



H2MOVES SCANDINAVIA: FINAL TECHNICAL REPORTING

5th and last reporting period

1/2013

SLIDE SELECTION

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Vehicles and infrastructure



Communication



Safety



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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



1. Technical Advancements

2. FCEV Performance Data

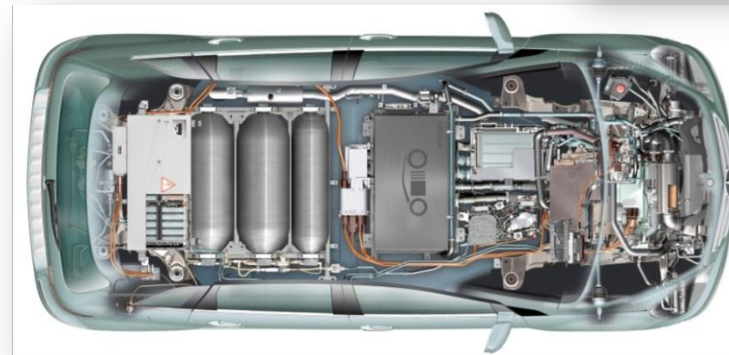
3. HRS Performance Data

4. Customer Survey

4. Outlook



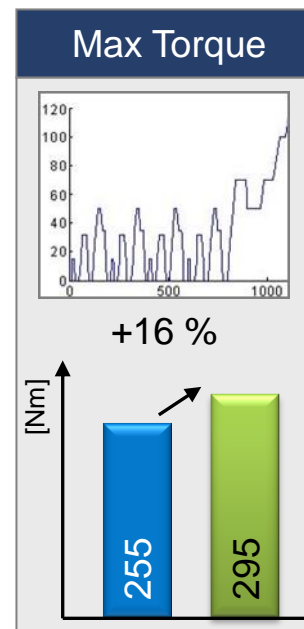
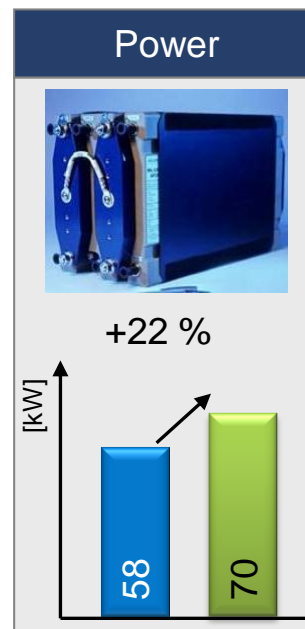
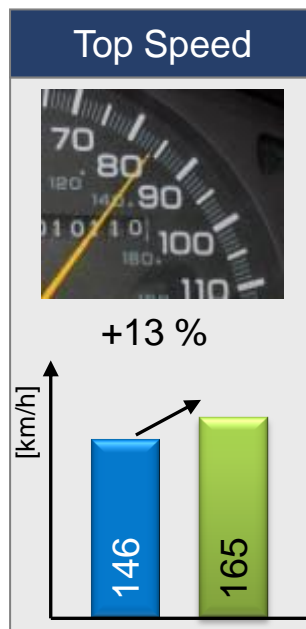
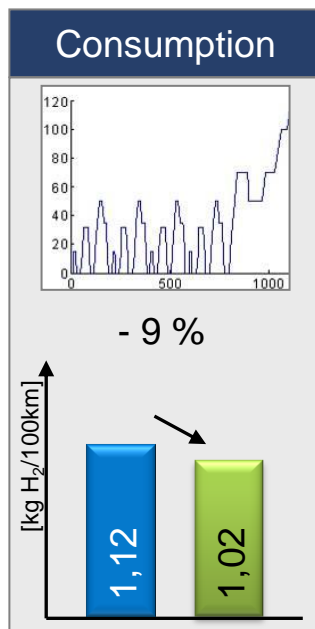
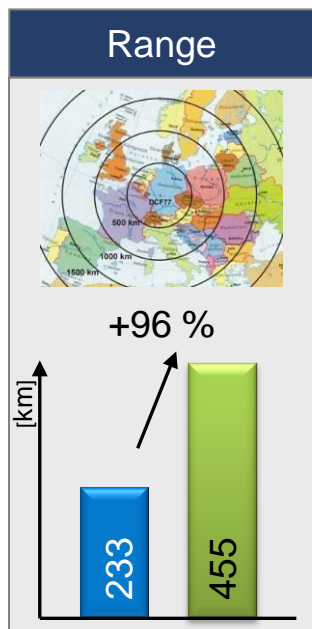
Source: Hyundai Motor Europe



Source: Daimler AG



Source: H2 Logic A/S



Last generation FCEVs

H2mS FCEVs 2012



- A standard BEV city car from TH!NK retrofitted with fuel cell system & H₂ 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





- 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



- HRS developed & operated by H2 Logic A/S
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- Refuelling time of ~3 minutes (-40 °C pre-cooling)



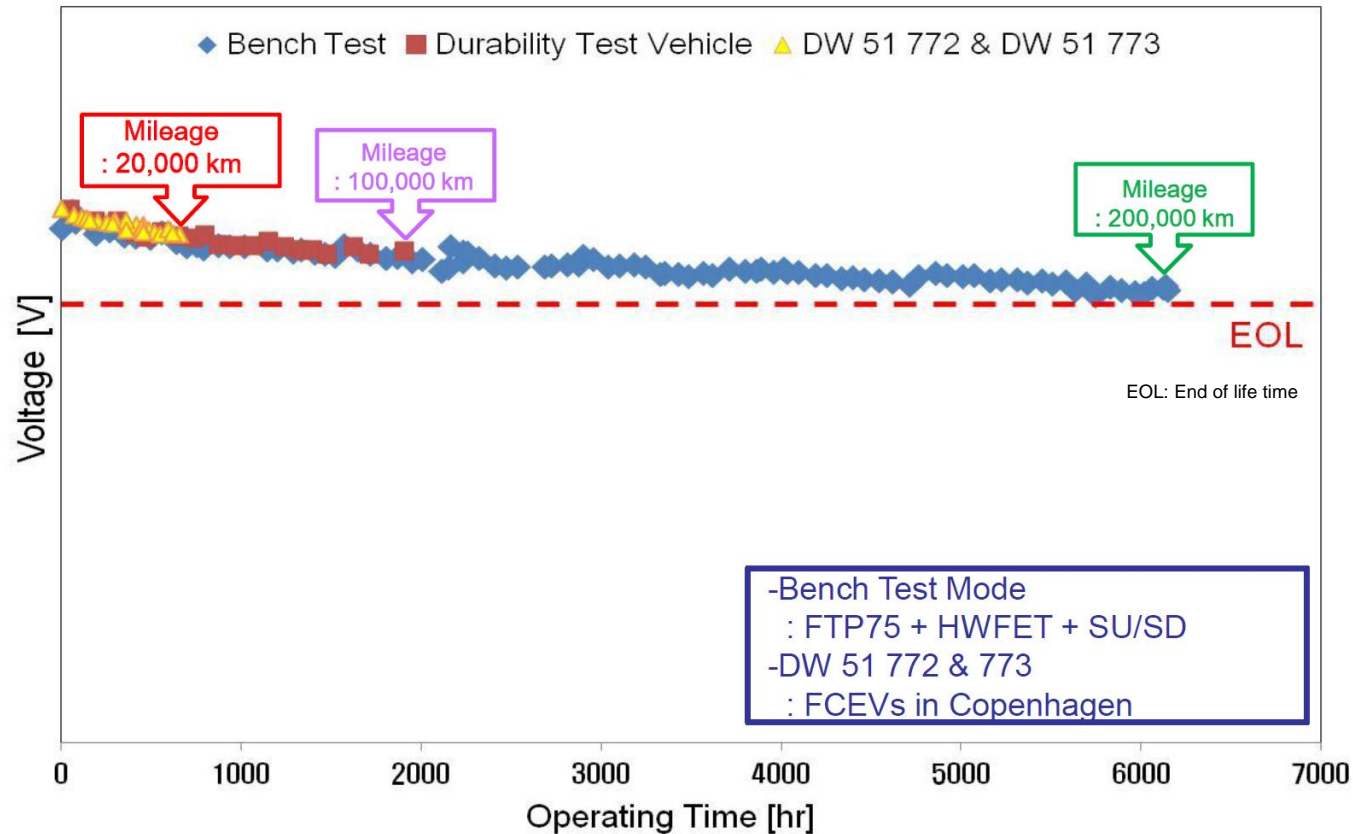
Moveable HRS – Technical specifications	
Specification parameter	Actual performance realised
Refuelling pressure	70MPa
Instant refuelling capacity	2x4 kg (back-to-back)
Daily refuelling capacity (24hour)	50 kg @ 2,5MPa inlet
Refuelling time	3 min. @ 70MPa (5,6 kg)
Refuelling nozzle	TK17 for 70MPa
Fuel 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



FCEV Performance Data

Comparison of H2mS Data with Bench Test Results (Hyundai)



- 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



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Source: Daimler AG



Source: Hyundai Motor Europe



Source: H2 Logic A/S



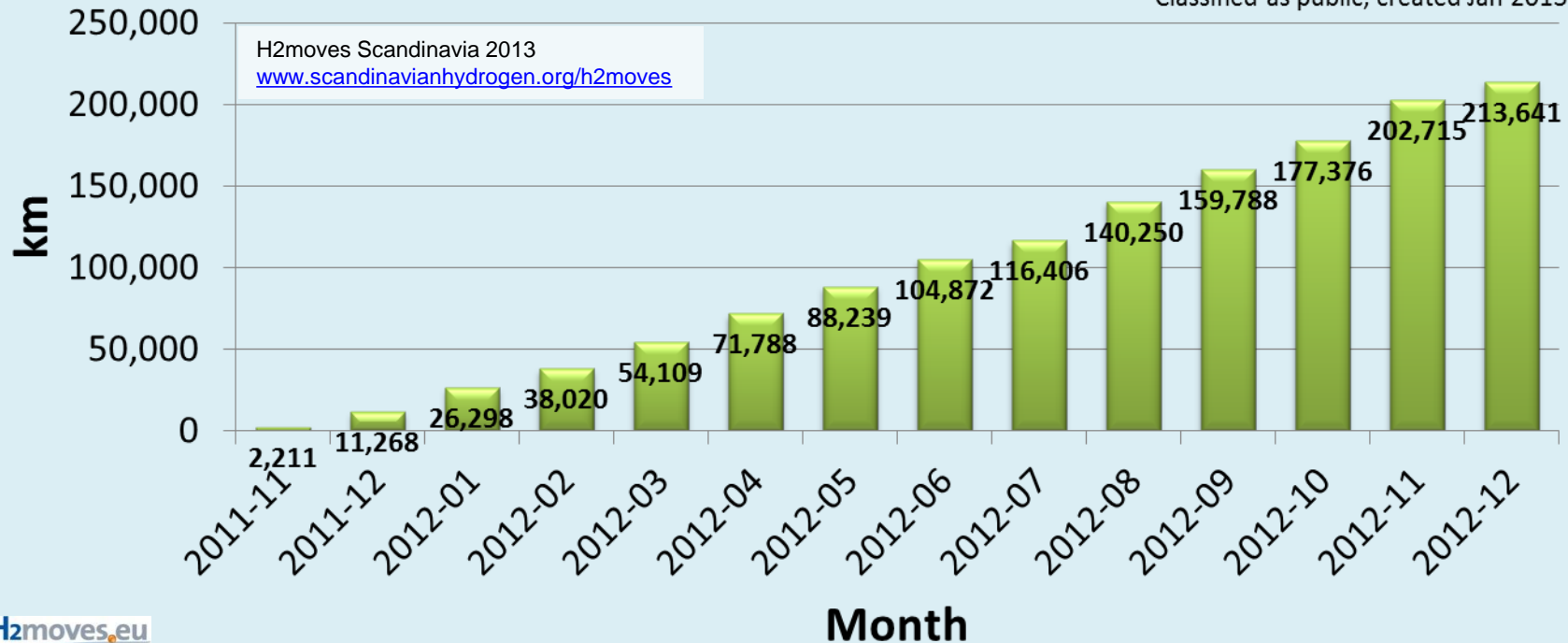
	H2moves Scandinavia fleet
Fuel consumption (NEDC) [kg H ₂ / 100 km]	0.97 – 1.07
Maximum speed [km/h]	160-170 Th!nk: 100
Acceleration 0-100 km/h [s]	11.4 – 14.0 Th!nk 0-50 km/h: 6.5 s
Tank capacity [kg]	3.7-5.6 Th!nk: 1.5
Driving range [km]	250-525
Number of B-Class F-CELL	10
Number of ix35 FCEV	4
Number of Th!nk	5



Cumulative km Driven

213,641 km in 13.5 Months

Classified as public, created Jan 2013



So far, our cars drove around the world more than five times.
Equivalent conventional cars would have emitted
24.5 tons CO₂ equivalent for this distance (well-to-wheel).

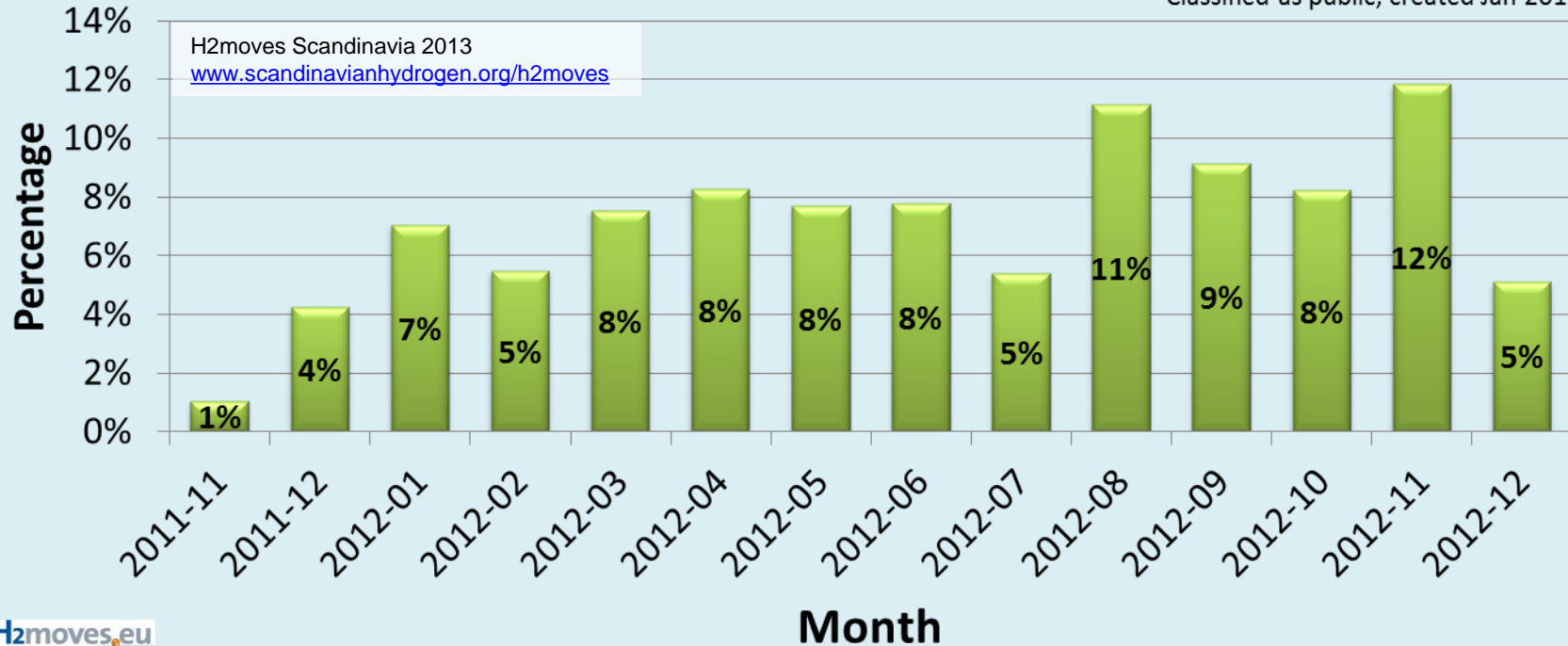
Sources: own calculations based on Hyundai 2012; Daimler AG 2012; JEC-Joint Research Centre-EUCAR-CONCAWE, Report EUR 24952 EN – 2011



km Driven

213,641 km = 100 %

Classified as public, created Jan 2013



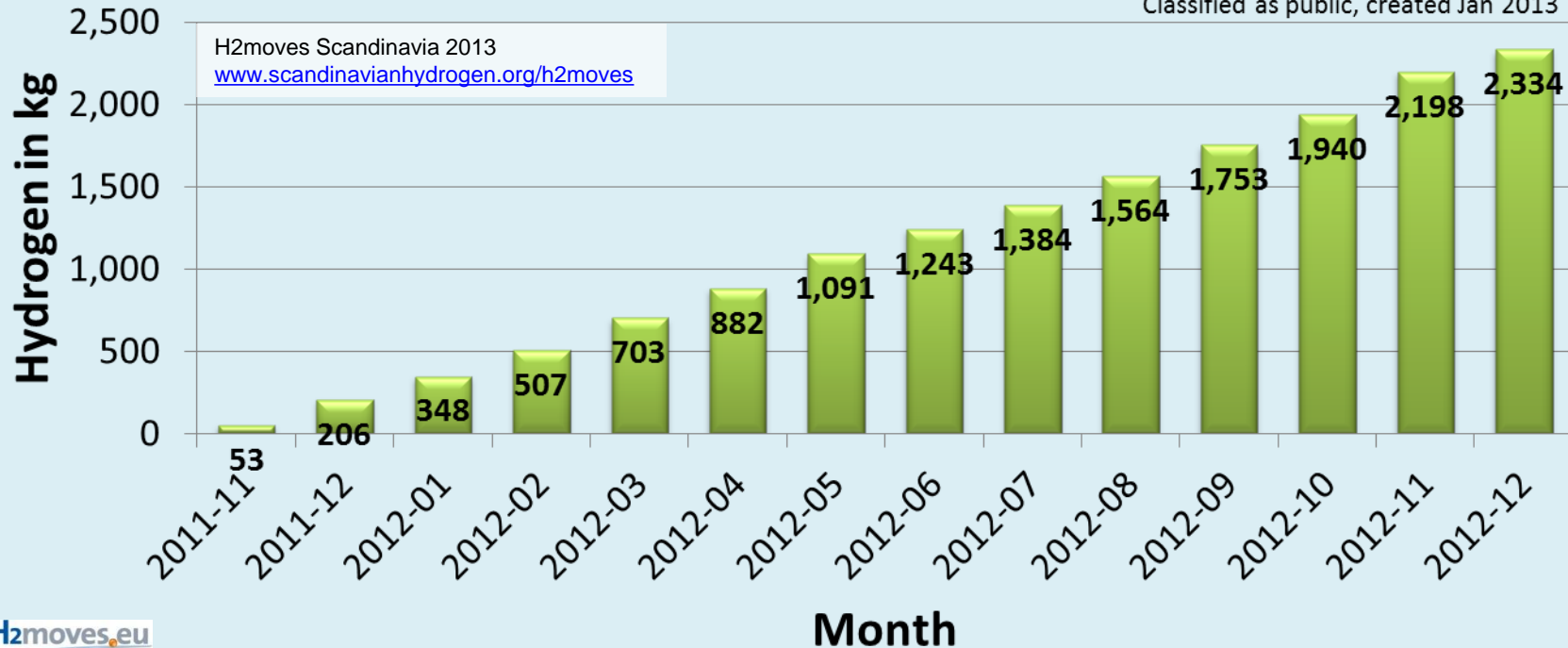
July and December are holiday seasons, so people drive significantly less.



