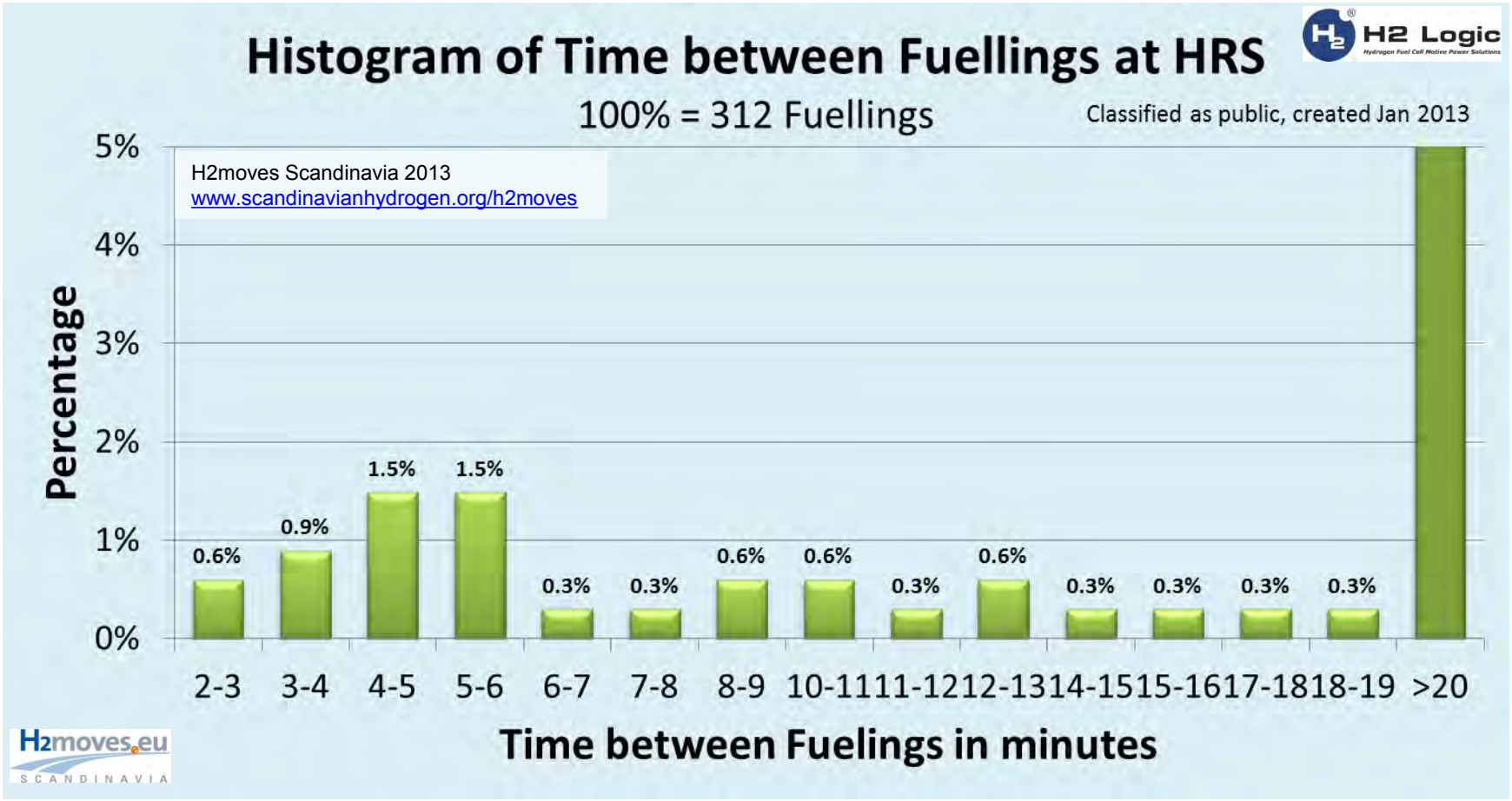
Less than 4 minutes for a full hydrogen tank

H2 Logic
Hydrogen Fuel Cell Motive Power Solutions

Showing actual refueling time at H2Station®



Refuelling faster than 4 minutes



http://www.nrel.gov/hydrogen/images/cdp_infr_08.jpg

Data comparable to NREL:

	H2mS	NREL
Fills within 0-5 minutes of each other	3 %	6 %
Fills with more than 20 minutes between them	92 %	82%