Hydrogen Refuelled (Cumulative)

2,334 kg in 13.5 Months

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H2moves Scandinavia 2013
www.scandinavianhydrogen.org/h2moves



- 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.



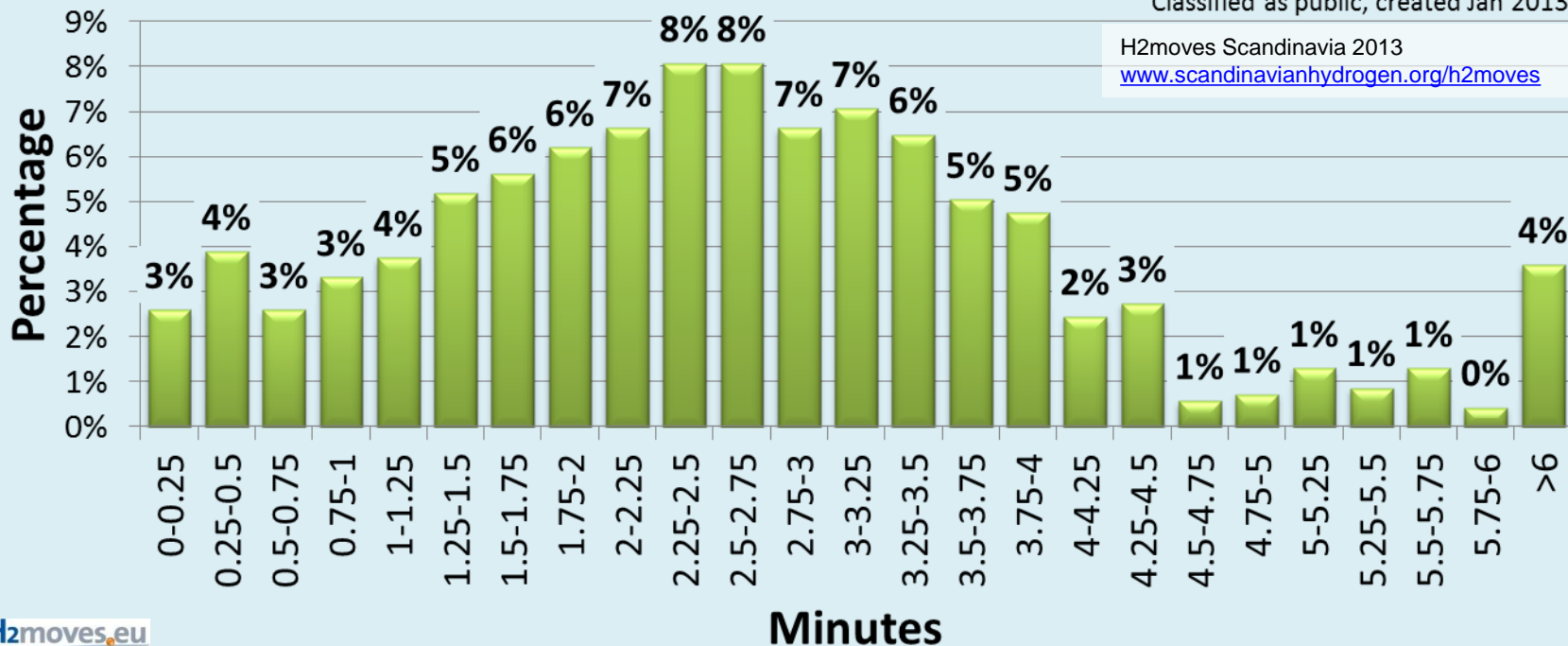
Refuelling Duration (B-Class F-CELL)


100 % = 694 Refuellings; average = 2.8 minutes

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H2moves Scandinavia 2013

www.scandinavianhydrogen.org/h2moves



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

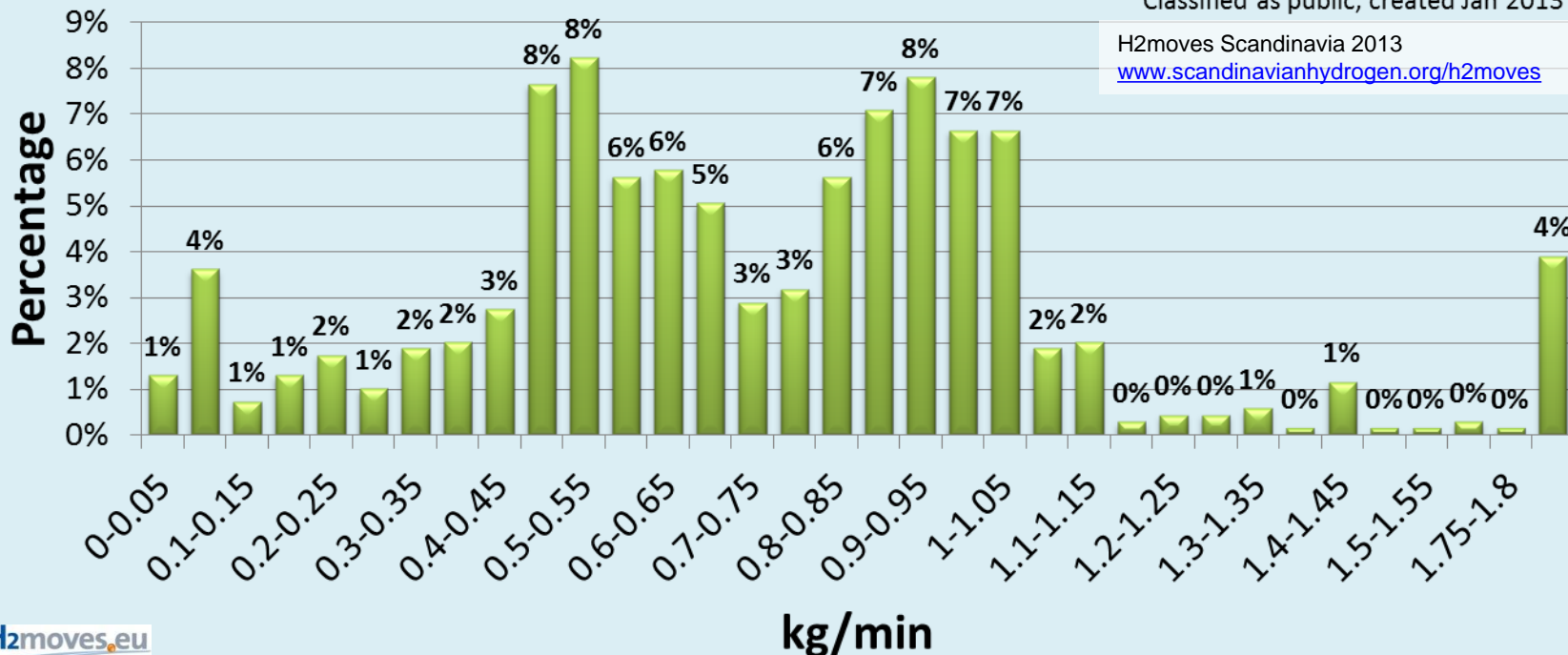


Refuelling rate (B-Class F-CELL)

100 % = 694 fillings

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www.scandinavianhydrogen.org/h2moves



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>



Average km Driven Between Refuelling

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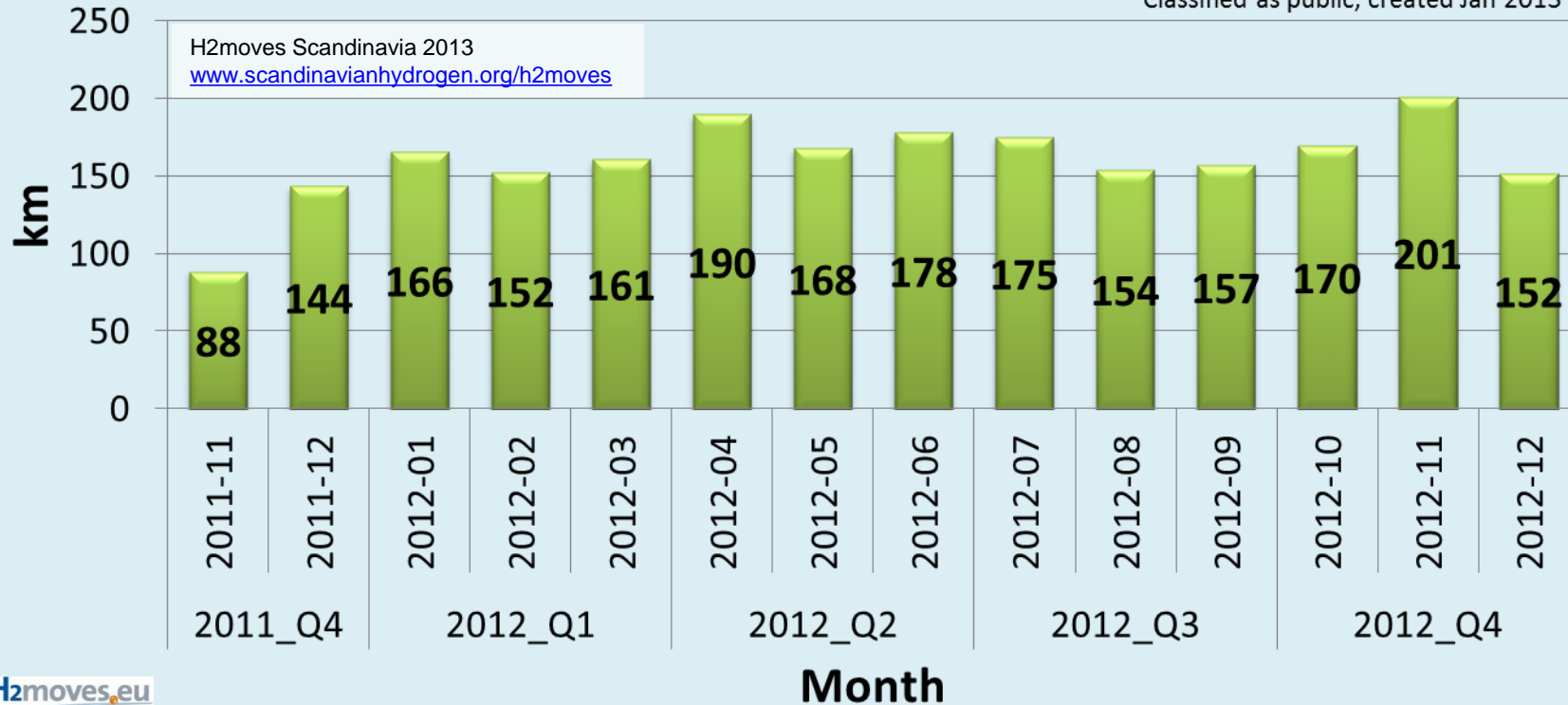


Decreasing range anxiety:
128 km → 160-180 km



Average km Driven Between Refuelling

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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.

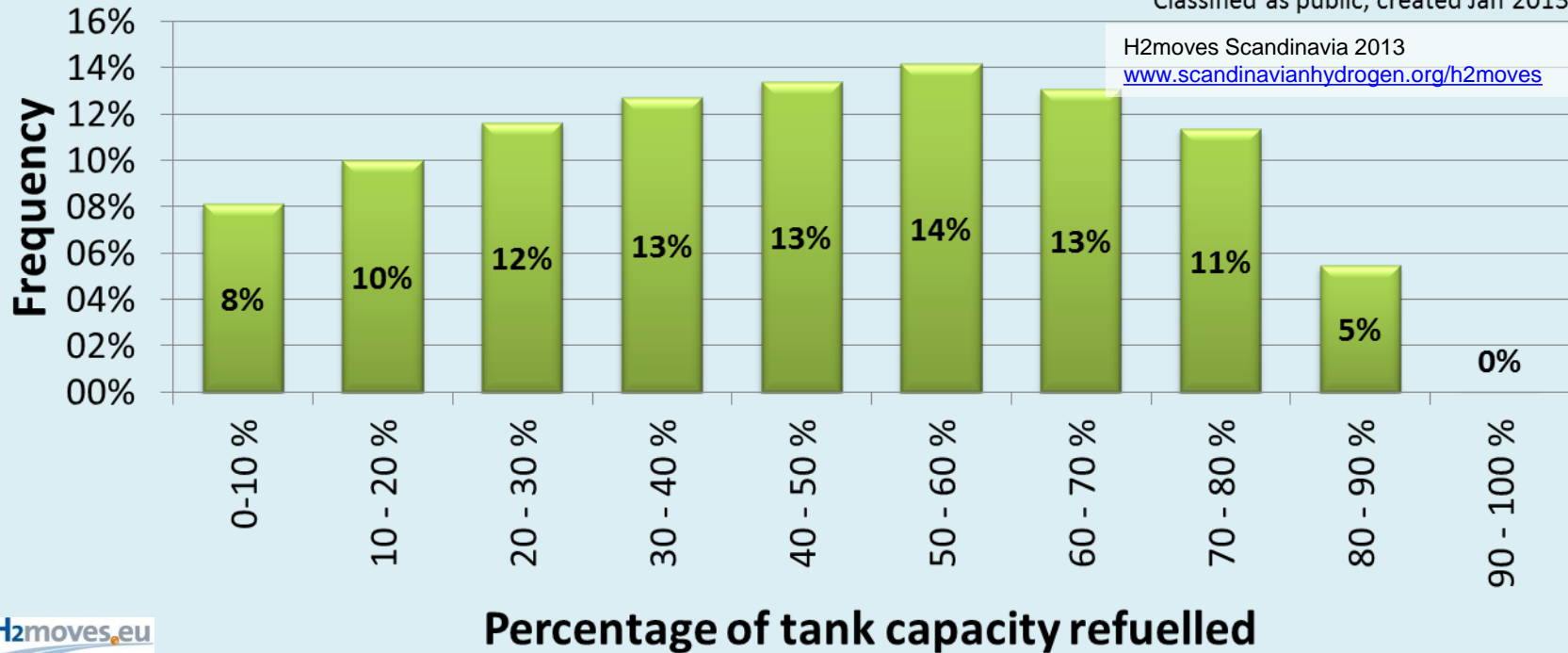


Refuelling Quantity Related to Tank Capacity

1,170 Refuellings = 100 %

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www.scandinavianhydrogen.org/h2moves