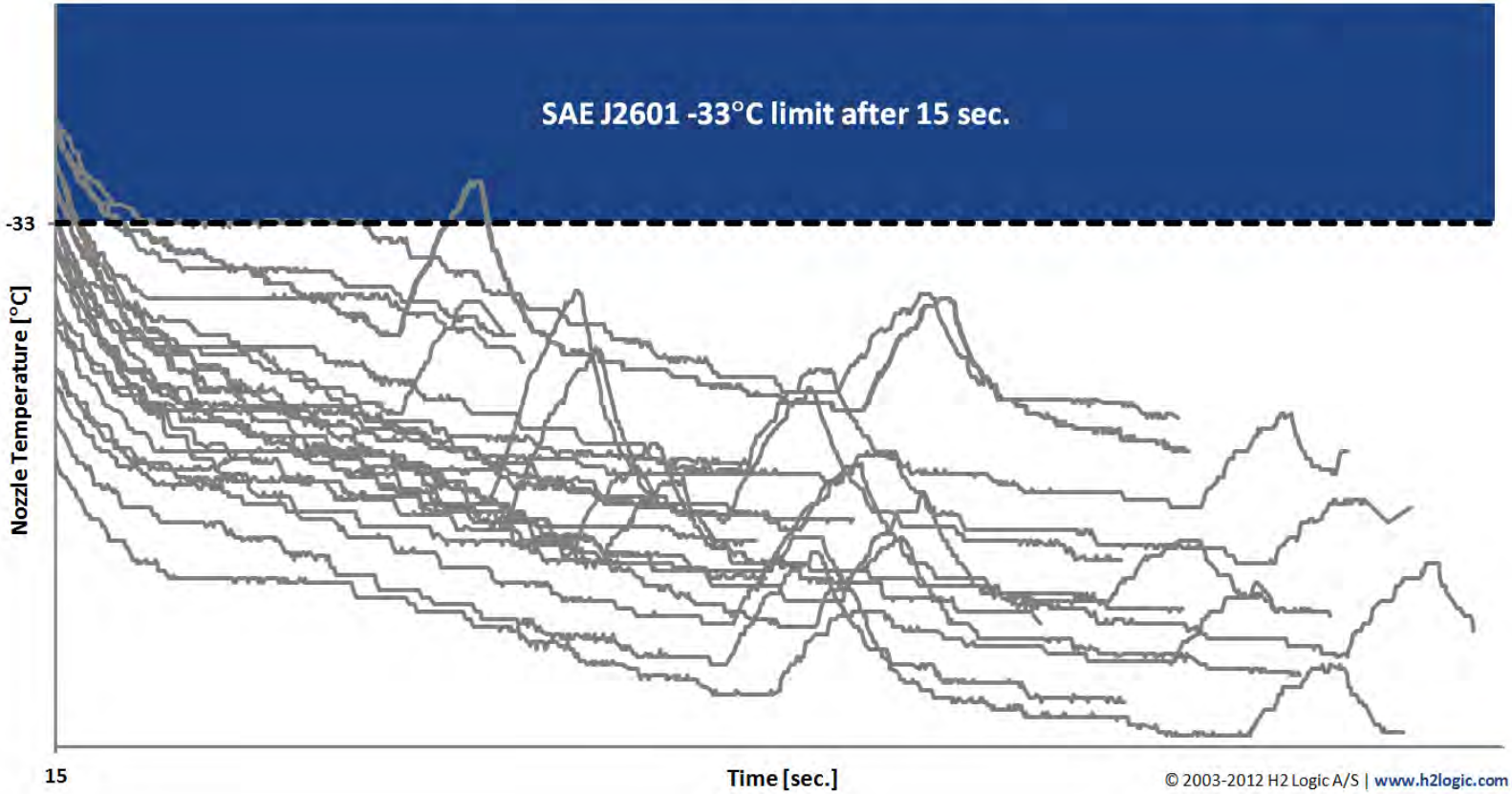
HRS Performance Data

H2moves.eu SCANDINAVIA

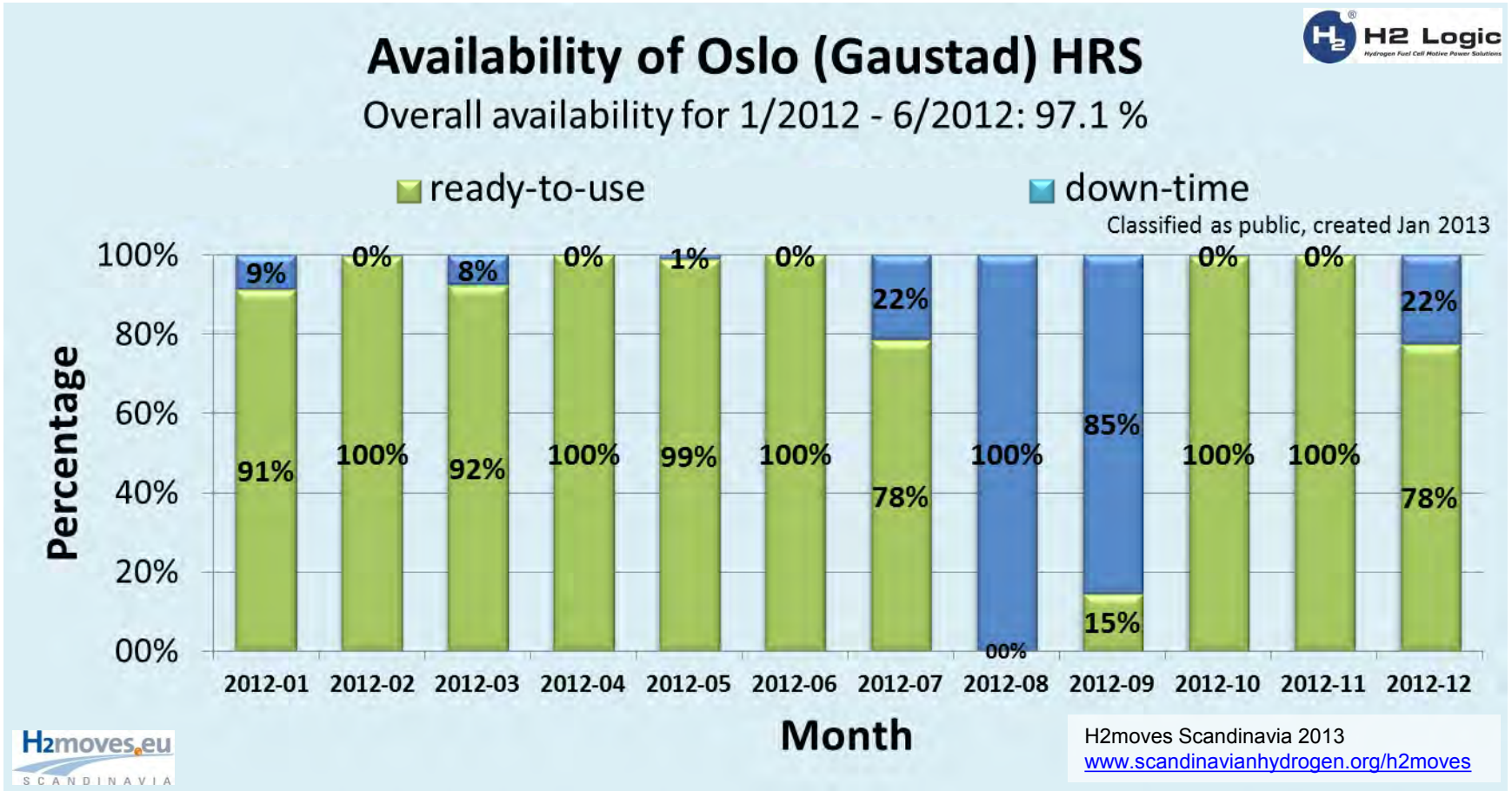
H2Station® 70MPa nozzle temperature - actual field data

25 randomly selected 70MPa refueling's from 3 different H2Station®

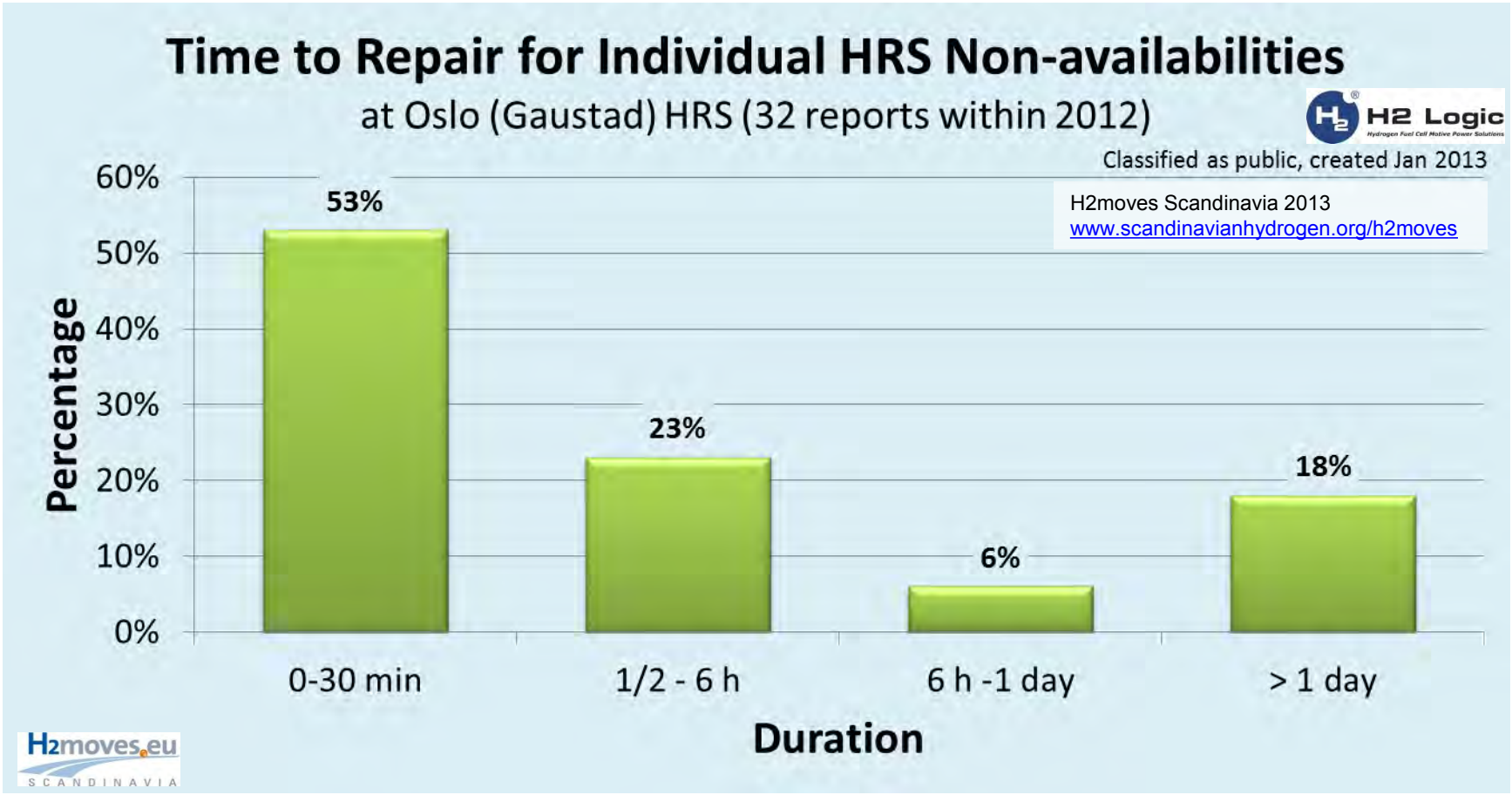
H2 Logic
Hydrogen Fuel Cell Motive Power Solutions



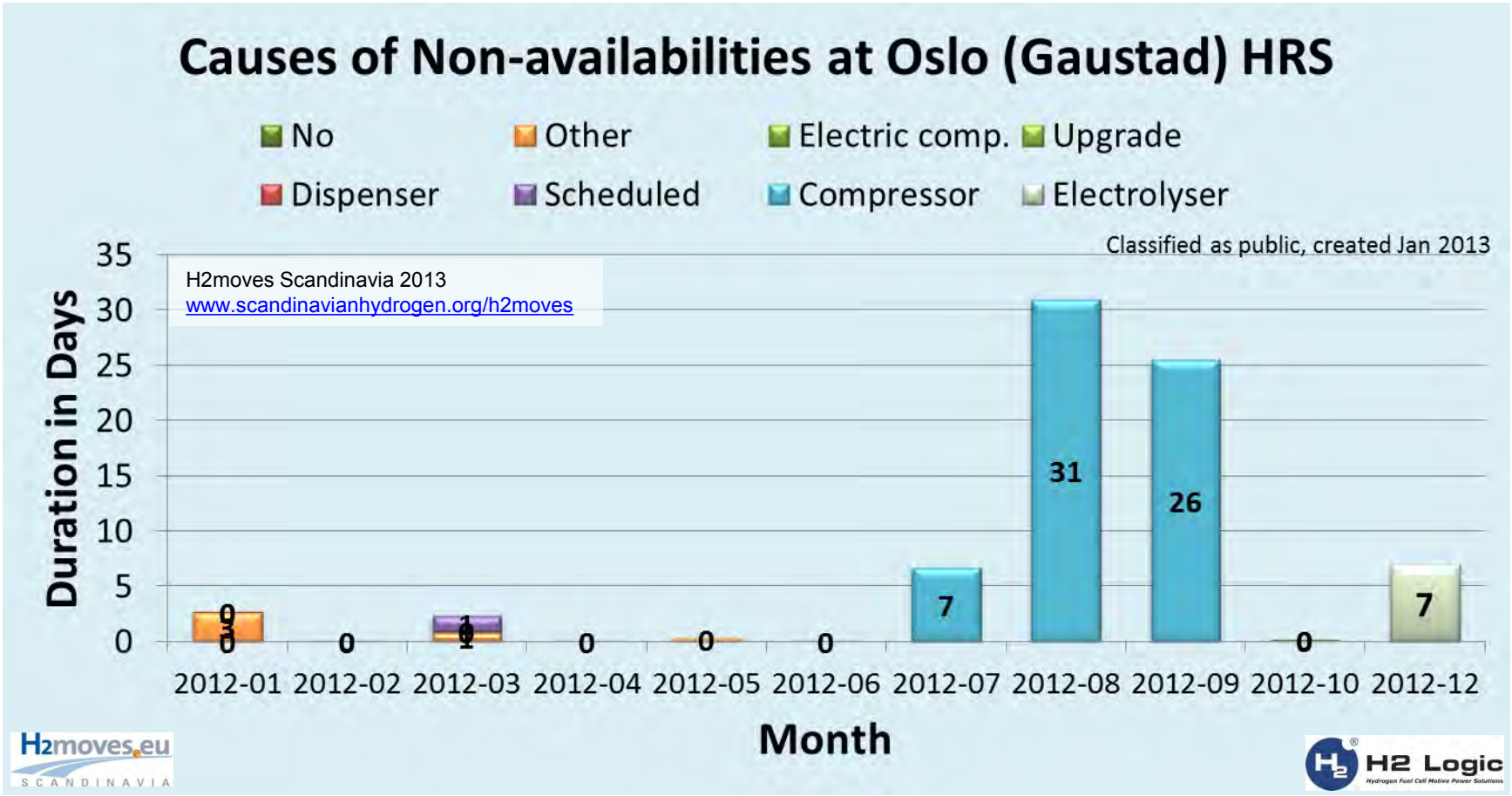
Station fulfills SAE J2601 temperature requirements



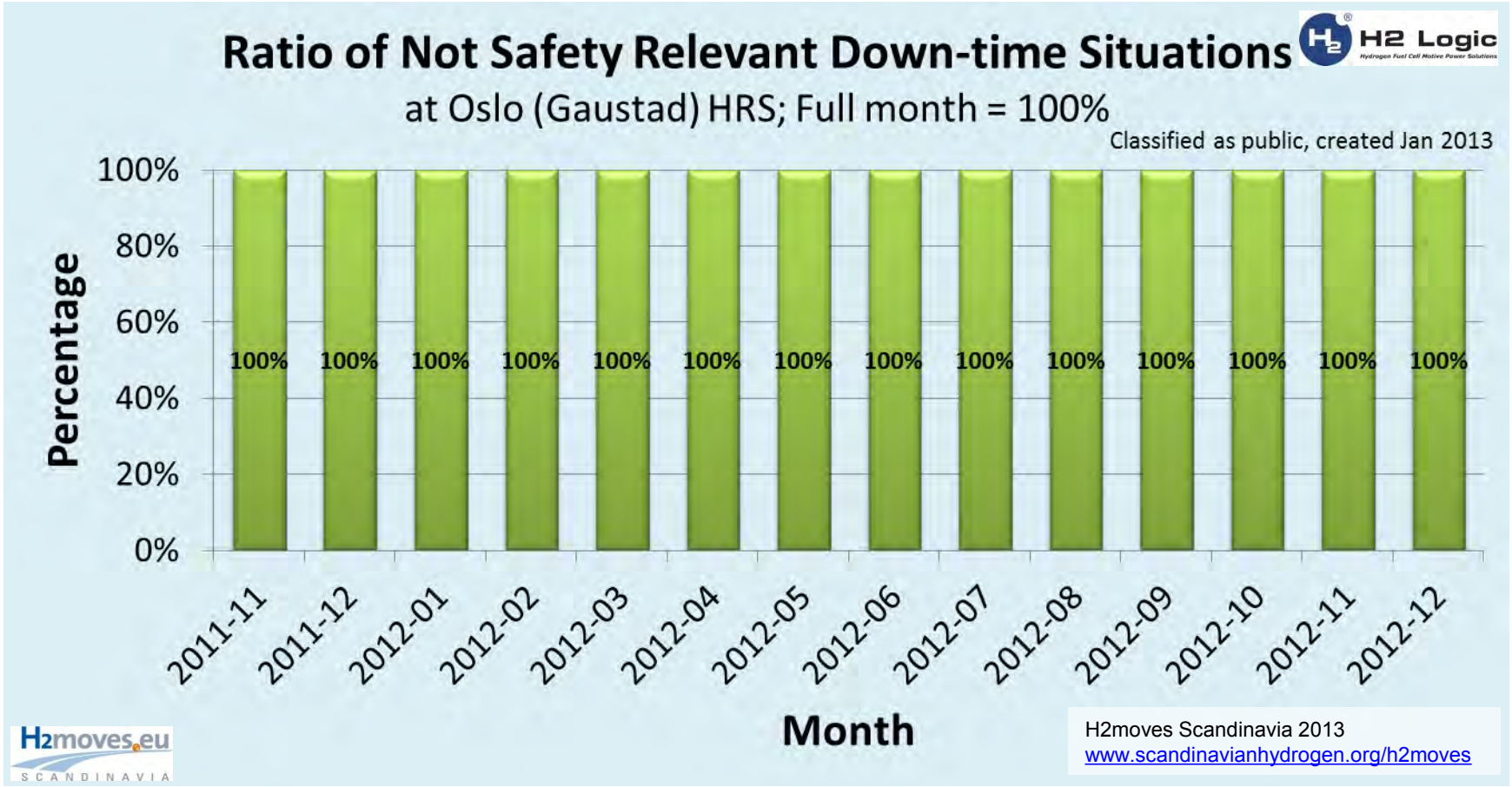
A long down-time from late July to early September was experienced due to a compressor failure. The compressor failure was caused by a sub-supplier and repair process more lenghty than expected. After repair the HRS again reached 100 % availability in October. Overall 79 % of the time ready to use between 1.1.2012 – 31.12.2012.



- 53 % of all down-time situations were solved within ½ hour
- 76 % within 6 hours
- 82 % within 1 day

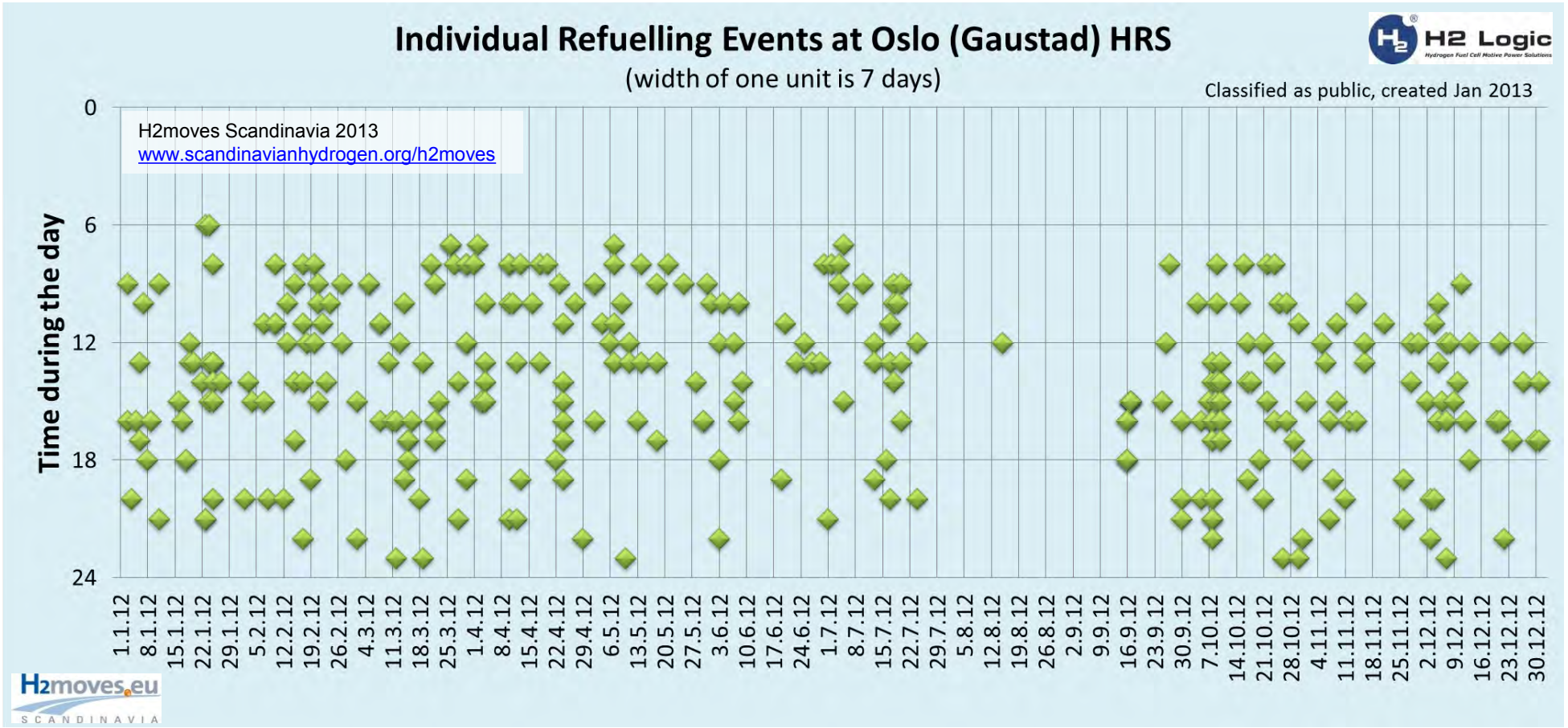


A long down-time from late July to early September was experienced due to a compressor failure. The compressor failure was caused by sub-supplier and repair process took longer than expected.