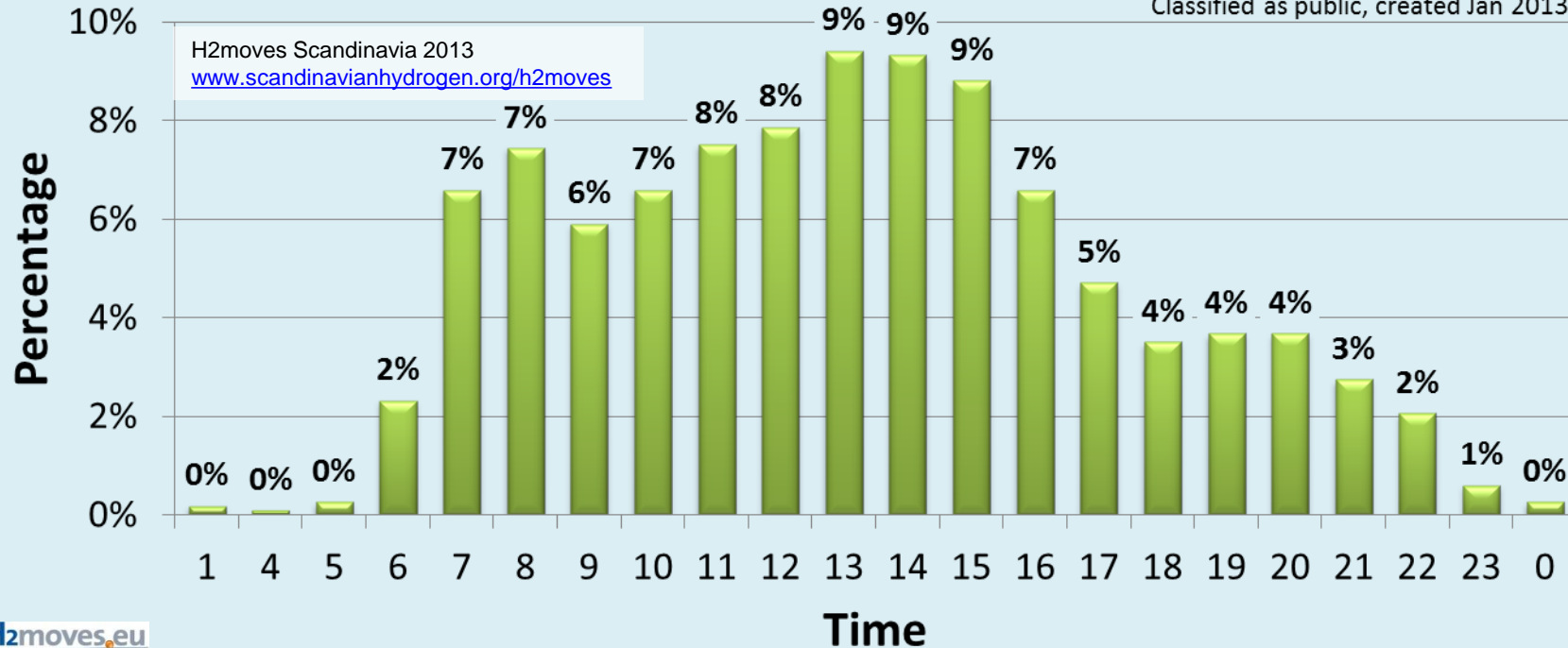


Refuelling quantity is driven by range anxiety

Refuelling Time of Day

1,170 Refuellings = 100 %

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

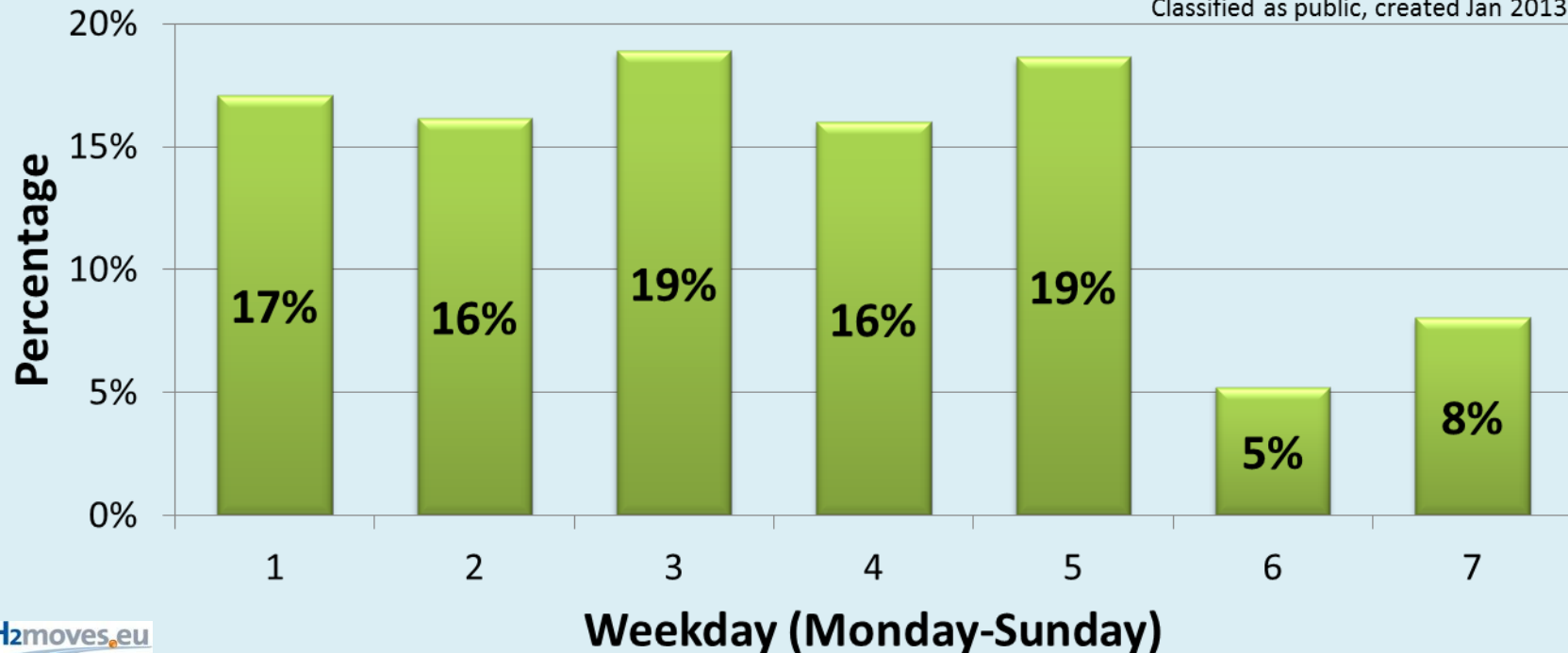


H2moves Scandinavia 2013
www.scandinavianhydrogen.org/h2moves

Refuelling by Weekday

1,170 Refuellings = 100 %

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

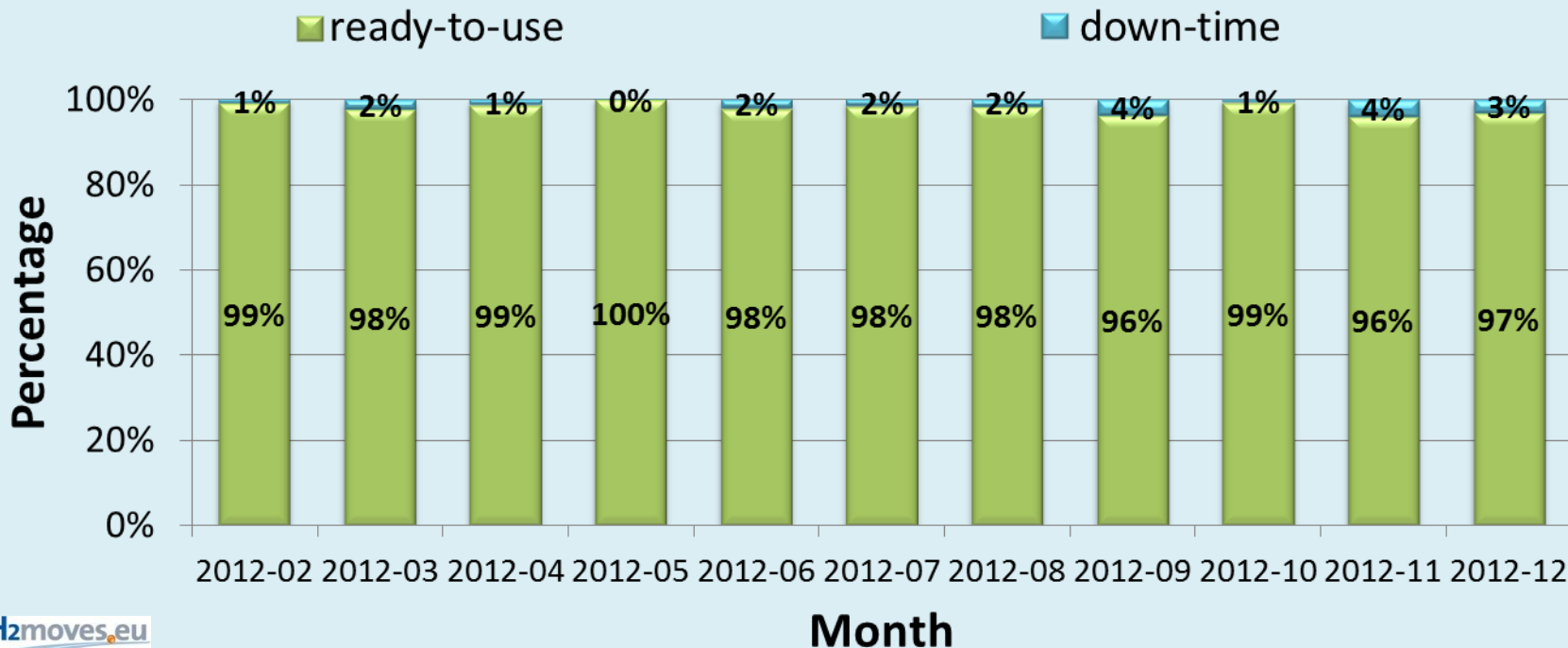


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FCEV Availability

Full Month = 100 %

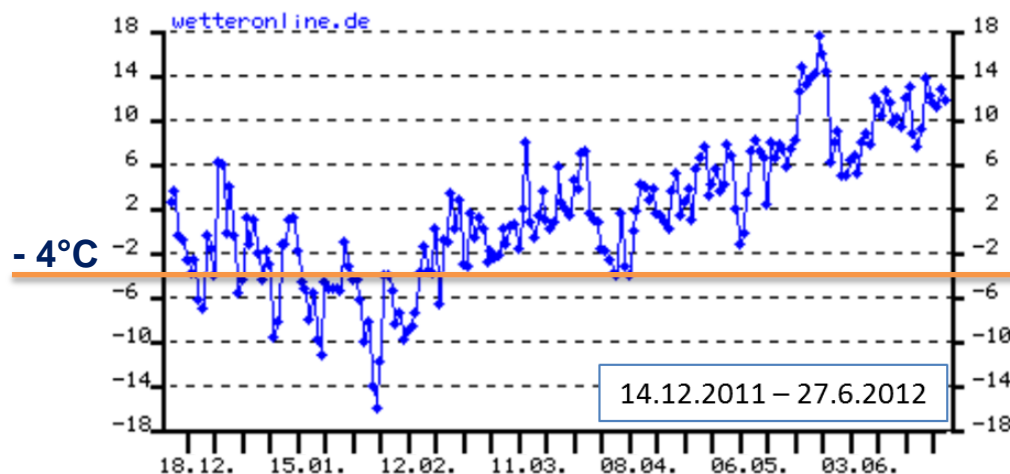
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Expected ready-to-use time: 24/7
→ Excellent performance: 98% overall availability

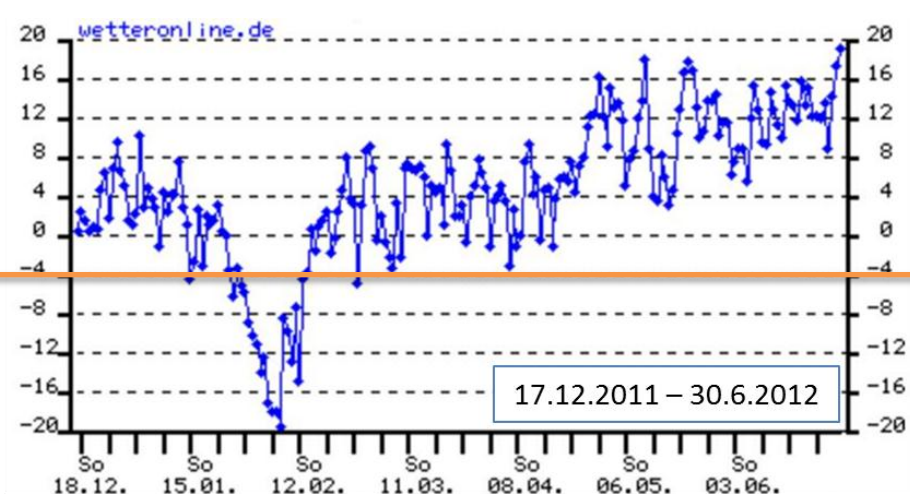


Oslo



Oslo/Blindern: lowest temperature at night in °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



Comparing H2moves Scandinavia with NREL and CEP

	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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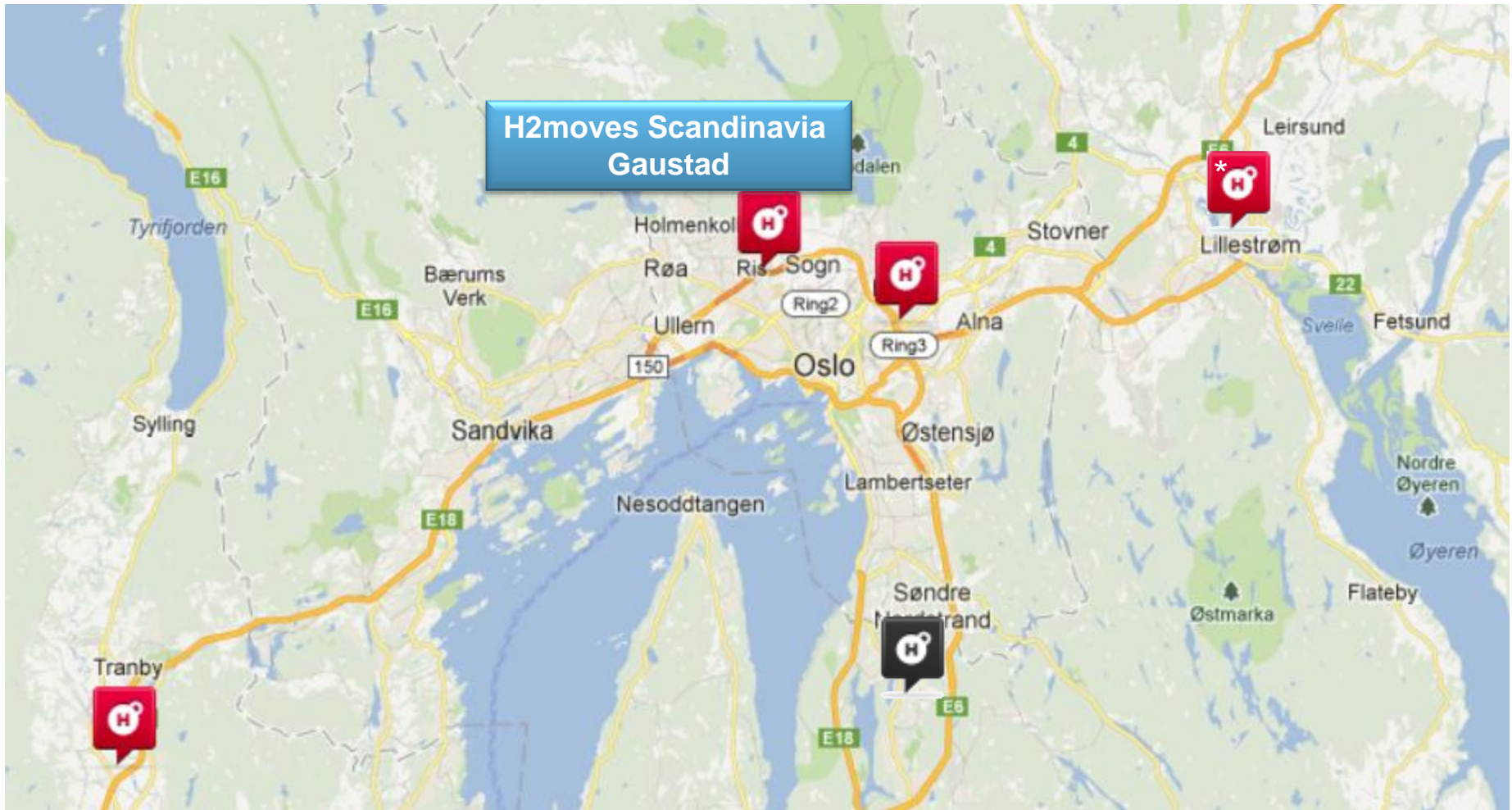
4. Outlook