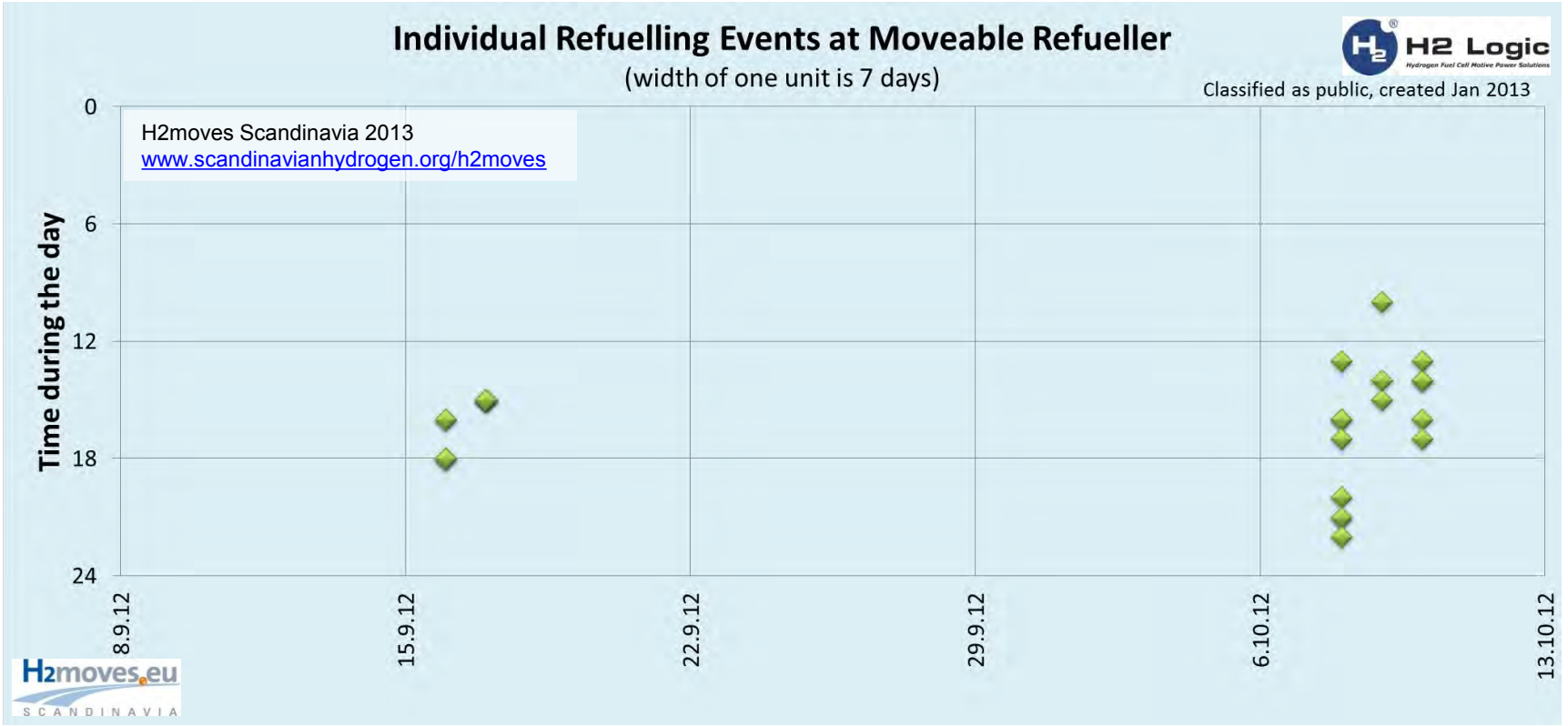
Of all down-time situations, none were related to or affected safety.

HRS Performance Data



Customers quickly returned to HRS after repair

HRS Performance Data:
Moveable HRS, RoadTour Stops: Hannover & Copenhagen



Moveable HRS capable of many back-to-back refuellings

HRS Performance Data

Individual Refuelling Events at Oslo (Gaustad) HRS

(width of one unit is 7 days)

H2 Logic

Classified as public, created Jan 2013

H2moves Scandinavia 2013
www.scandinavianhydrogen.org/h2moves

Amount of Hydrogen Refuelled [kg]

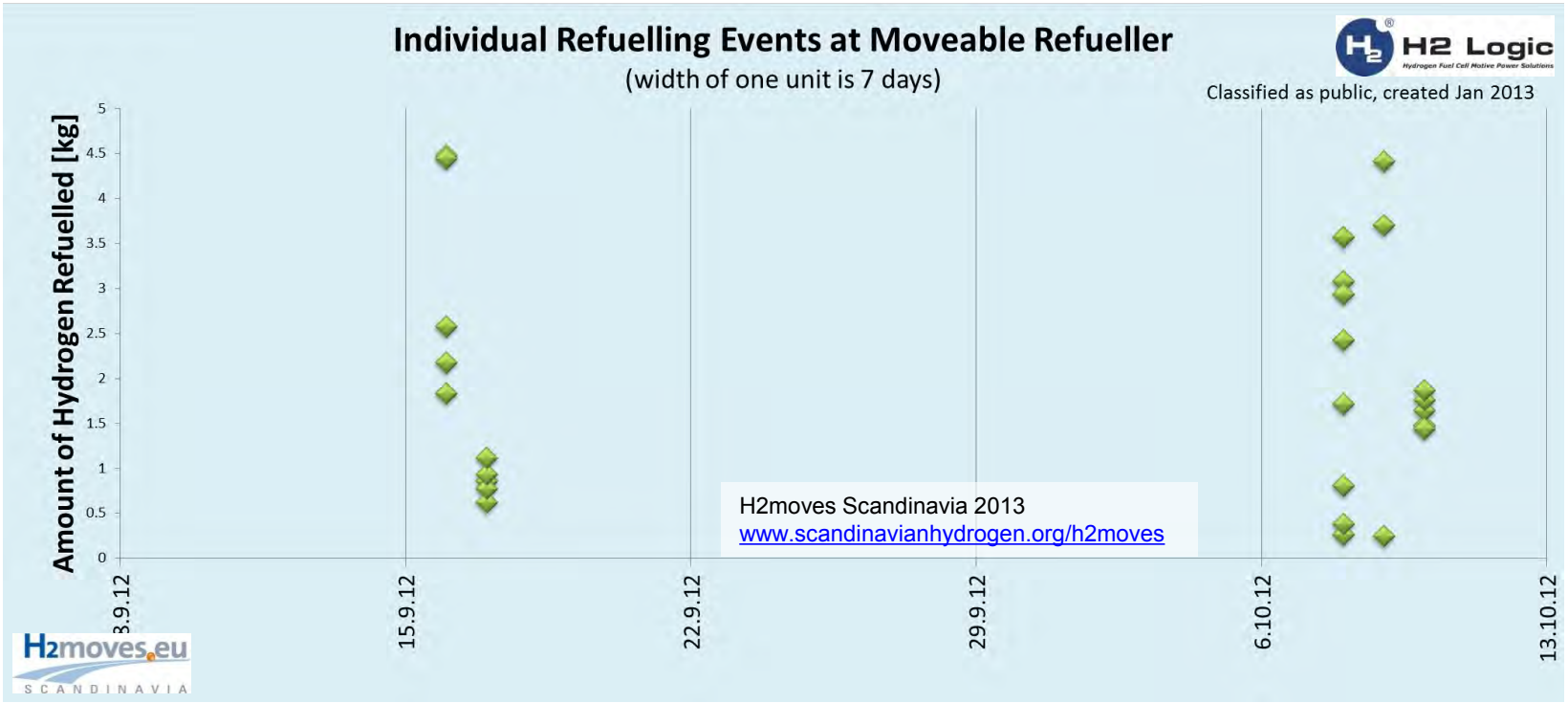
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

1.1.12
8.1.12
15.1.12
22.1.12
29.1.12
5.2.12
12.2.12
19.2.12
26.2.12
4.3.12
11.3.12
18.3.12
25.3.12
1.4.12
8.4.12
15.4.12
22.4.12
29.4.12
6.5.12
13.5.12
20.5.12
27.5.12
3.6.12
10.6.12
17.6.12
24.6.12
1.7.12
8.7.12
15.7.12
22.7.12
29.7.12
5.8.12
12.8.12
19.8.12
26.8.12
2.9.12
9.9.12
16.9.12
23.9.12
30.9.12
7.10.12
14.10.12
21.10.12
28.10.12
4.11.12
11.11.12
18.11.12
25.11.12
2.12.12
9.12.12
16.12.12
23.12.12
30.12.12

H2moves Scandinavia

Due to range anxiety, refuelling quantities do not come close to tank capacity.
Drivers refuell when passing by the station, not when their tank is on reserve.

HRS Performance Data:
Moveable HRS, RoadTour Stops: Hannover & Copenhagen



First day: all cars fully refuell. Afterwards: (public) ride & drive event
Last day: all cars refill the hydrogen consumed during ride & drive.
➔ FCEVs consumed roughly same amount of H2 during the ride&drive events

Content

H2moves.eu SCANDINAVIA

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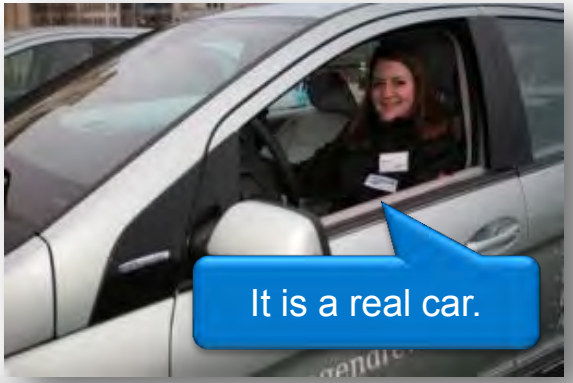
4. Customer Survey
4. Outlook



Customer Survey Background

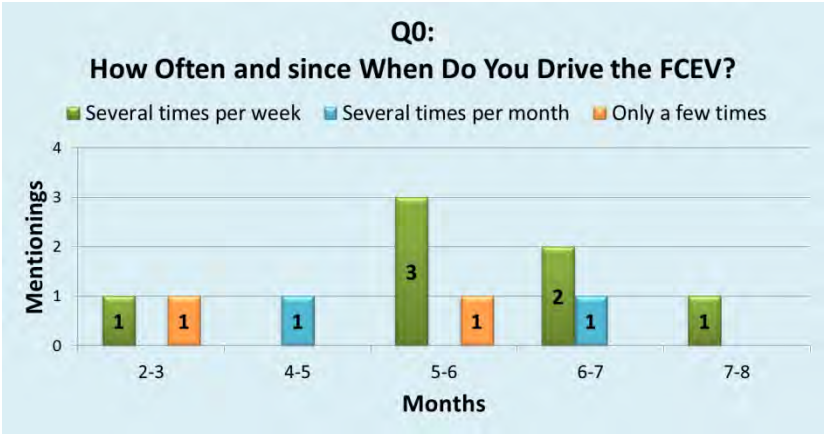
- In April 2012, 11 interviews with customers of H2moves Scandinavia were conducted.
- 18 questions
- Most questions were open. After the first spontaneous answer, interviewers asked deepening questions to pre-defined aspects (see questionnaire).
- Multiple answers were possible whenever meaningful.

Aim:

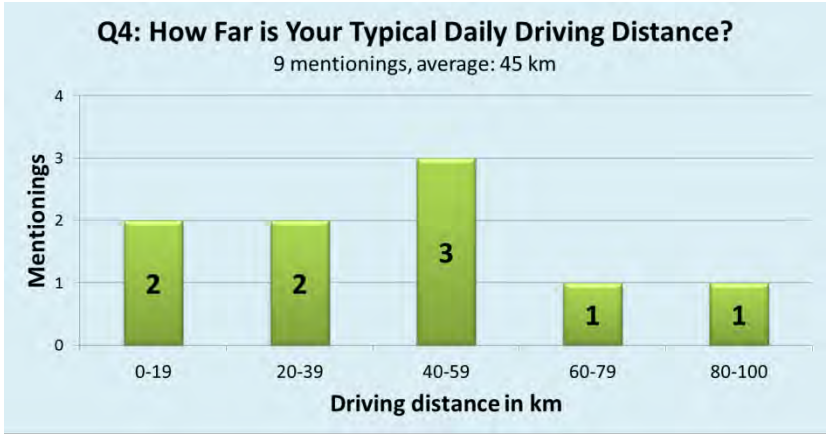
- To improve quality of interpretation of data collected from hardware, e.g.:
  - Cars often refuel rather small quantities of hydrogen. Do you always fully refuel? If not: why?
  - Range is an issue with FCEVs. What is your typical daily driving distance and how often do you need a significantly higher range?
- Testimonials for marketing purposes

Remark:
The questionnaire is not representative and does not fulfill scientific standards.
It‘s purpose is to fulfill the specific demand of the project H2mS as mentioned above.

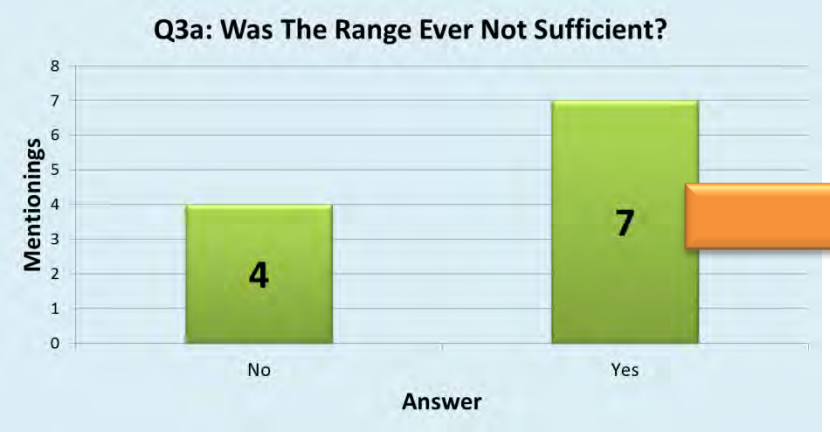
Customer Survey
Driving Patterns: Frequency and Distances



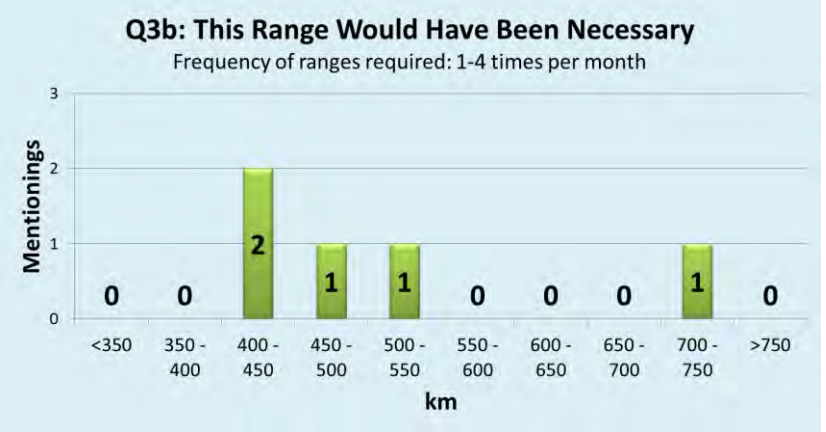
11 interviews were conducted with 9 people including our super-user who drives all three kinds of cars on a regular basis.



The range of daily driving range goes from 10 to 100 km. All H2mS vehicles can cover this and only few customers have to take detours for refuelling several times per week.

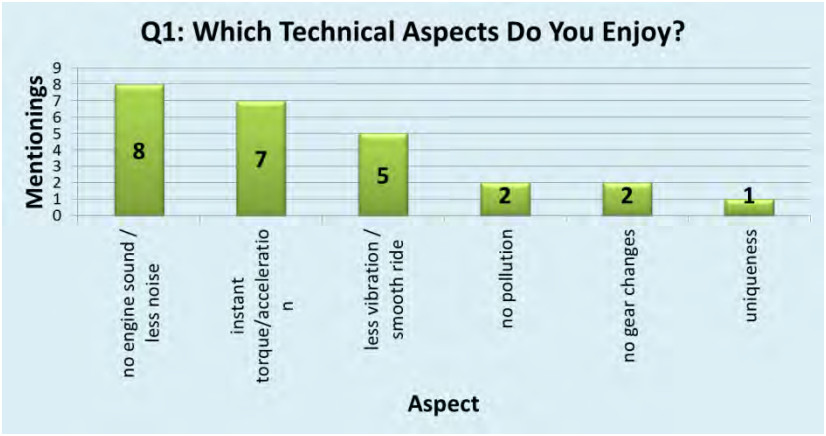


Answers depended on individual expectations. As for most people the FCEV is not the only car available, they just choose another car.



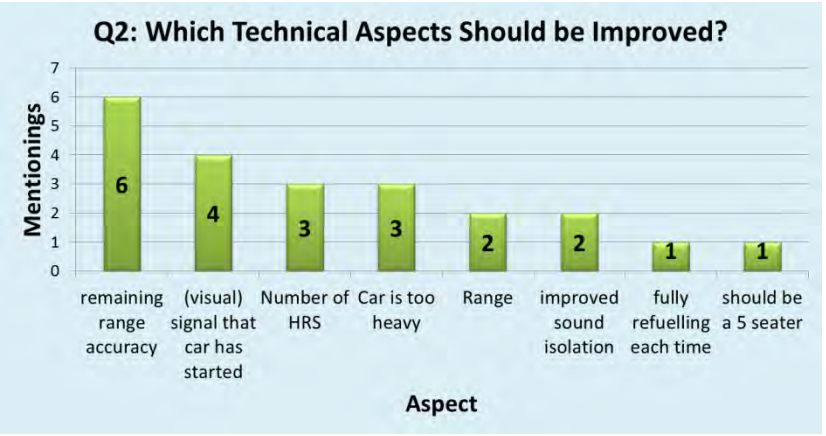
In 7 interviews we received the answer that the range is not sufficient. Due to our super-user, we have 5 individual ranges required.

Customer Survey
Technical Aspects



Multiple answers possible.
In Norway, about 50% of the conventional cars sold are with manual gear shifts, the remaining half are equipped with automatic transmission.

All customers always fully refuel – until HRS or FCEV stops process.



Multiple answers possible.

The frequency of mentionings is not too significant (compare questionnaire underneath) as after some time we suggested answers.

Reactions concerning artificial noise:

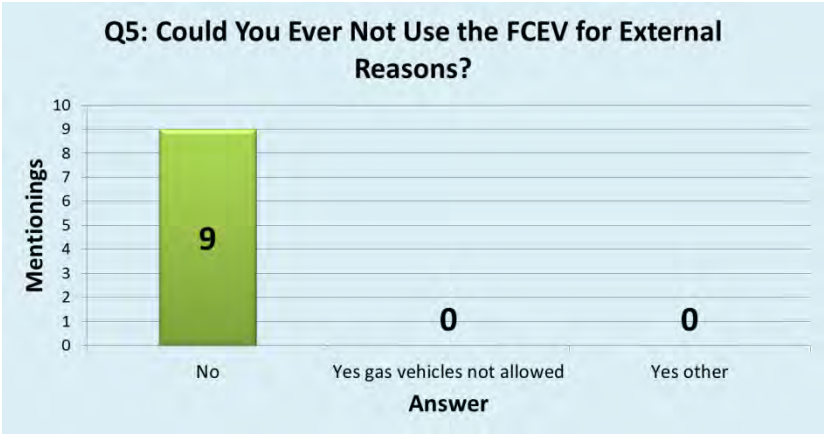
- "I rarely use the artificial noise but it's like with seat belts: if you know it exists, you want to have this safety feature."
- "When taking the bike, pedestrians don't hear you and the speed is in the same range as FCEVs: up to 30 km/h. When going faster, the cars are getting louder anyway."
- "The car on its own is loud enough…"

➔ Varrying opinions

2. Which technical aspects should be improved?

- [there needs to be an artificial noise so pedestrians can hear me.
- I want to choose from several artificial noise options.
- I am driving the car for 3 months now and still can't tell whether the engine is already running or not.
- I don't trust the predicted remaining range, so I refuel rather often.]