Source: H2 Logic A/S



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



 70MPa Car HRS

 35MPa Bus HRS * Opened in summer 2012

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



	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

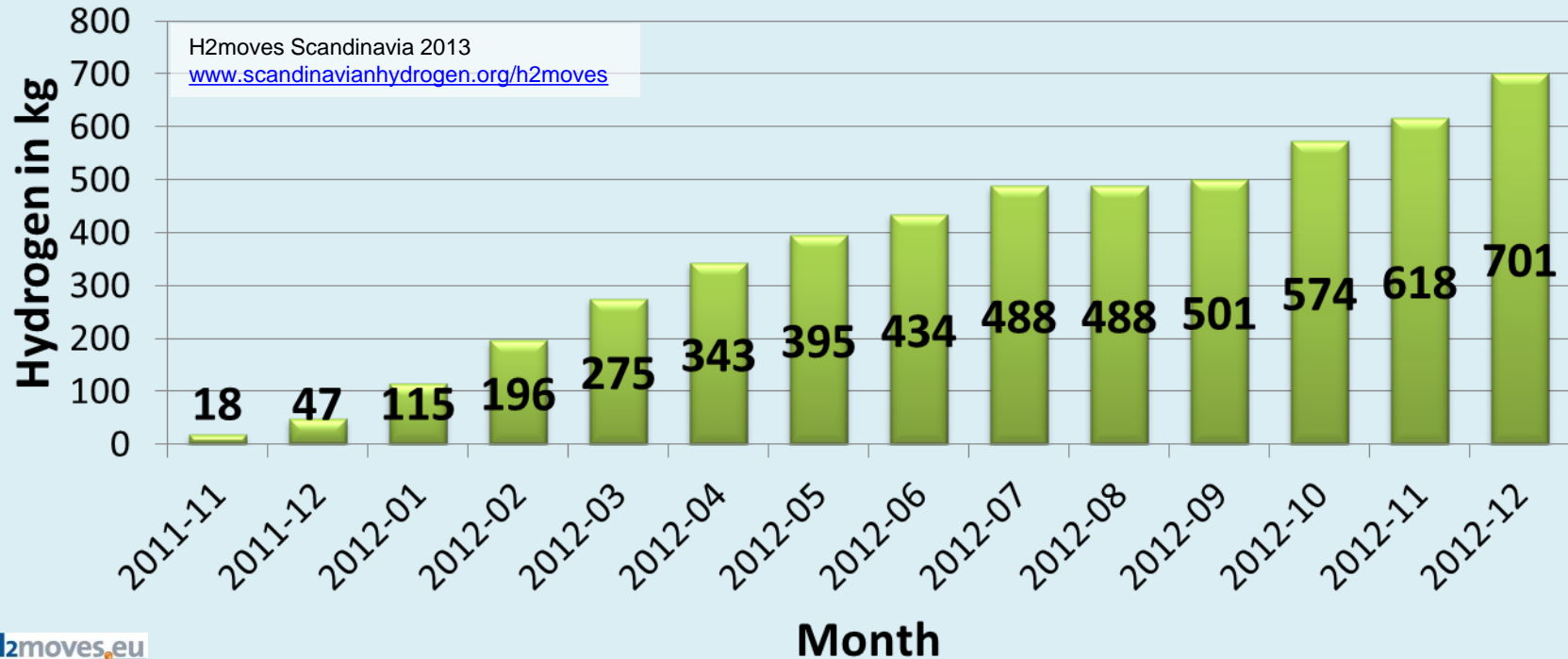


Cumulative Hydrogen Dispensed at Oslo (Gaustad) HRS



701 kg in 13.5 Months

Classified as public, created Jan 2013



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

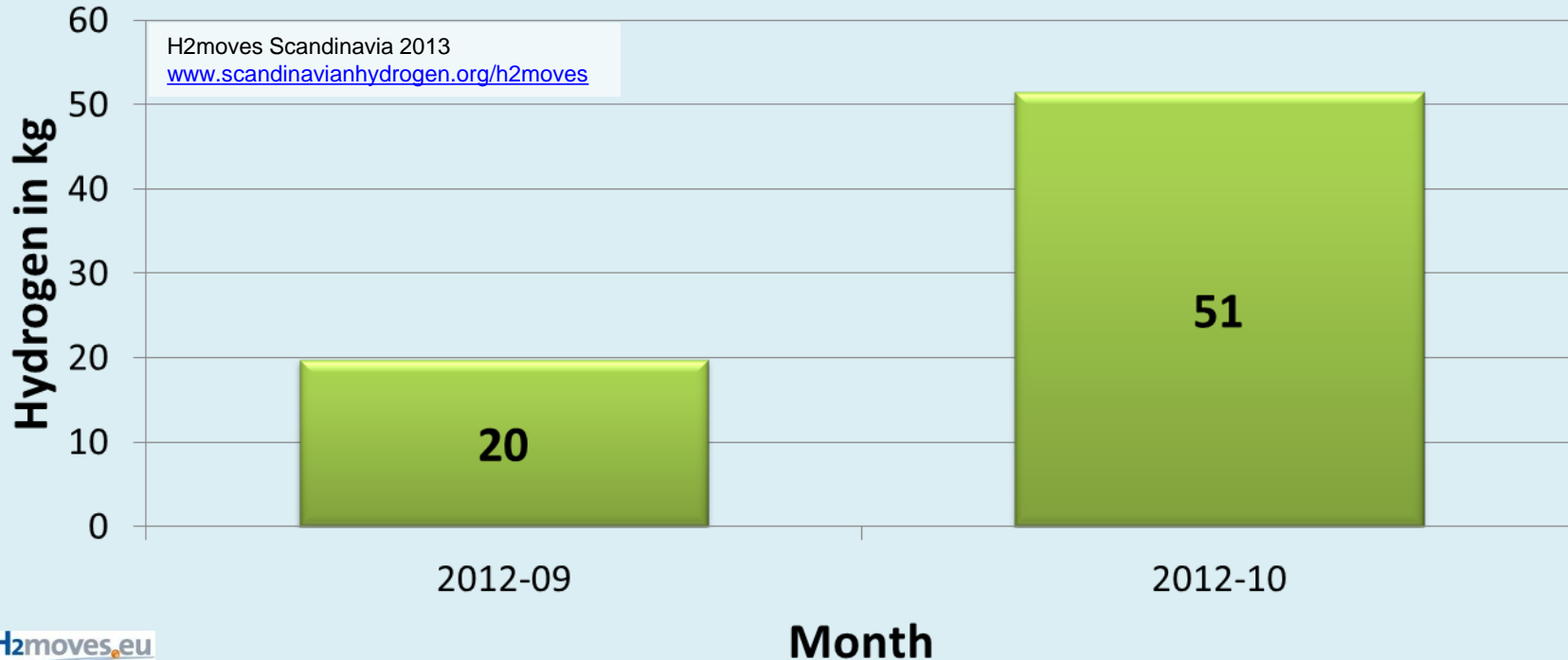


Cumulative Hydrogen Dispensed at Moveable Refueller



51 kg in 1 Month

Classified as public, created Jan 2013



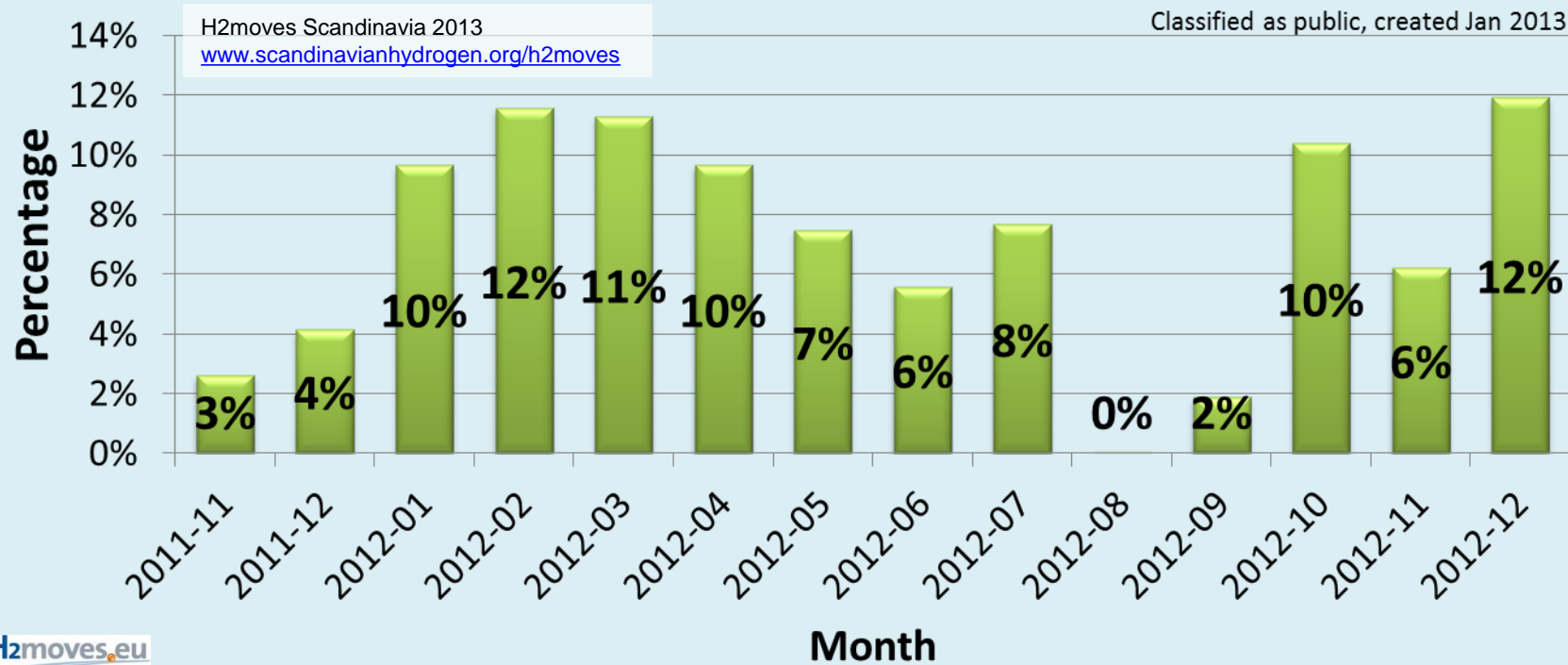
No problem experienced with the moveable refueller during Road Tour:
100% availability



Hydrogen Dispensed at Oslo (Gaustad) HRS



701 kg = 100 %



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

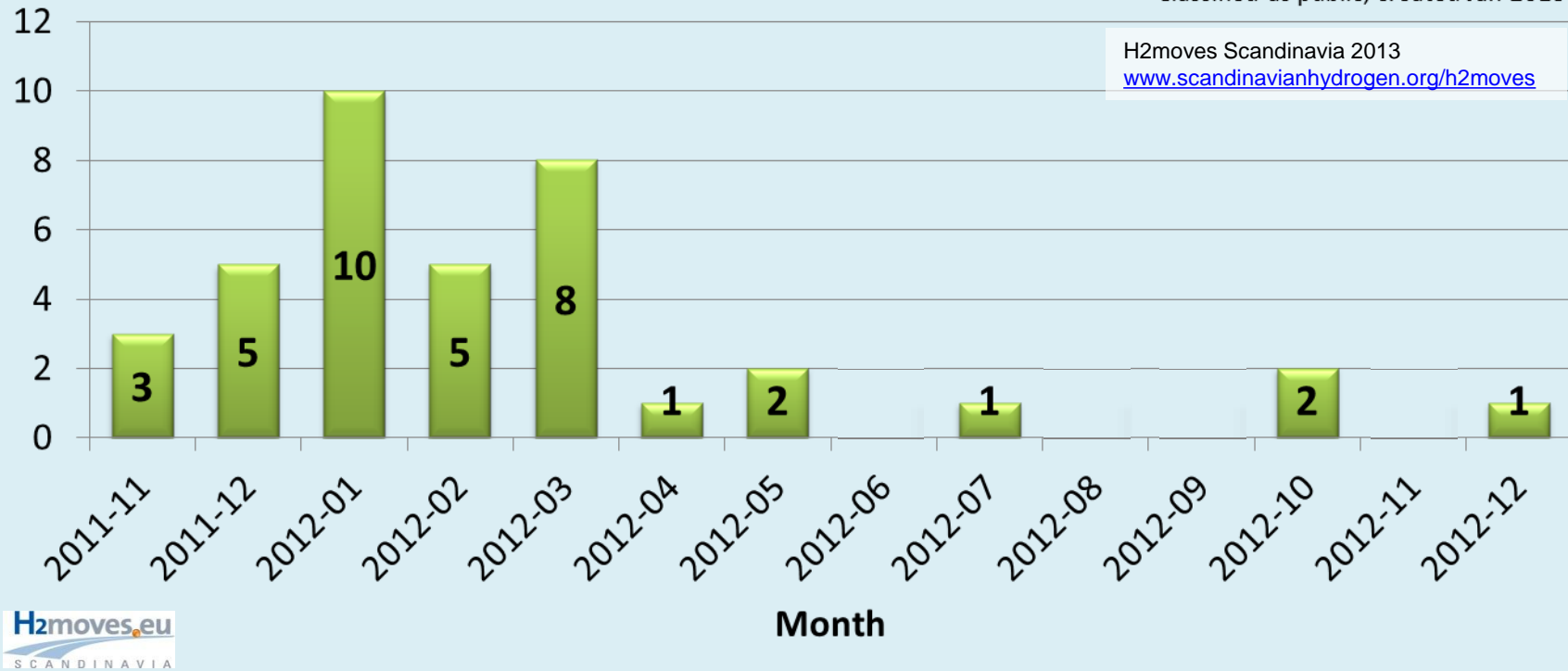


Number of Reports at Oslo (Gaustad) HRS


38 reports in 13.5 Months



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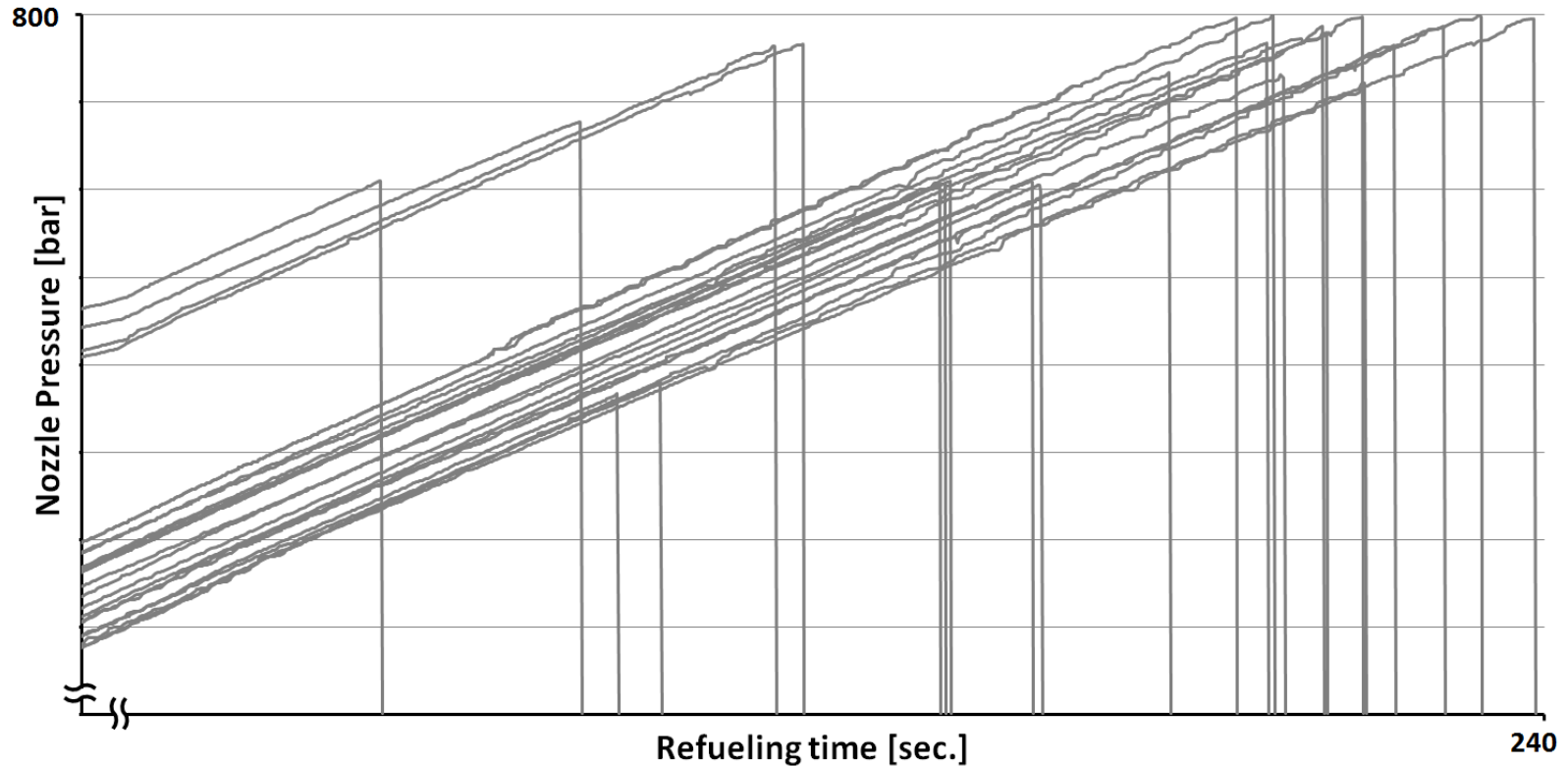
H2moves Scandinavia 2013
www.scandinavianhydrogen.org/h2moves


 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).