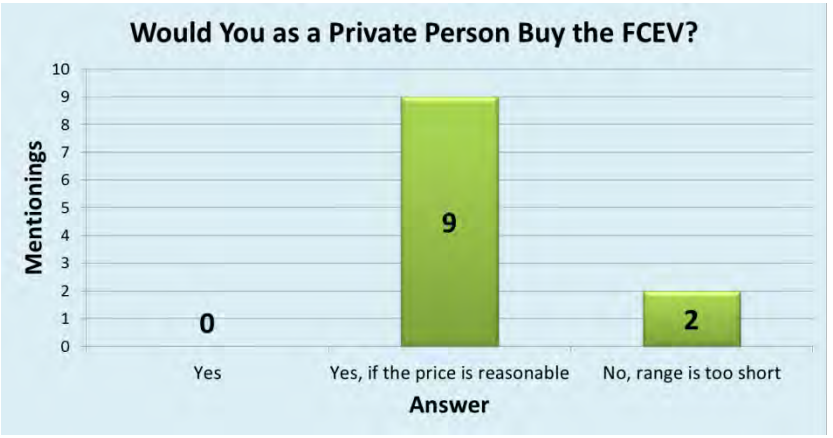
Customer Survey
External influences



Even taking one of the cars on a car ferry on a frequent basis was no problem. No one ever had problems in car parks.

Customer: “Lowest temperature during the night was -27°C, starting the car the next morning was no problem.”
No customer noticed “sleepiness” of the car within the first minutes. Several mentioned that in winter it takes longer until the inside of the car gets warm.

During rush hour this is a major benefit – when driving in the city area.



The buying decision was only driven by range and price, which should range between “reasonable” and “only as second hand car”/”only if I don’t have to pay a single NOK more – cars are expensive enough anyway”.

Customer Survey Testimonials

H2moves.eu SCANDINAVIA

People loving FCEVs

People used to BEVs fall in love with FCEVs as soon as they try them.

FCEVs are “babe magnets”.

In our company, about 20 people drive the FCEV from time to time – fighting about who can have the FCEV tomorrow.

My 13year old kid “forced” me to demonstrate the car at school to his class mates. The FCEV was clearly the most special car around.

Driving experience

The FCEV exceeded my expectations – especially the instantly available torque.

The driving experience is better than with a gasoline car.

I am fascinated by the torque and the silence.

It is such a smooth ride.

Boundary conditions

I never experienced any restrictions because it is a gas vehicle. I frequently take a car ferry.

Refuelling doesn’t stink. Although I sometimes liked the smell of gasoline…

Starting the car at -27°C in the morning was no problem at all.

The most comfortable aspect? Driving in the bus lane – makes your weekend longer.

Too few HRS

I will buy one for myself, as soon as there are enough HRS and the price is reasonable.

The only annoying aspect about FCEVs is the lack of hydrogen stations.

Customer Survey Questionnaire I/III

H2moves.eu SCANDINAVIA

WP 7 Technical Monitoring and Assessment

Customer Satisfaction Survey

This survey is primarily H2moves Scandinavia internal. Please give us you honest and sincere opinion so that we can learn from your experience. What are the real benefits that you enjoy in everyday life? Which improvements would boost your daily experience?

[yellow marked text will not be part of the questionnaire. Questionaire will be filled out by interviewer, not customer. The customer just talks, but doesn't write.]

Your Name (optional)	Date

Car Type(s) [SC: only one car type per questionnaire]

☐ B-Class F-CELL ☐ ix35 FCEV ☐ Th!nk

For how many months are you driving the FCEV now?

_____ months

How often do you usually drive the FCEV?

☐ Several times per week ☐ Several times per month ☐ Only a few times

1. Which technical aspects (that are unique for an FCEV or electric vehicle) did you recognize that you especially enjoyed?

[I listen to my music, not the engine. No gear changes.]

2. Which technical aspects should be improved?

- [there needs to be an artificial noise so pedestrians can hear me.
- I want to choose from several artificial noise options.
- I am driving the car for 3 months now and still can't tell whether the engine is already running or not.
- I don't trust the predicted remaining range, so I refuel rather often.]

H2moves.eu SCANDINAVIA

WP 7 Technical Monitoring and Assessment

Customer Satisfaction Survey

When starting the car under very cold conditions (e.g. -10 °C): Did you notice a different behaviour of the car within the first few minutes?

[e.g. it feels a bit "sleepy" not being on full power]

3. Did you experience situations, where you could not use the FCEV due to its range?

☐ No

☐ Yes

This range would have been necessary: _____ km

This happens _____ times per month

Your comments:

[Driving to cabins in remote areas on the weekends is a Scandinavian speciality. Not being able to go there with a FCEV is probably of minor relevance for the rest of Europe.]

4. How far is the typical distance you drive with the car?

_____ km

5. Did you experience situations, where you could not use the FCEV due to other reasons than its range?

☐ No

☐ Yes

☐ Gas-vehicles were not allowed. Please specify: _____

☐ Other. Please specify: _____

Your comments:

Customer Survey Questionnaire II/III

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WP 7 Technical Monitoring and Assessment

Customer Satisfaction Survey

6. In Oslo, with an electric vehicle you are allowed to use the bus lanes. How much time does this save?

☐ None, I don't use this possibility (e.g. because of not driving in the city center)

☐ With a regular car, my usual tour takes _____ minutes. When driving on the bus lane, I only need _____ minutes in total for the same route.

Your comments:

7. During Refuelling: Which differences do you recognize compared to regular refuelling?

a) ☐ None

☐ It is faster

☐ It is slower

b) ☐ If I could choose freely, I would prefer the usual refuelling process, because:

[e.g. easier to handle? I want to pay in cash? I can't buy my favourite chocolate and coffee??]

☐ If I could choose freely, I would stick with refuelling hydrogen, because:

[e.g. Doesn't stink; I can smoke; it is so much fun I already refuel even when the tank is still full]

Your comments:

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WP 7 Technical Monitoring and Assessment

Customer Satisfaction Survey

8. We noticed that the possible range of the cars is not being utilized. Why don't you drive further on each tank?

[e.g. I don't trust the "km left" notice, because I made bad experience with it. There are so few HRS. I noticed that the HRS is down sometimes, so to be on the safe side I refuel each time I pass a HRS.]

9. Do you fully refuel each time when refuelling?

☐ Yes

☐ No, only until a certain amount of money / hydrogen, because _____

[e.g. because it is my "lucky number"]

☐ No, for this reason: _____

Do you sometimese show how to refuel to other people? E.g. when you want to show to your colleagues and friends how it works?

☐ No

☐ Yes, this often: _____

[to find out more reasons why the "distance driven between refuellings" is so short]

10. Did you ever experience any problems with the HRS? Please specify which one it was.

11. Is there anything else you want to mention concerning the FCEV or HRS?

Customer Survey Questionnaire III/III

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WP 7 Technical Monitoring and Assessment

Customer Satisfaction Survey

The FCEV Experience

(adopted from "Spiegel Online" http://www.spiegel.de/auto/fahrkultur/0,1518,814045,00.html)

Please elaborate your answers.

What were your expectations beforehand?
What fascinates you? [SC: Here not focussing on technical aspects though.]
What annoys you? [SC: Here not focussing on technical aspects though.]
What was the greatest situation you experienced?
Would you as a private person buy the car?