Less than 4 minutes for a full hydrogen tank

Showing actual refueling time at H2Station®



Refuelling faster than 4 minutes

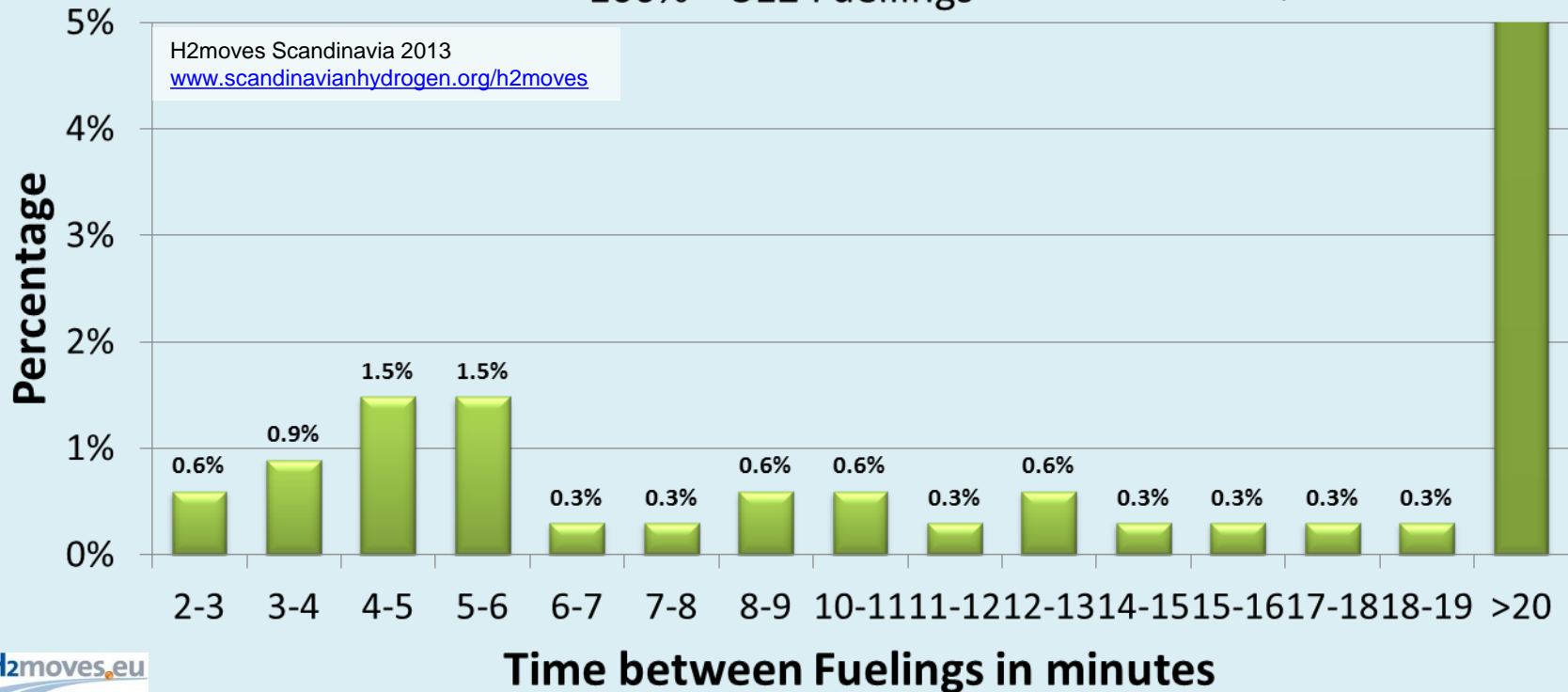


Histogram of Time between Fuellings at HRS



100% = 312 Fuellings

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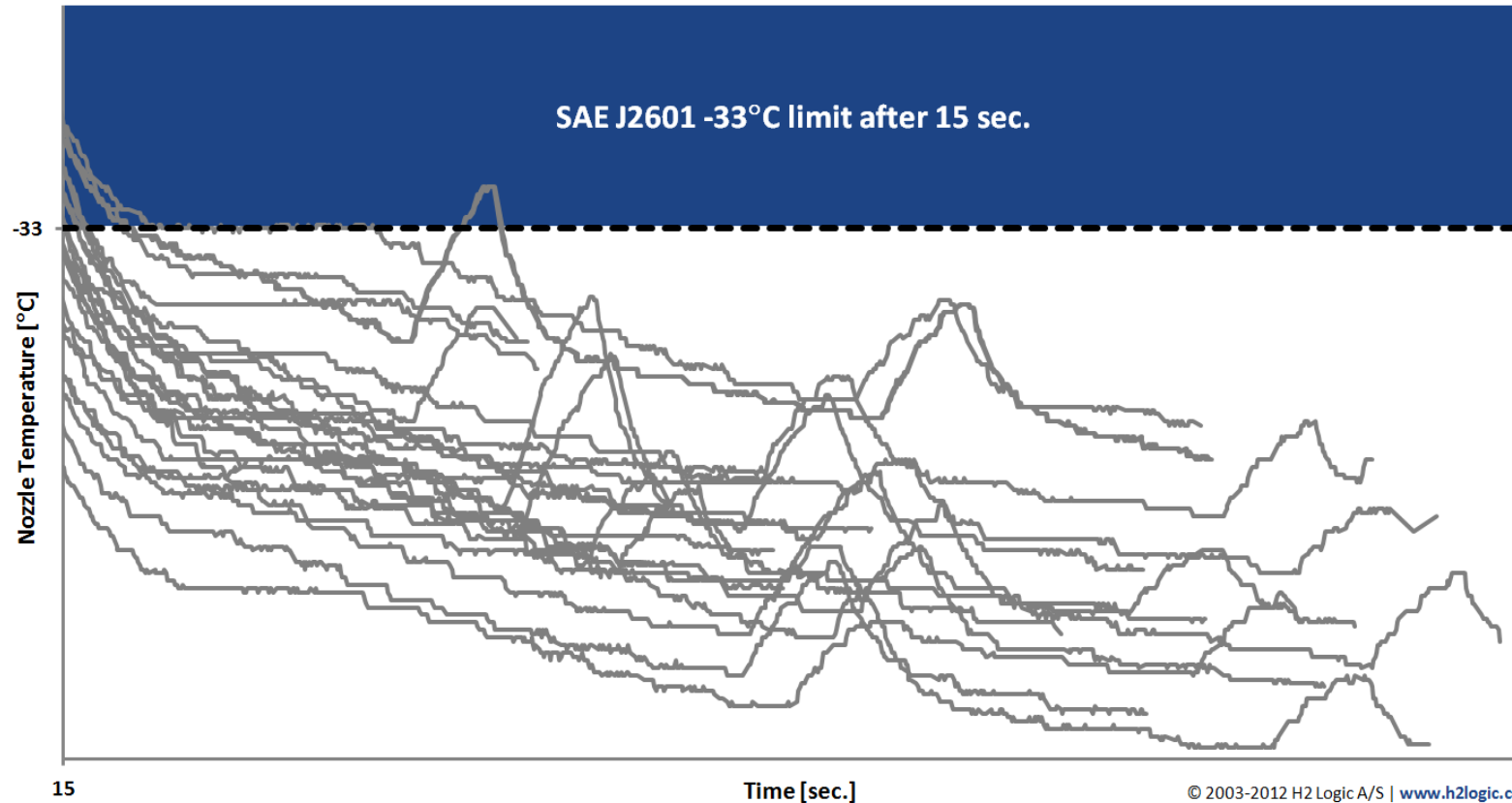
http://www.nrel.gov/hydrogen/images/cdp_infr_08.jpg

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%



H2Station® 70MPa nozzle temperature - actual field data 25 randomly selected 70MPa refueling's from 3 different H2Station®

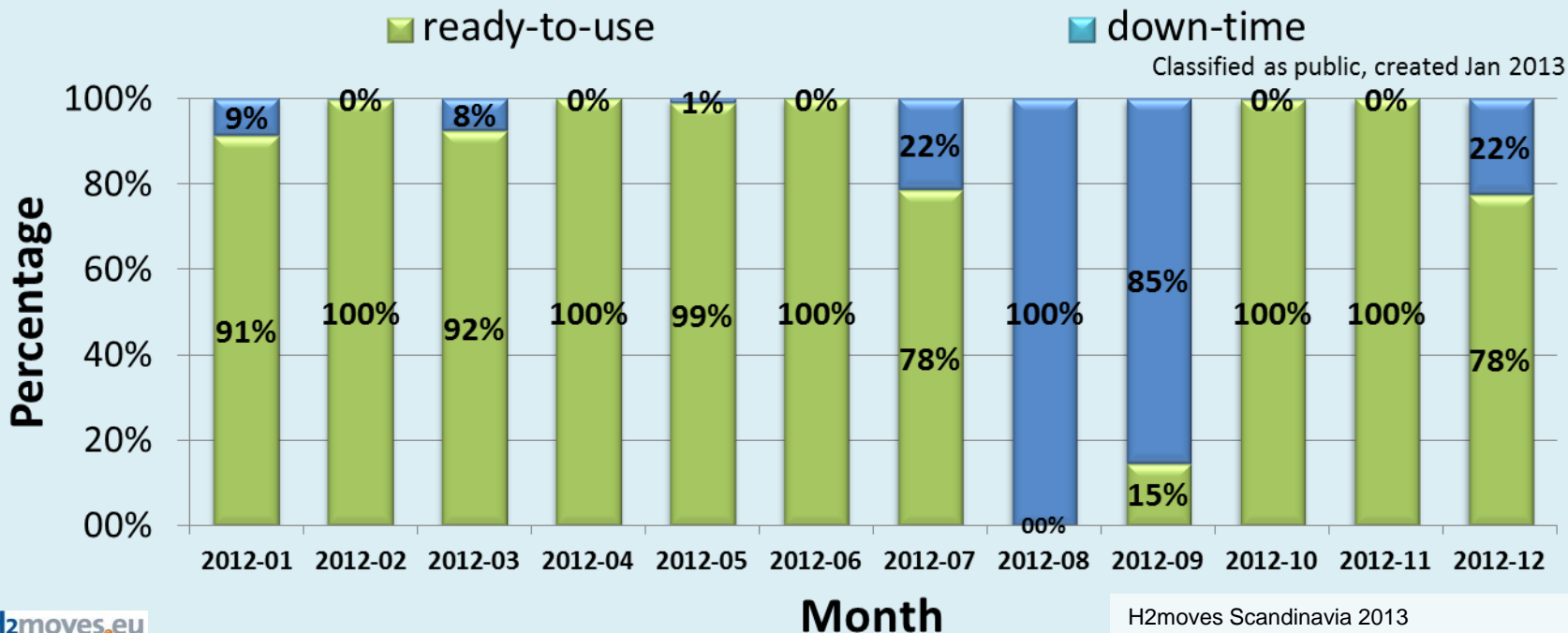


Station fulfills SAE J2601 temperature requirements



Availability of Oslo (Gaustad) HRS

Overall availability for 1/2012 - 6/2012: 97.1 %



H2moves Scandinavia 2013
www.scandinavianhydrogen.org/h2moves

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 lengthy 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.



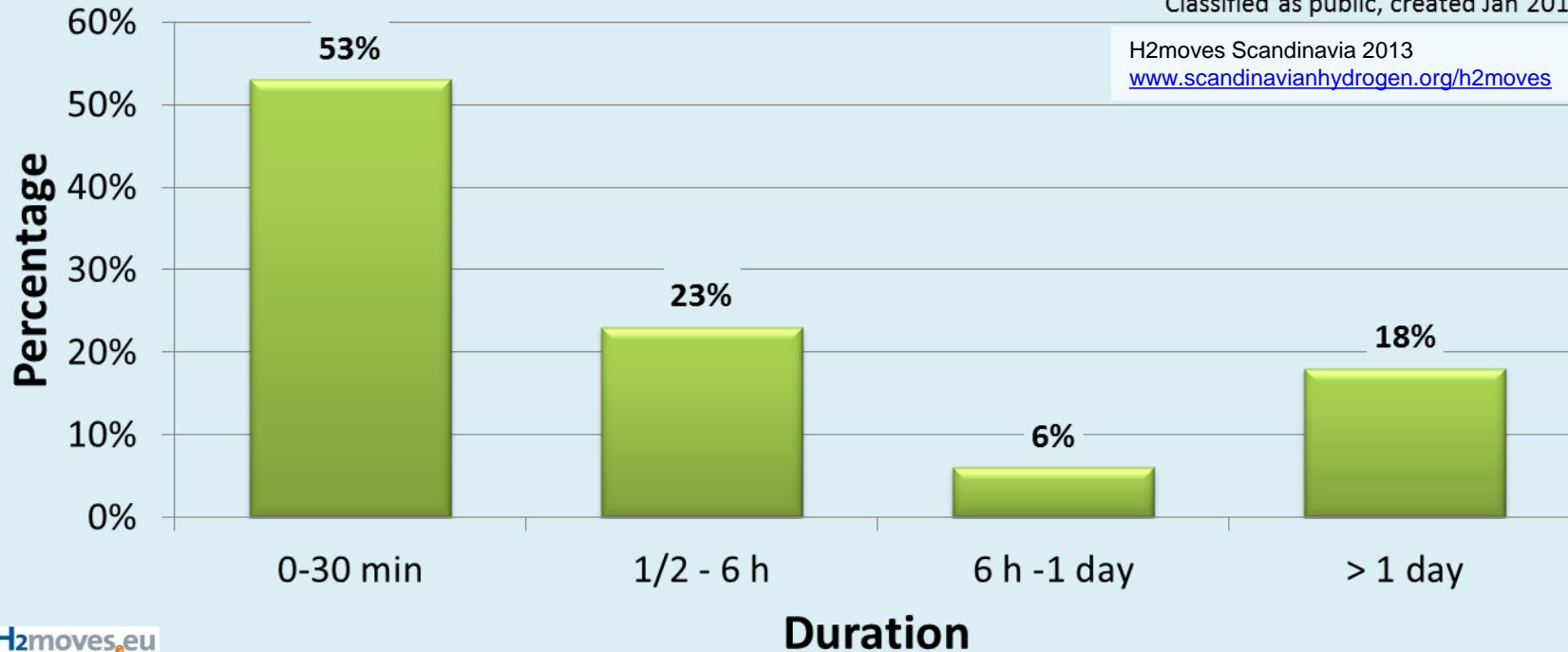
Time to Repair for Individual HRS Non-availabilities

at Oslo (Gaustad) HRS (32 reports within 2012)



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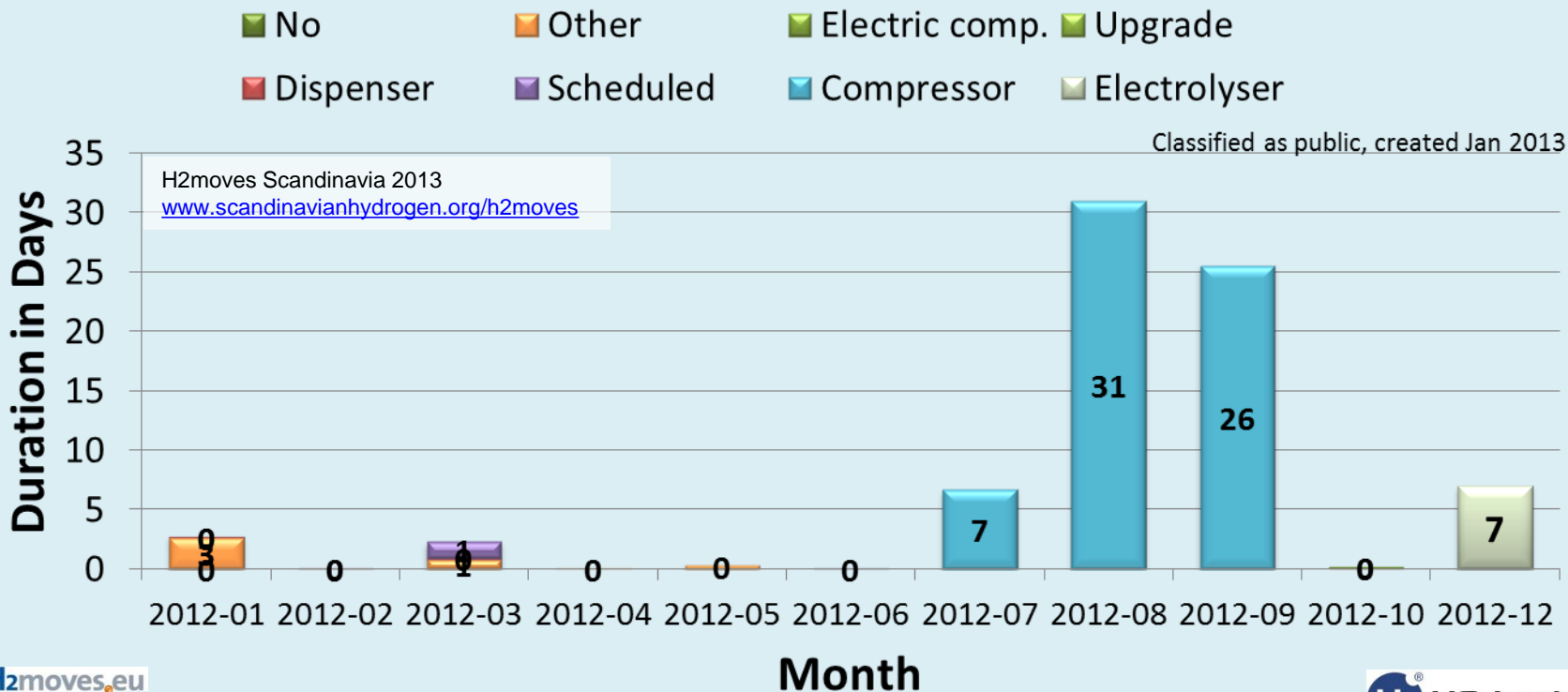
H2moves Scandinavia 2013
www.scandinavianhydrogen.org/h2moves




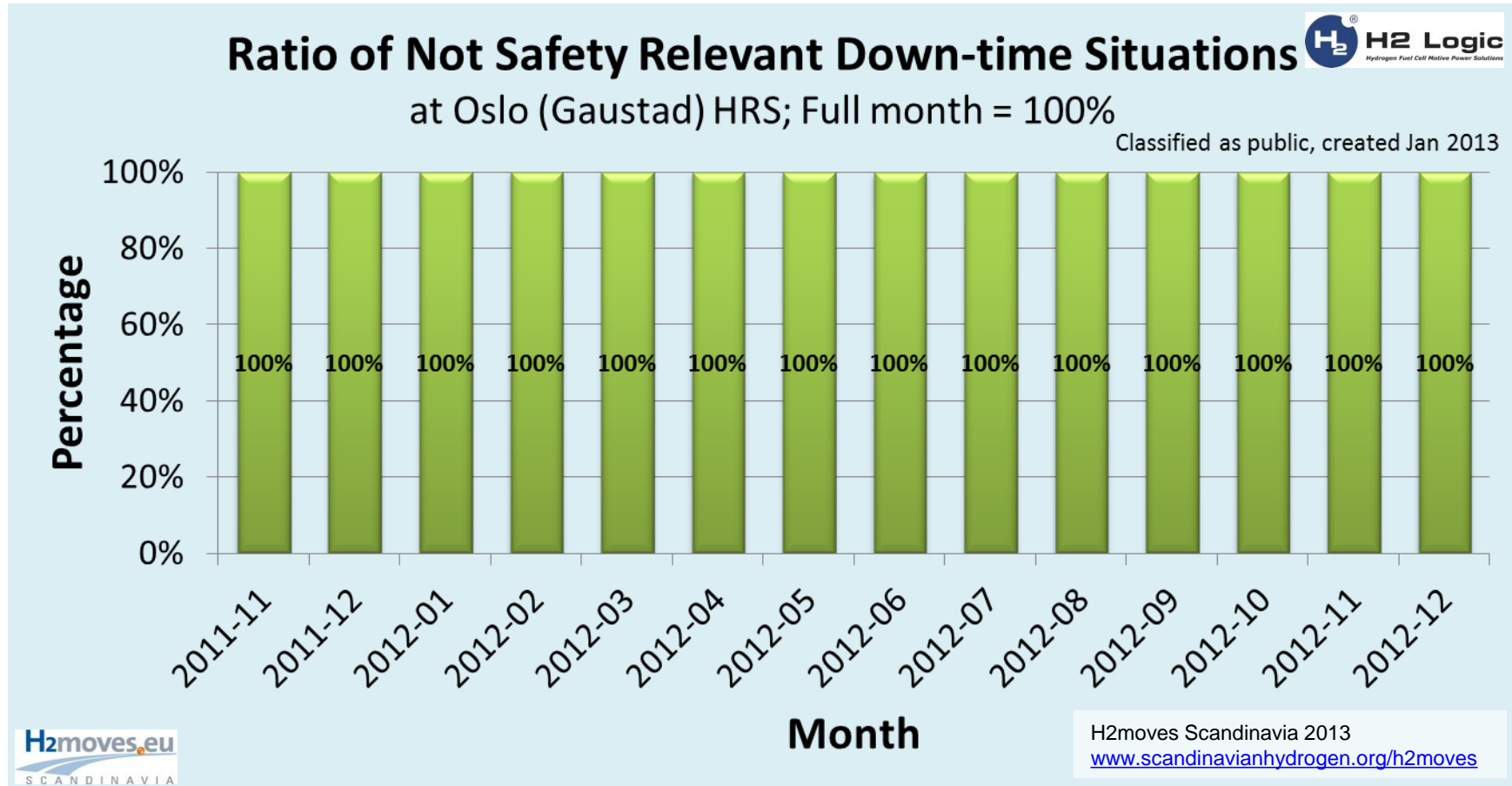
- 53 % of all down-time situations were solved within ½ hour
- 76 % within 6 hours
- 82 % within 1 day



Causes of Non-availabilities at Oslo (Gaustad) HRS



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.

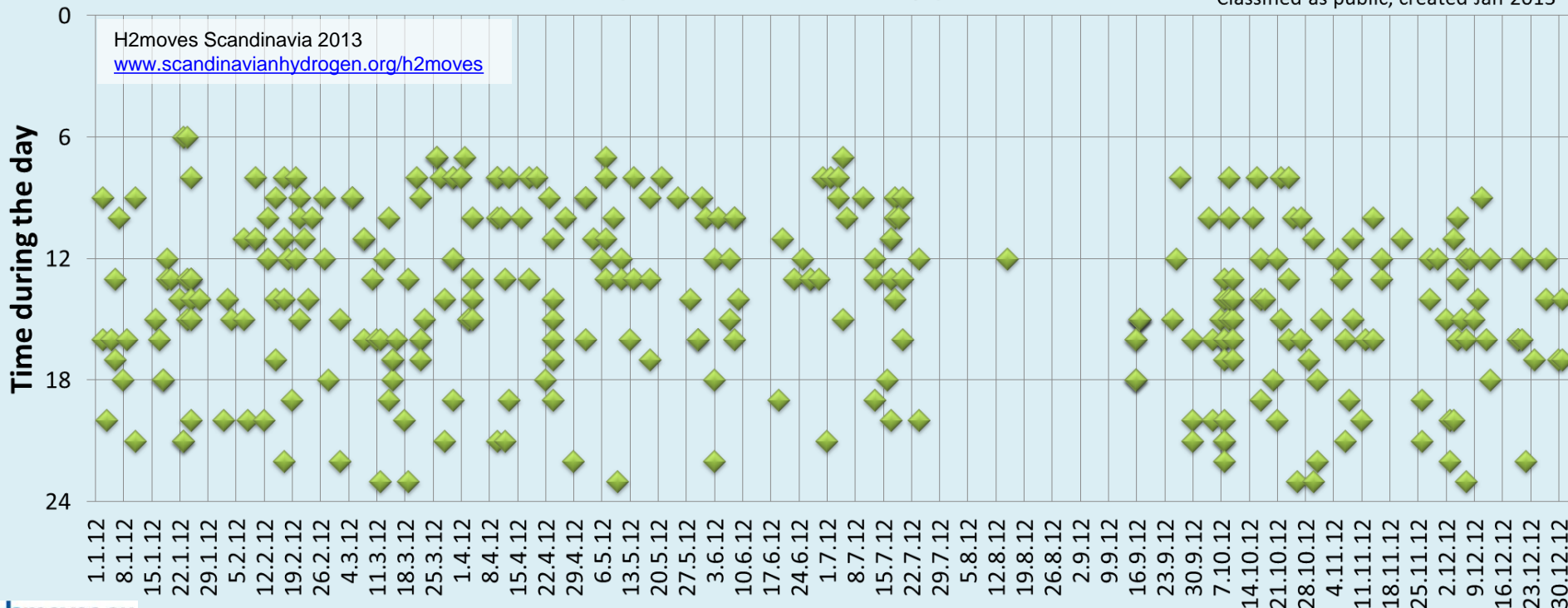



Individual Refuelling Events at Oslo (Gaustad) HRS

(width of one unit is 7 days)



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 Customers quickly returned to HRS after repair

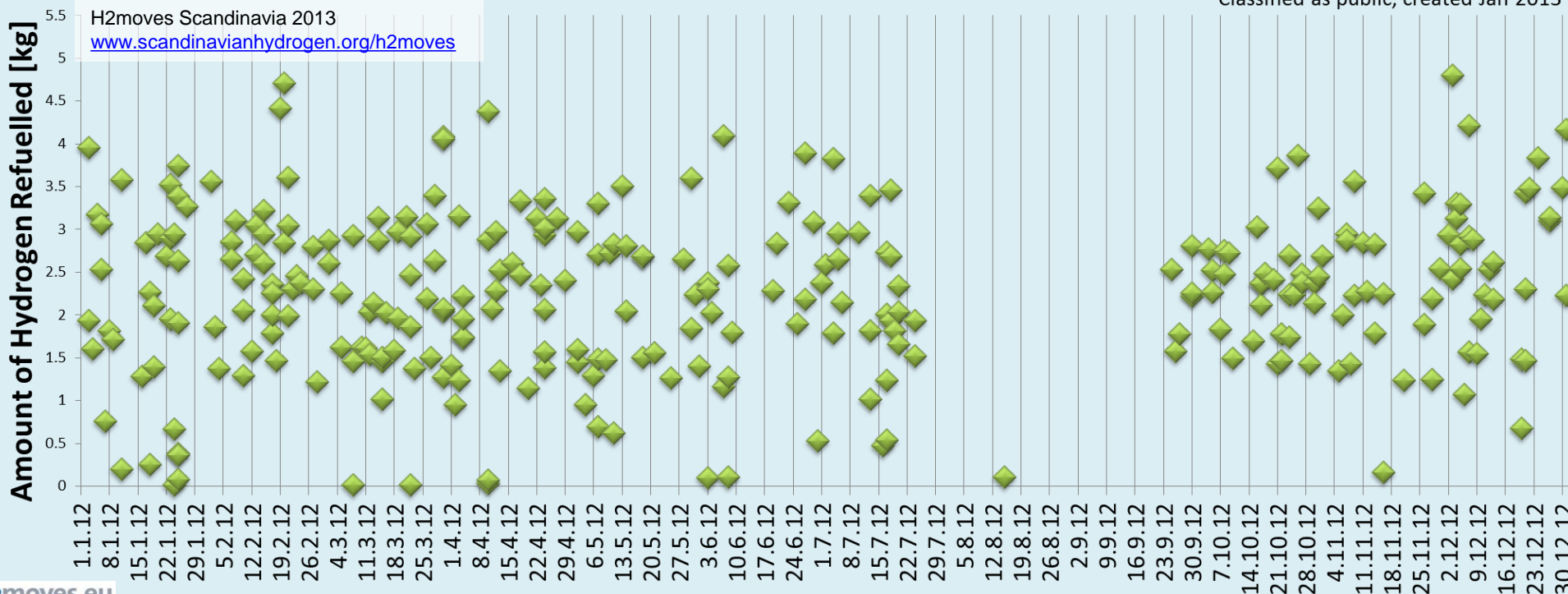


Individual Refuelling Events at Oslo (Gaustad) HRS

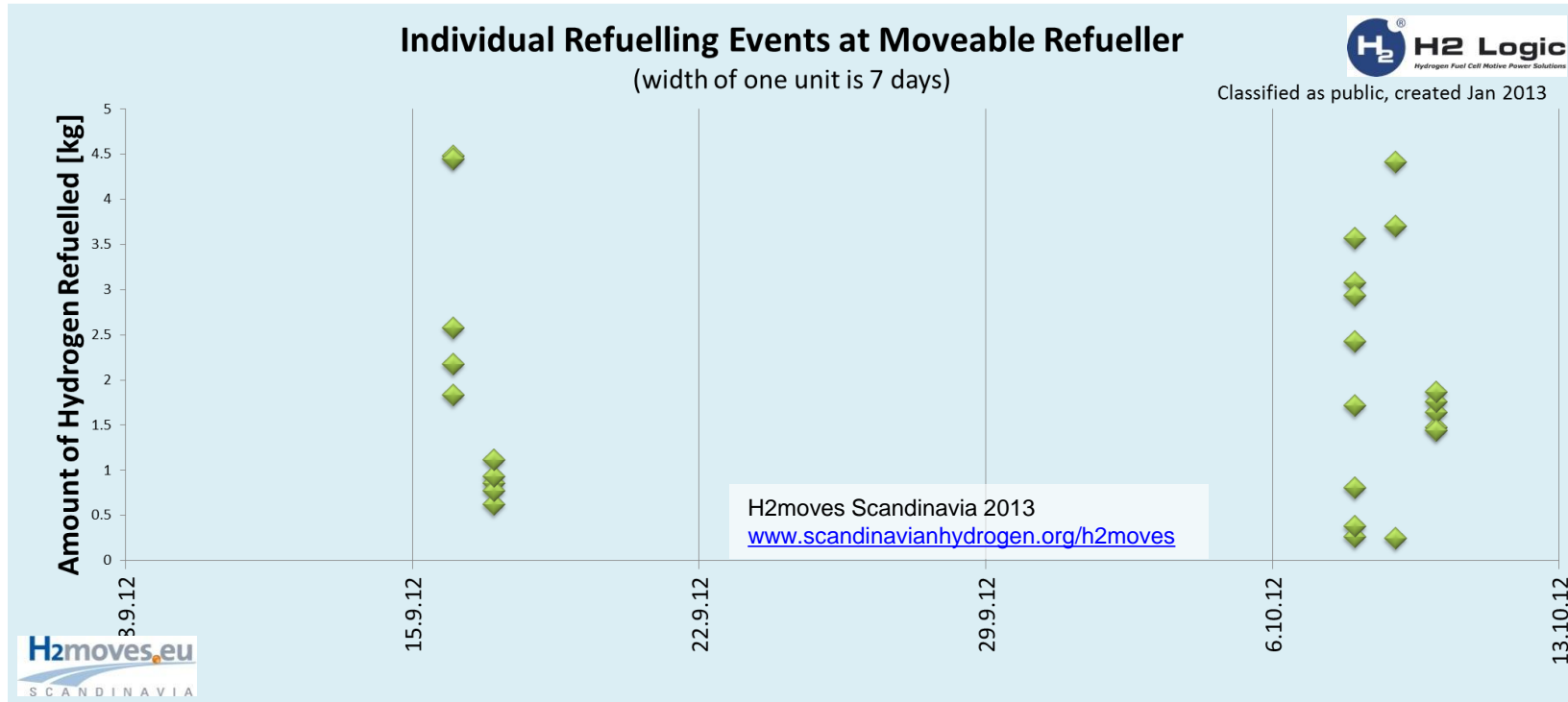
(width of one unit is 7 days)



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



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



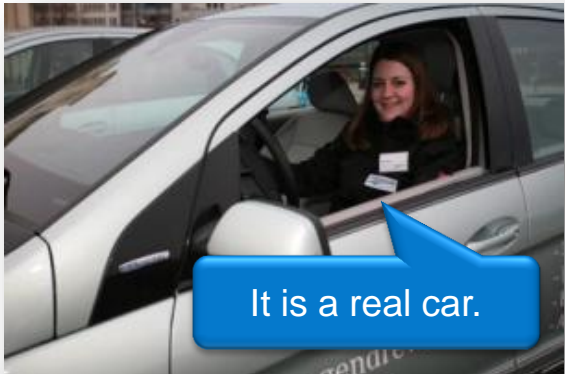
1. Technical Advancements

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- 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

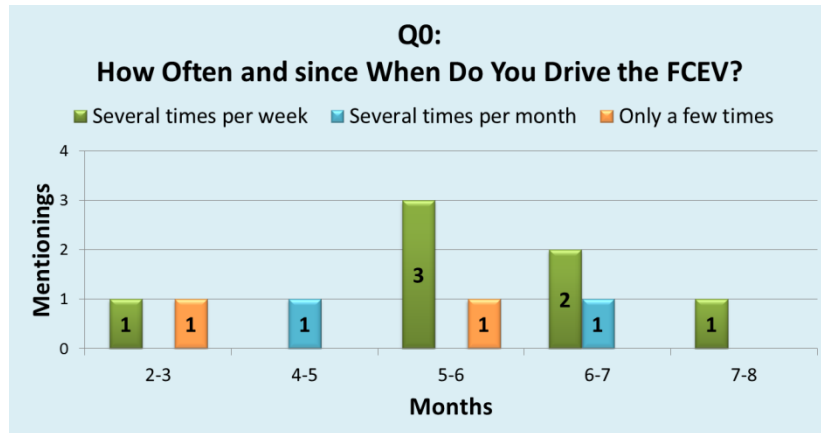
Remark:

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.