Content

Source: LBST GmbH
H2 Logic A/S

Source: Hyundai Motor Europe

Source: Daimler AG

1. Technical Advancements

2. FCEV Performance Data

3. HRS Performance Data

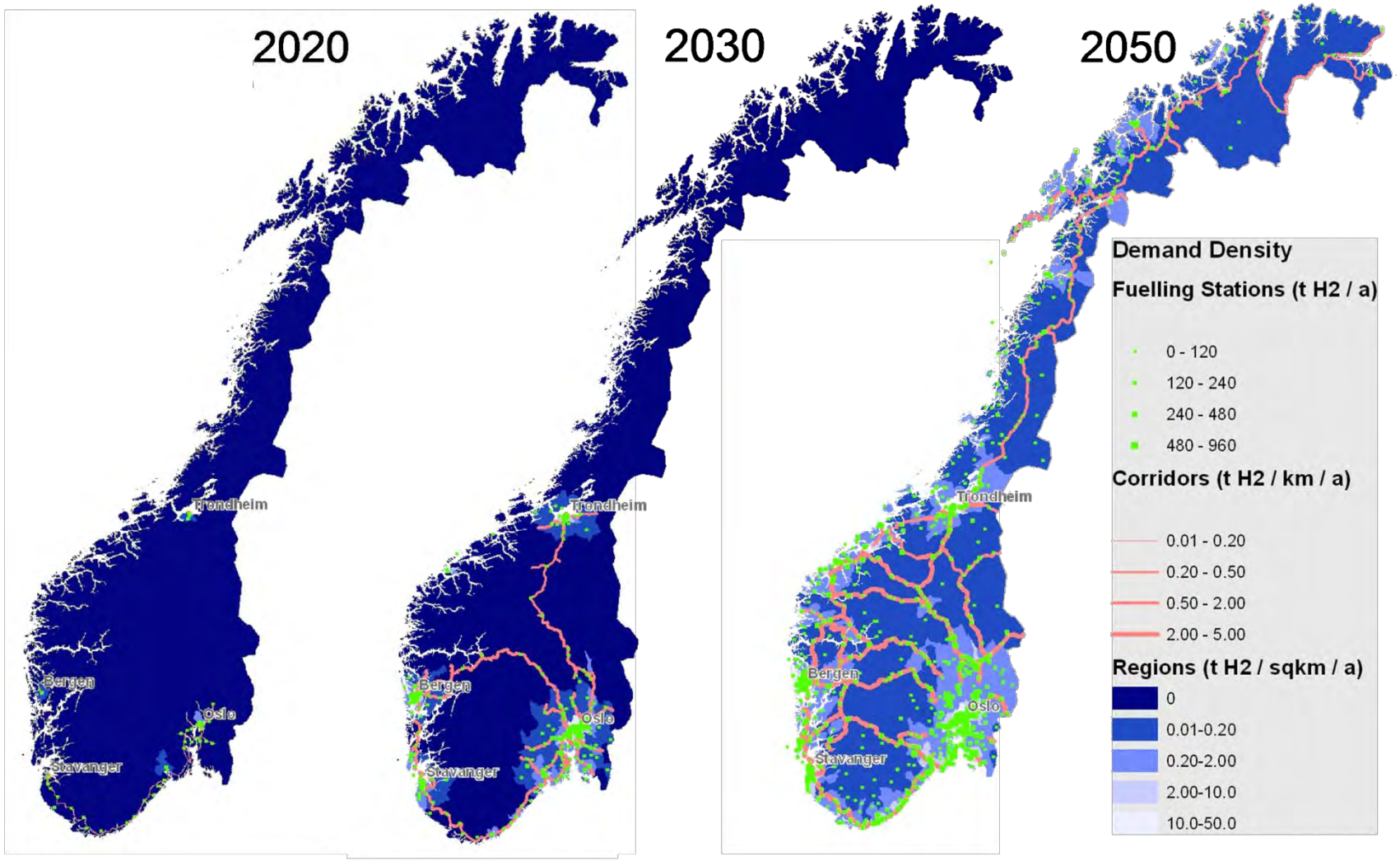
4. Outlook

Source: Daimler AG

Source: LBST GmbH
H2 Logic A/S

Source: Hyundai Motor Europe

Norway:
HRS and Hydrogen Demand Evolution



Source: NorWays Roadmap 2006-2008

Denmark:
Outlook for Hydrogen Stations Roll-out

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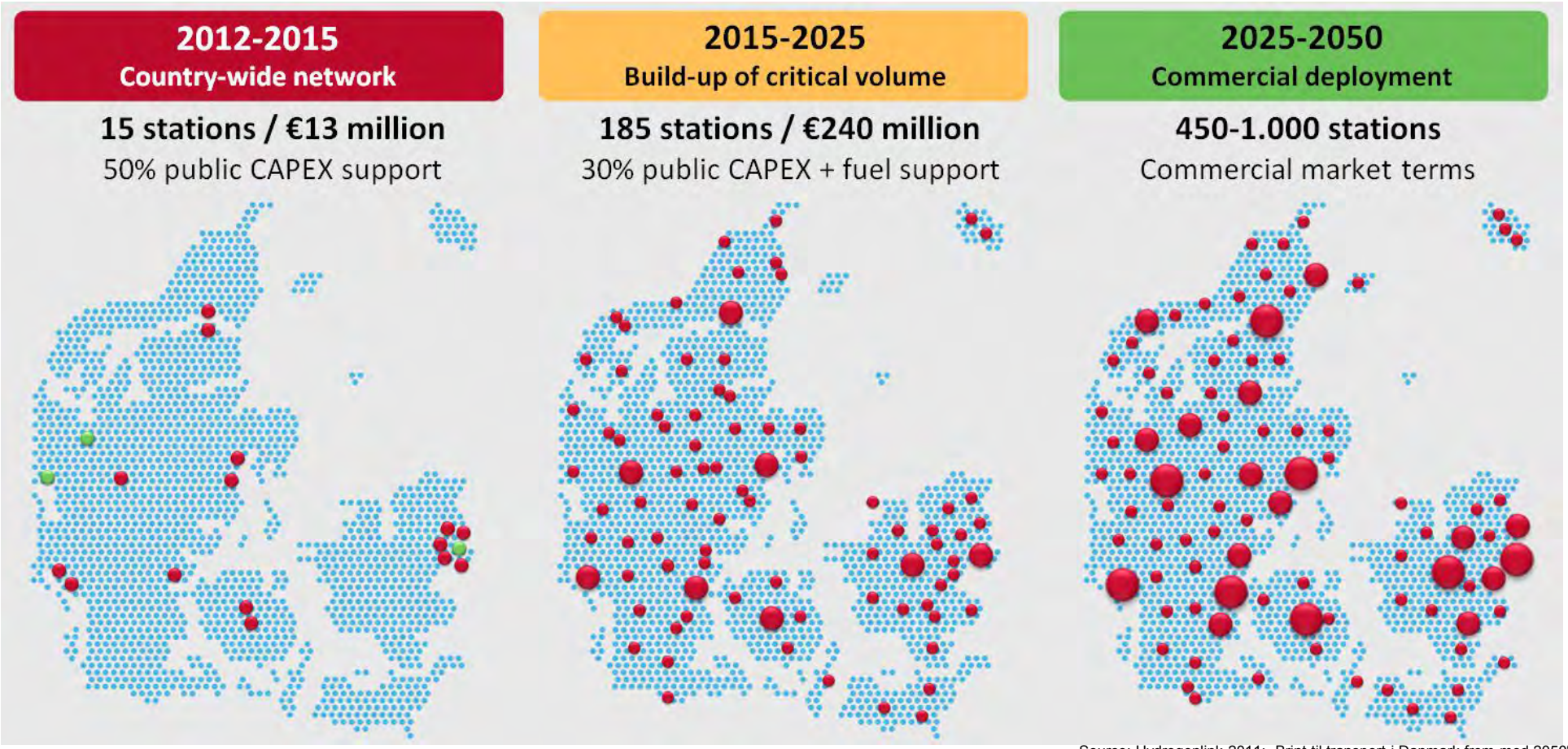
- A staged roll-out - ensuring availability of refueling to the growing fuel cell vehicle fleet
- Appropriate public market support mechanisms to ensure attractive investment case



Source: Hydrogenlink 2011: „Brint til transport i Danmark frem mod 2050“

Scandinavia:
Scandinavian Hydrogen Highway Partnership

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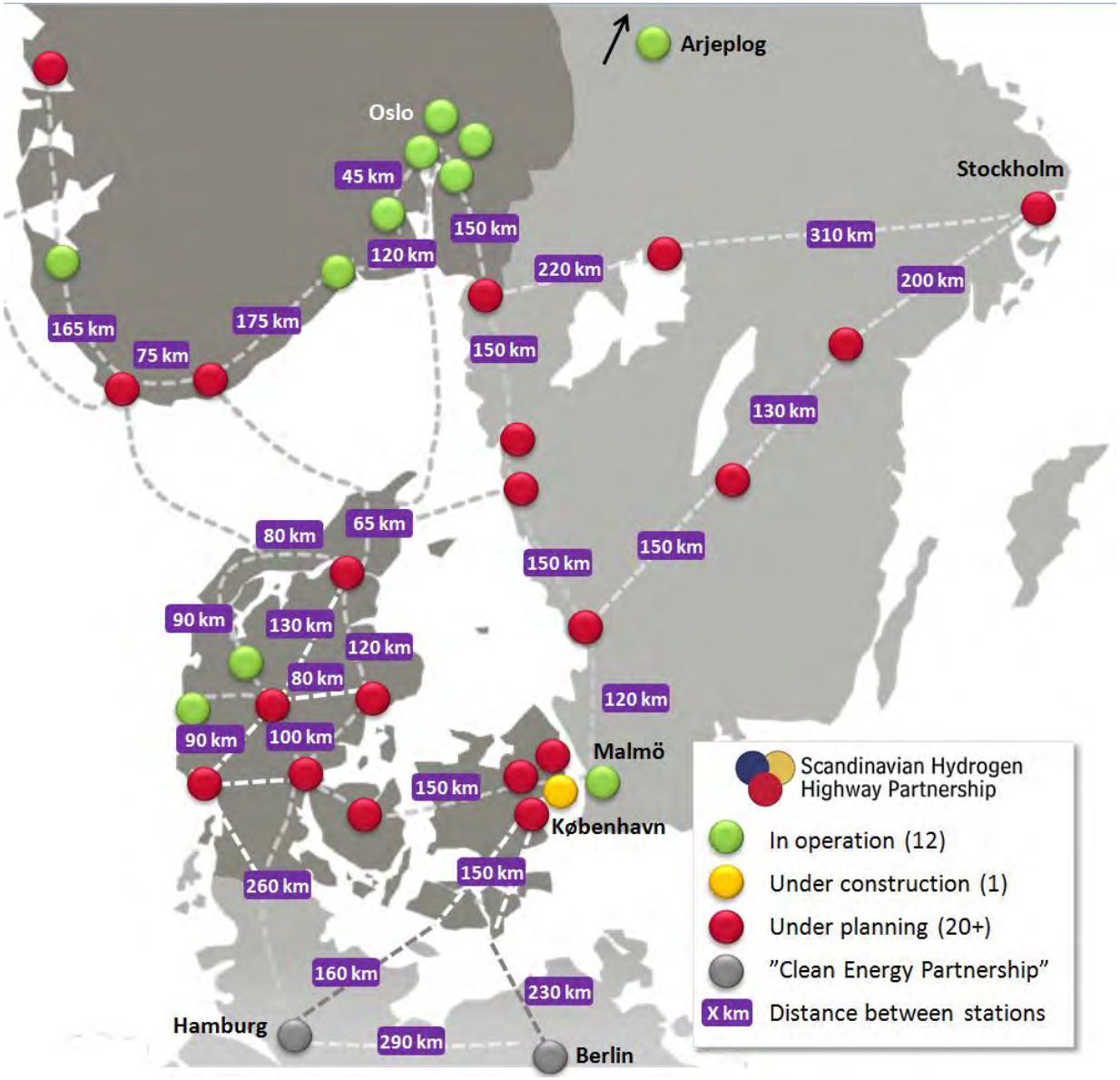

SCANDINAVIA 2015 VISION

»In 2015 it shall be possible to buy fuel cell cars and refuel hydrogen all across Scandinavia and drive to the surrounding countries«

Source: Scandinavian Hydrogen Highway Partnership - SHHP

Europe:
Public Car Hydrogen Stations in Europe

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The blue dots indicate those hydrogen refuelling stations currently being operated that provide public access and match the requirements of major car companies.