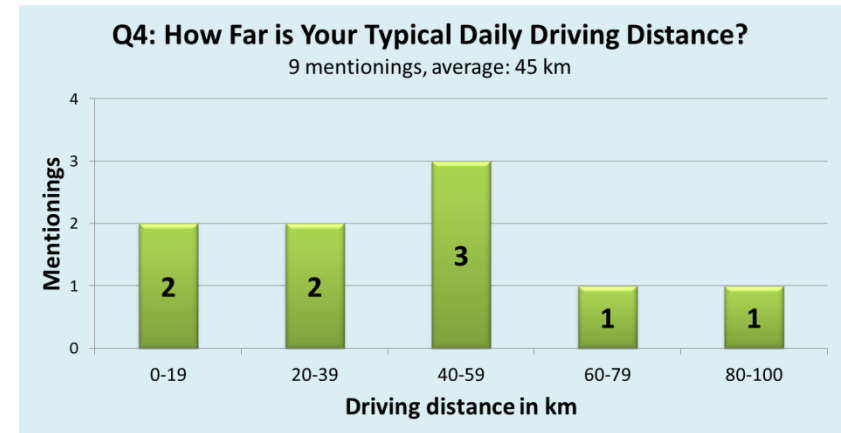


Customer Survey

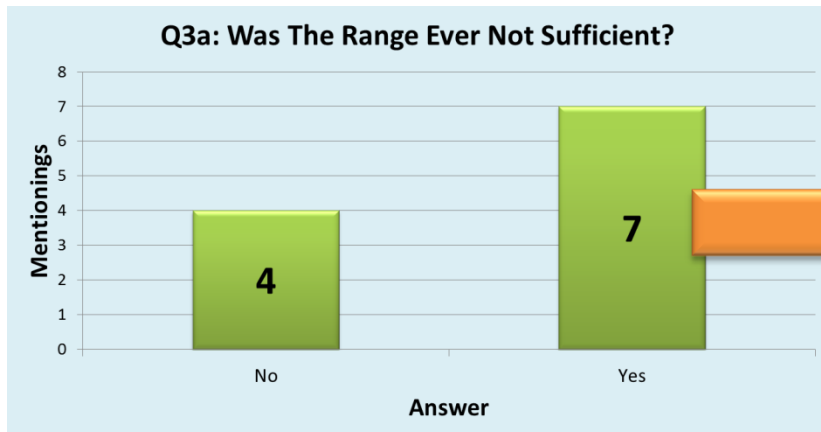
Driving Patterns: Frequency and Distances



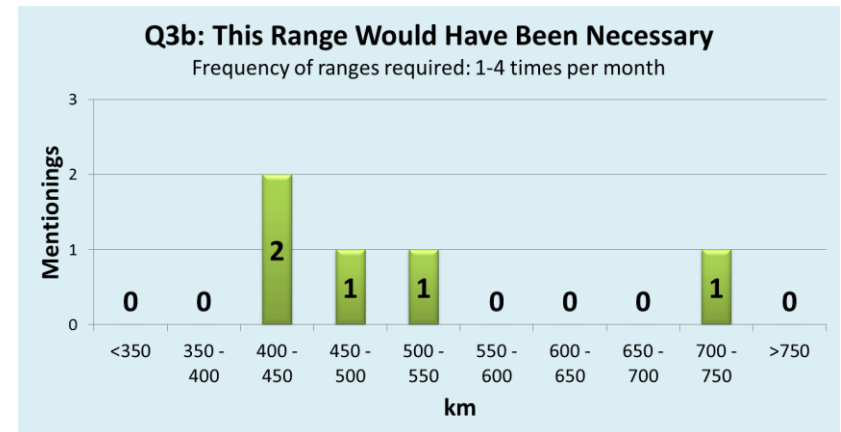
11 interviews were conducted with 9 people including our super-user who drives all three kinds of cars on a regular basis.



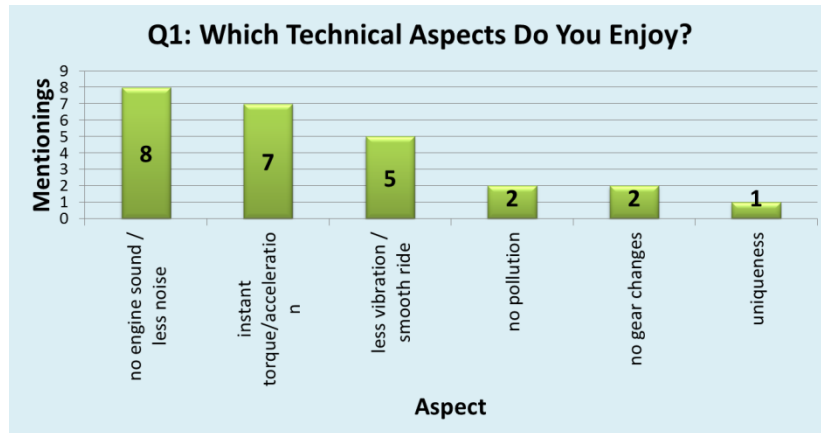
The range of daily driving range goes from 10 to 100 km. All H2mS vehicles can cover this and only few customers have to take detours for refuelling several times per week.



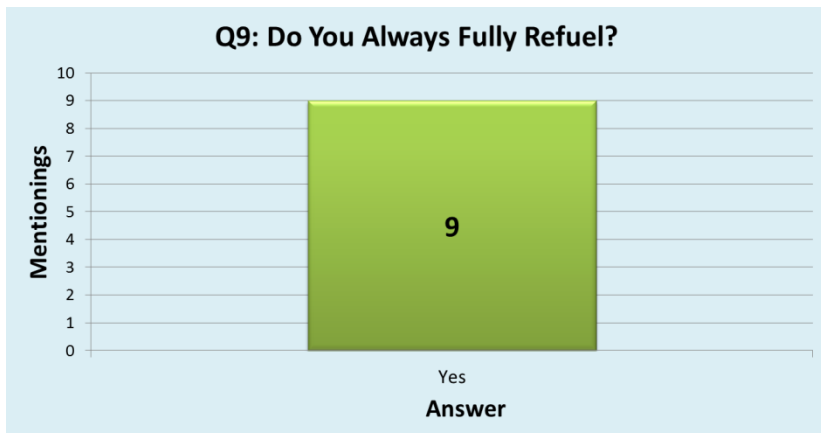
Answers depended on individual expectations. As for most people the FCEV is not the only car available, they just choose another car.



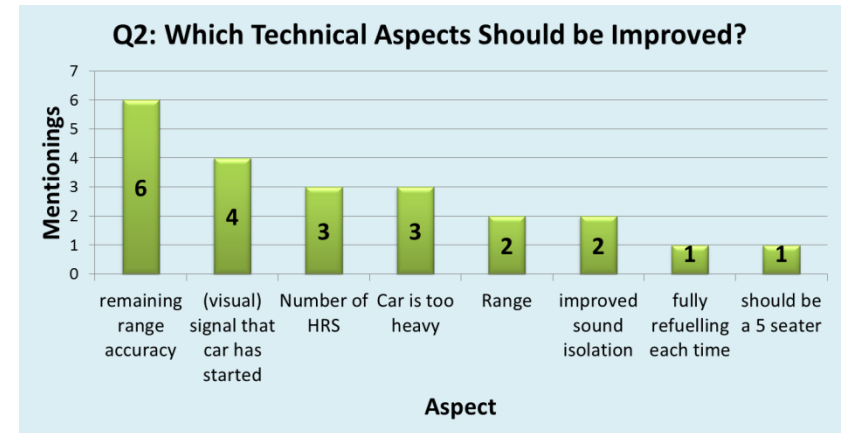
In 7 interviews we received the answer that the range is not sufficient. Due to our super-user, we have 5 individual ranges required.



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.

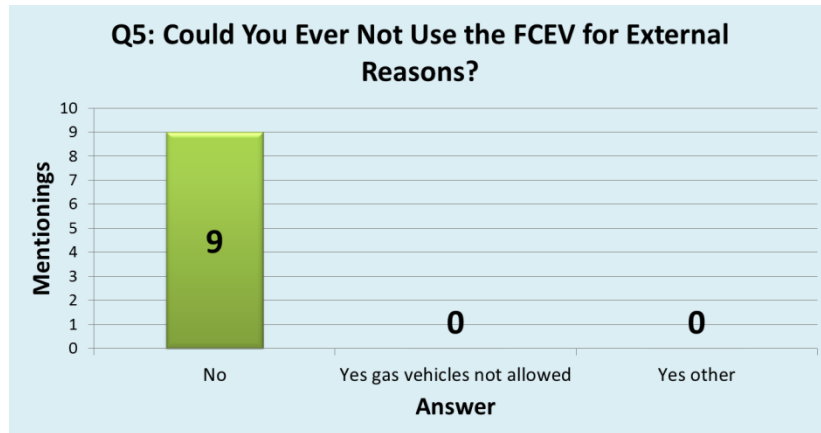
Reactions concerning artificial noise:

- “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...”

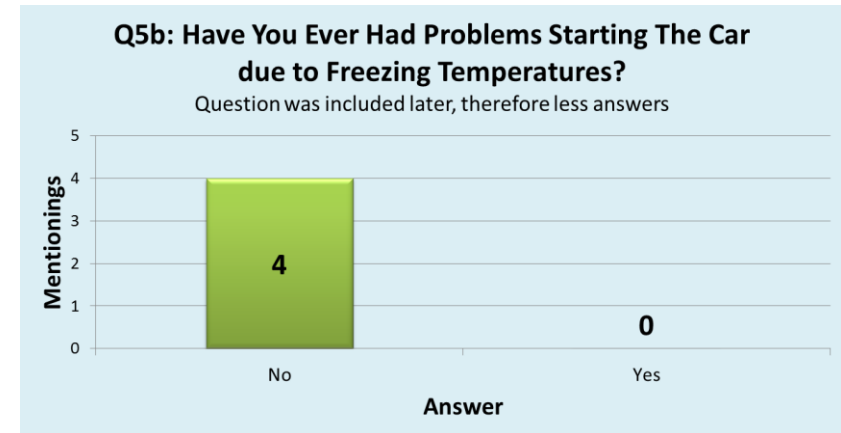
➔ Varying opinions

2. Which technical aspects should be improved?

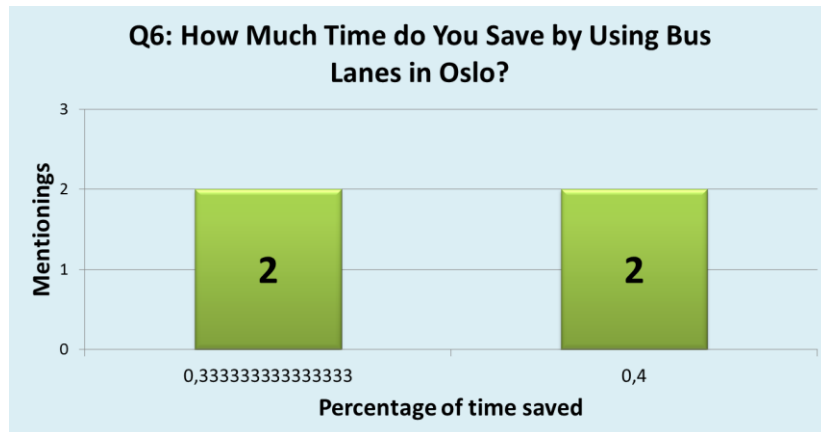
- [there needs to be an artificial noise so pedestrians can hear me.]
- I want to choose from several artificial noise options.
- I am driving the car for 3 months now and still can't tell whether the engine is already running or not.
- I don't trust the predicted remaining range, so I refuel rather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



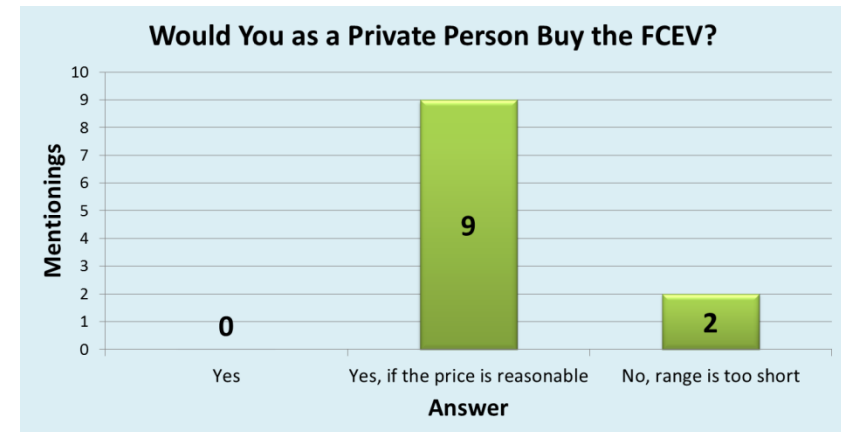
Even taking one of the cars on a car ferry on a frequent basis was no problem. No one ever had problems in car parks.



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".



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



WP 7 Technical Monitoring and Assessment Customer Satisfaction Survey

This survey is primarily H2moves Scandinavia internal. Please give us your 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. Questionnaire 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 Think

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.]



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:



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:



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 _____
- No, for this reason: _____

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

Do you sometimes 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?



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?