Source: LBST GmbH

Example Germany:
The way to an area-wide hydrogen-infrastructure network

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Chicken-Egg Dilemma

No vehicles without the infrastructure, no infrastructure without vehicles

I — **Clean Energy Partnership (2002-2016)**

H_2 and FC Demonstration project in following federal states: Berlin, Hamburg, Hessen, Nordrhein-Westfalen and Baden-Württemberg

II — **H_2 Mobility (since 2009)**

Initiative for build-up of nationwide H_2-Infrastructure. Development of a business plan and joint venture negotiations were the first steps

III — **Daimler/Linde Cooperation (2011-2014)**

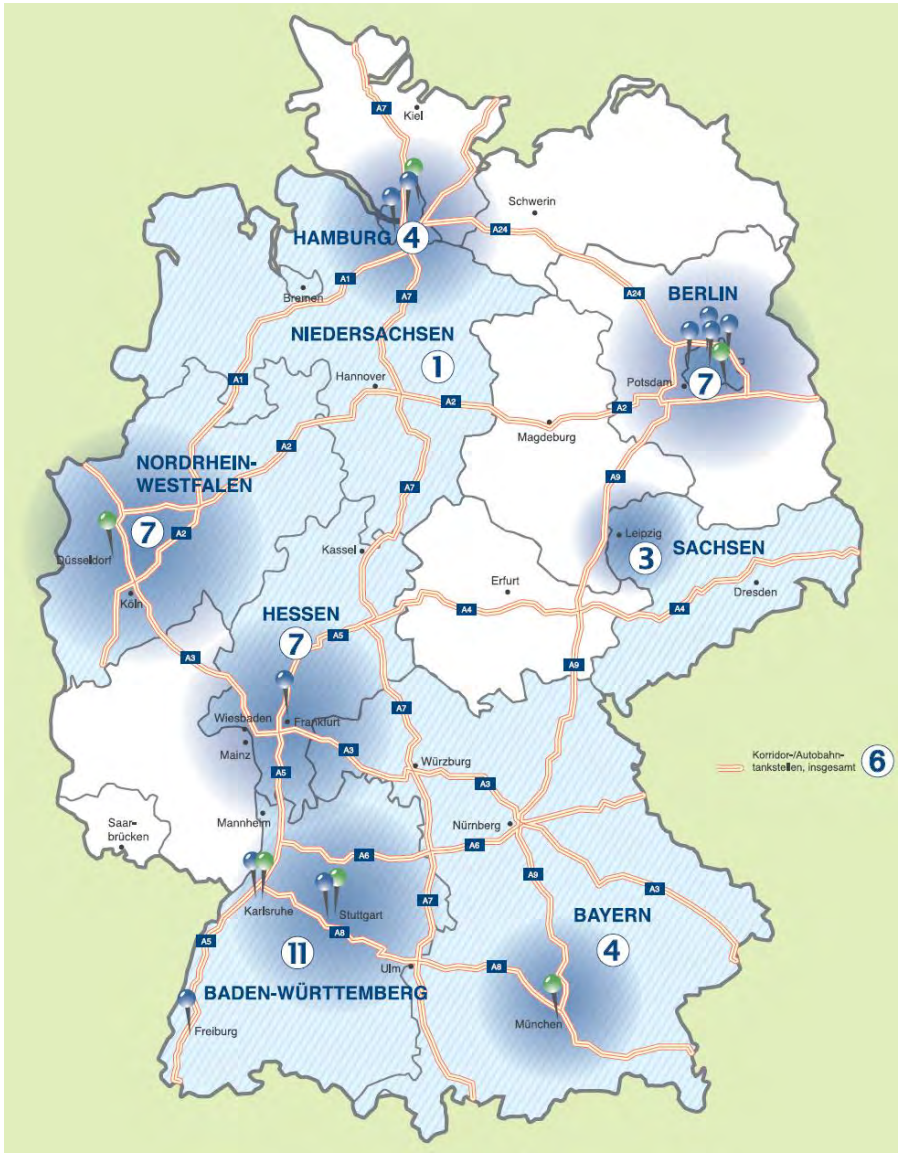
20 new H_2 fuelling stations are planned in Germany in a cooperation with The Linde Group and Daimler AG. The first station will be built in 2012

IV — **H_2 Mobility Joint Venture (from 2012/13)**

Transformation of H_2 Mobility to a Joint Venture

Source: Daimler AG

Germany:
50 HRS in Germany until 2015



Clean Energy Partnership
CEP

Ein Projekt im Nationalen Innovationsprogramm
Wasserstoff- und Brennstoffzellentechnologie

nip

Gefördert durch:
Bundesministerium
für Verkehr, Bau
und Stadtentwicklung

Koordiniert durch:
NOW

existing HRS

HRS under construction / locations determined

0 Locations per federal state by end of 2015

metropolitan area

Source: German Transport Ministry 2012

Germany:
1,000 HRS Needed for Full Coverage in 2030 (H2 Mobility)

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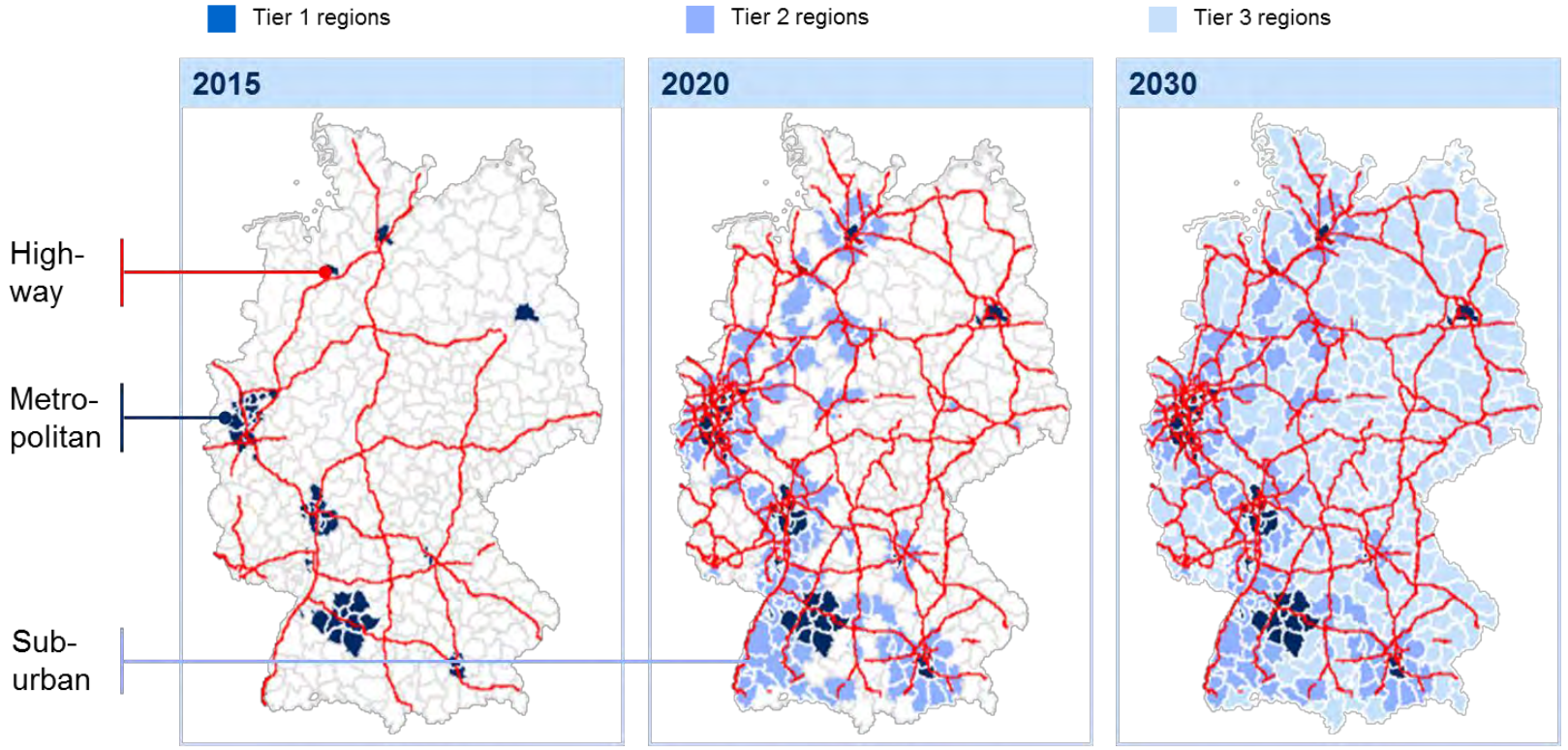

Coverage of population	20 %	60 %	100 %
FCEVs	5.000	150.000	1.800.000
HRS	100	400	1.000

Source: NOW, Hannovermesse 2012

Expected technical advancement H2 Logic: "MUST WIN BATTLES" for hydrogen infrastructure

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- Same fast refueling & long range as gasoline
- Hydrogen pump price competitive to gasoline
- Commercial attractive payback time for station for owner/operator
- Close to 100% station availability
- Investment decision on start of FCEV market introduction
- Investment decision on start construction of countrywide station networks

H2 Logic achievement on HRS product streamlining:

H2 Logic
Hydrogen Fuel Cell Motive Power Solutions

Source: H2 Logic A/S

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New Energy World JU
fuel cells & hydrogen for sustainability

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