1. Technical Advancements

2. FCEV Performance Data

3. HRS Performance Data

4. Customer Survey

4. Outlook



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



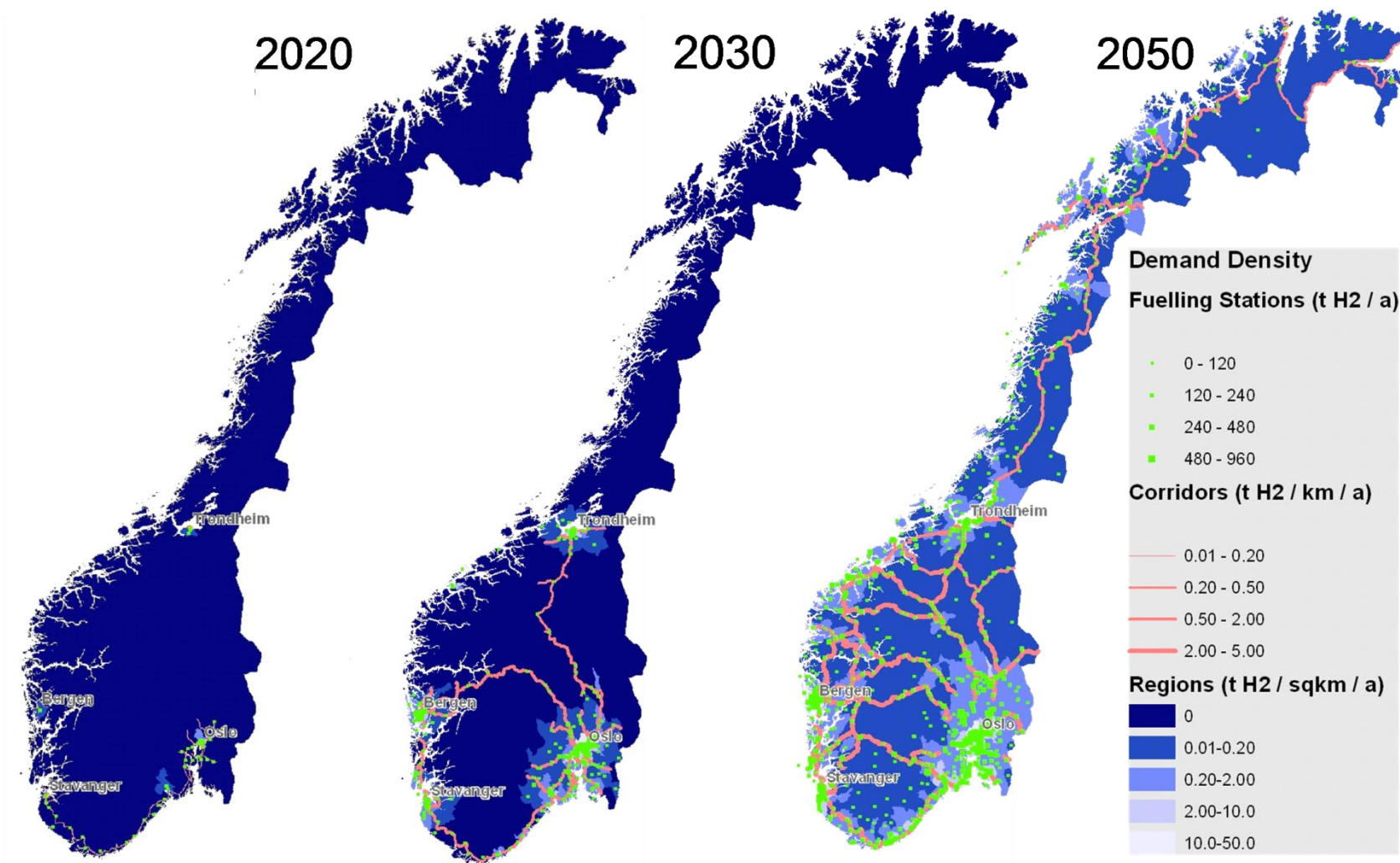
Source: LBST GmbH
H2 Logic A/S



Source: Hyundai Motor Europe



Norway: HRS and Hydrogen Demand Evolution

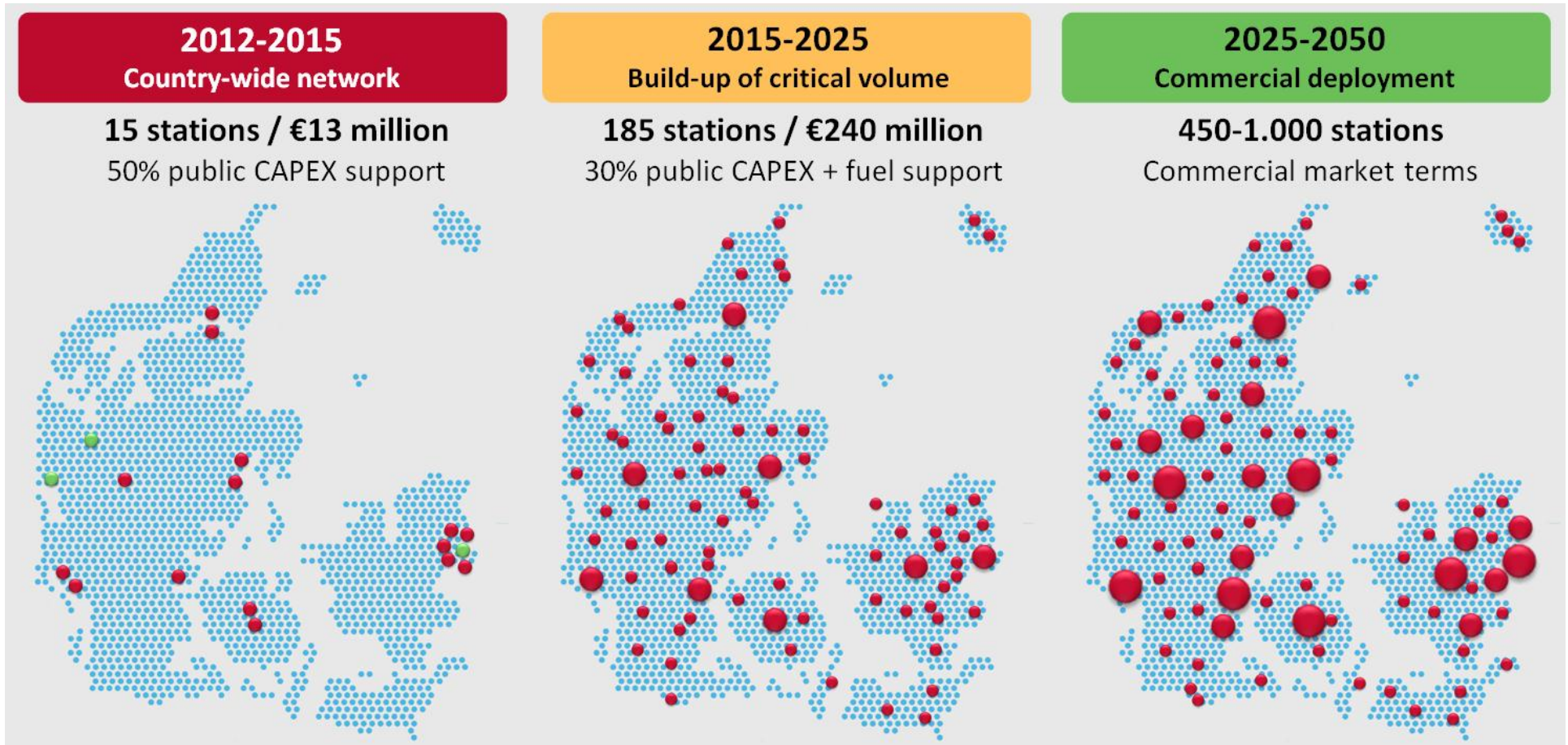


Source: NorWays Roadmap 2006-2008



Denmark: Outlook for Hydrogen Stations Roll-out

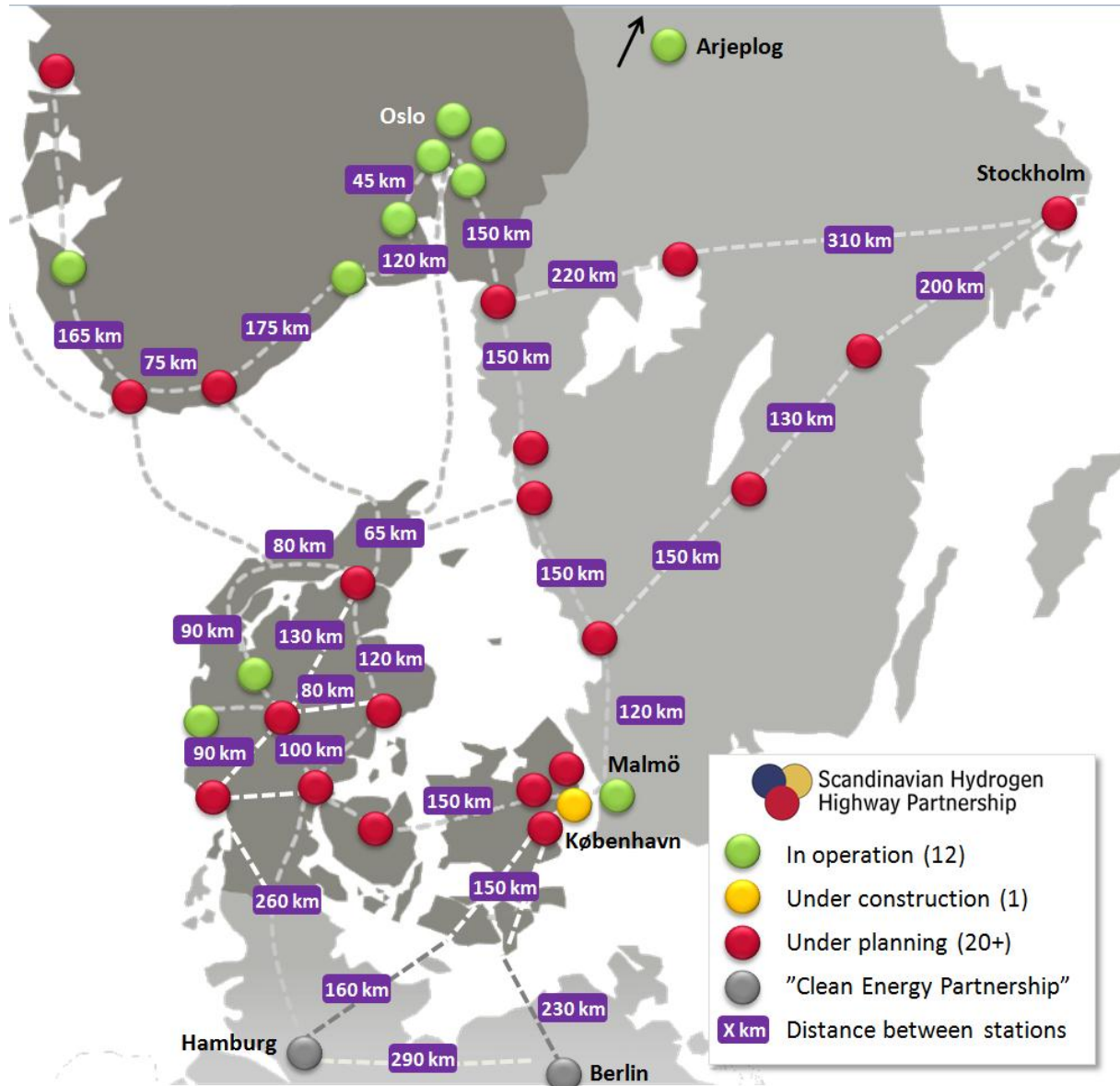
- A staged roll-out - ensuring availability of refueling to the growing fuel cell vehicle fleet
- Appropriate public market support mechanisms to ensure attractive investment case



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



Scandinavia: Scandinavian Hydrogen Highway Partnership

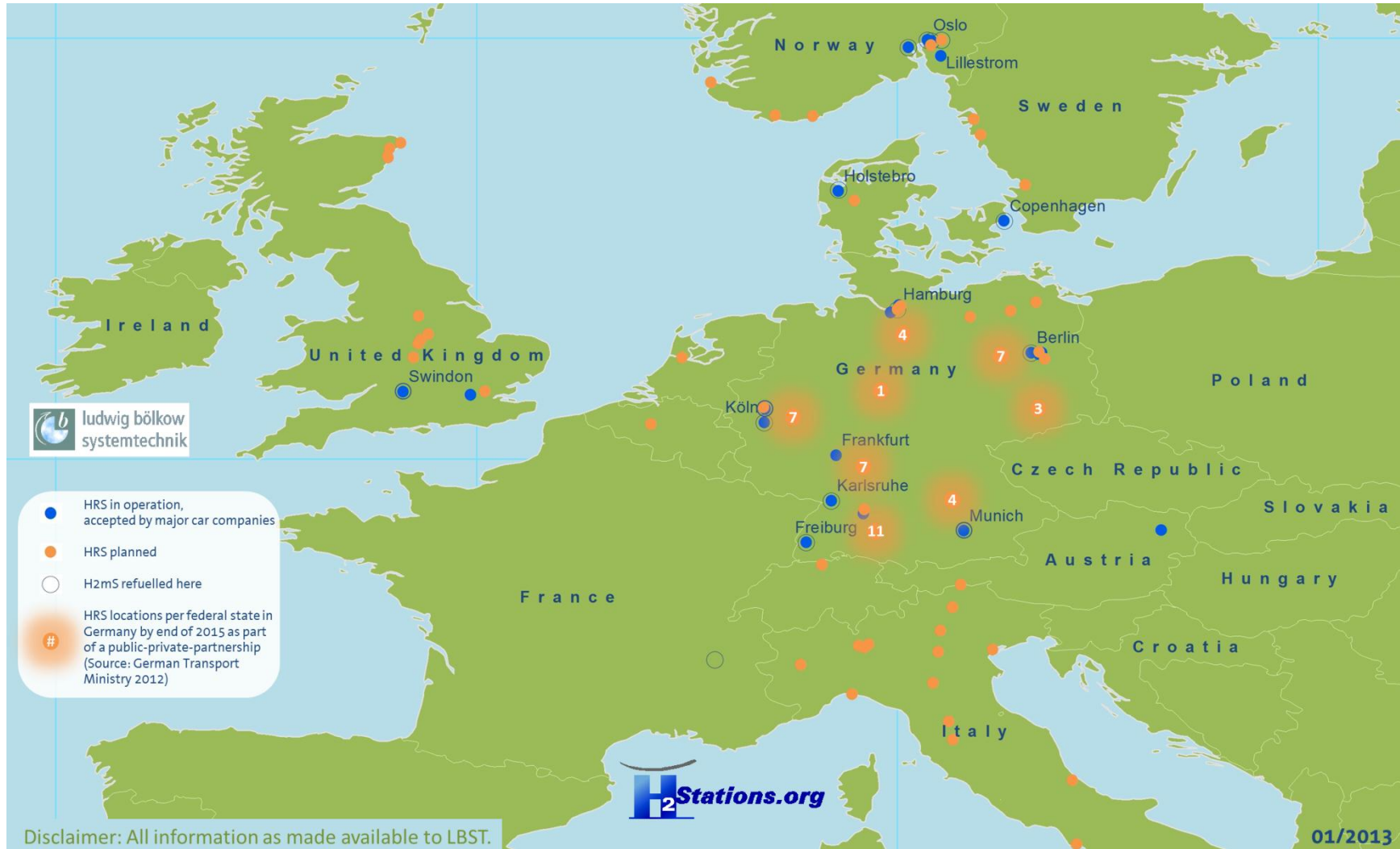


SCANDINAVIA 2015 VISION

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



Europe: Public Car Hydrogen Stations in Europe

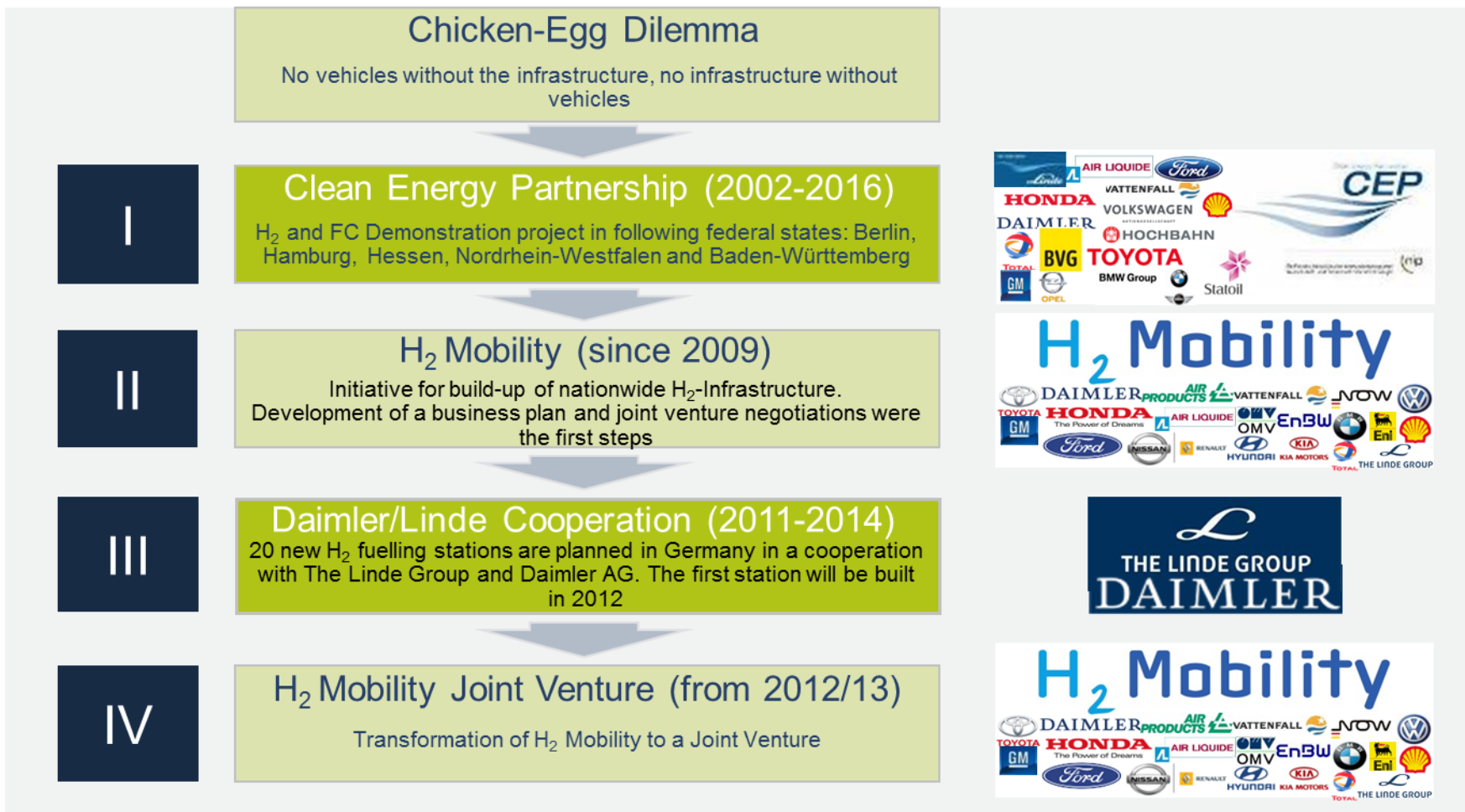


The blue dots indicate those hydrogen refuelling stations currently being operated that provide public access and match the requirements of major car companies.

Source: LBST GmbH



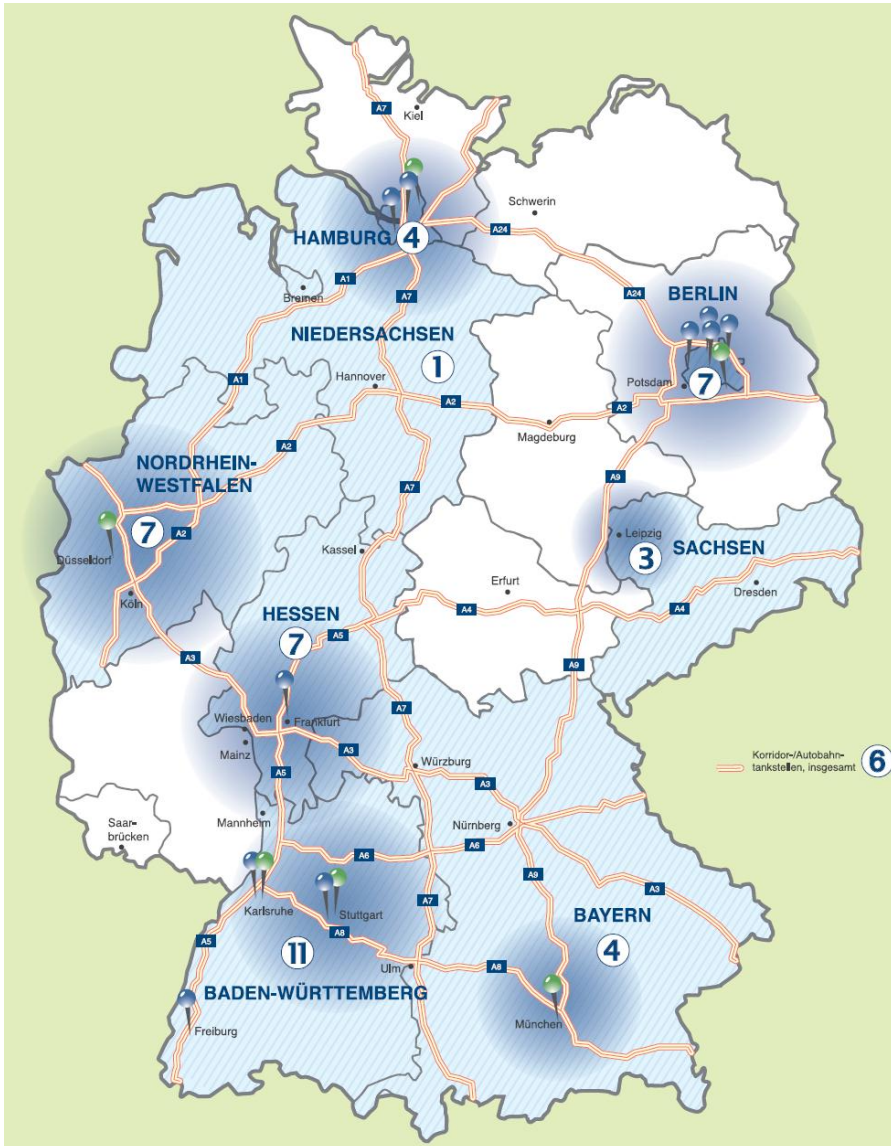
Example Germany: The way to an area-wide hydrogen-infrastructure network



Source: Daimler AG



Germany: 50 HRS in Germany until 2015



Clean Energy Partnership CEP

Ein Projekt im Nationalen Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie



Gefördert durch:



Bundesministerium für Verkehr, Bau und Stadtentwicklung

Koordiniert durch:

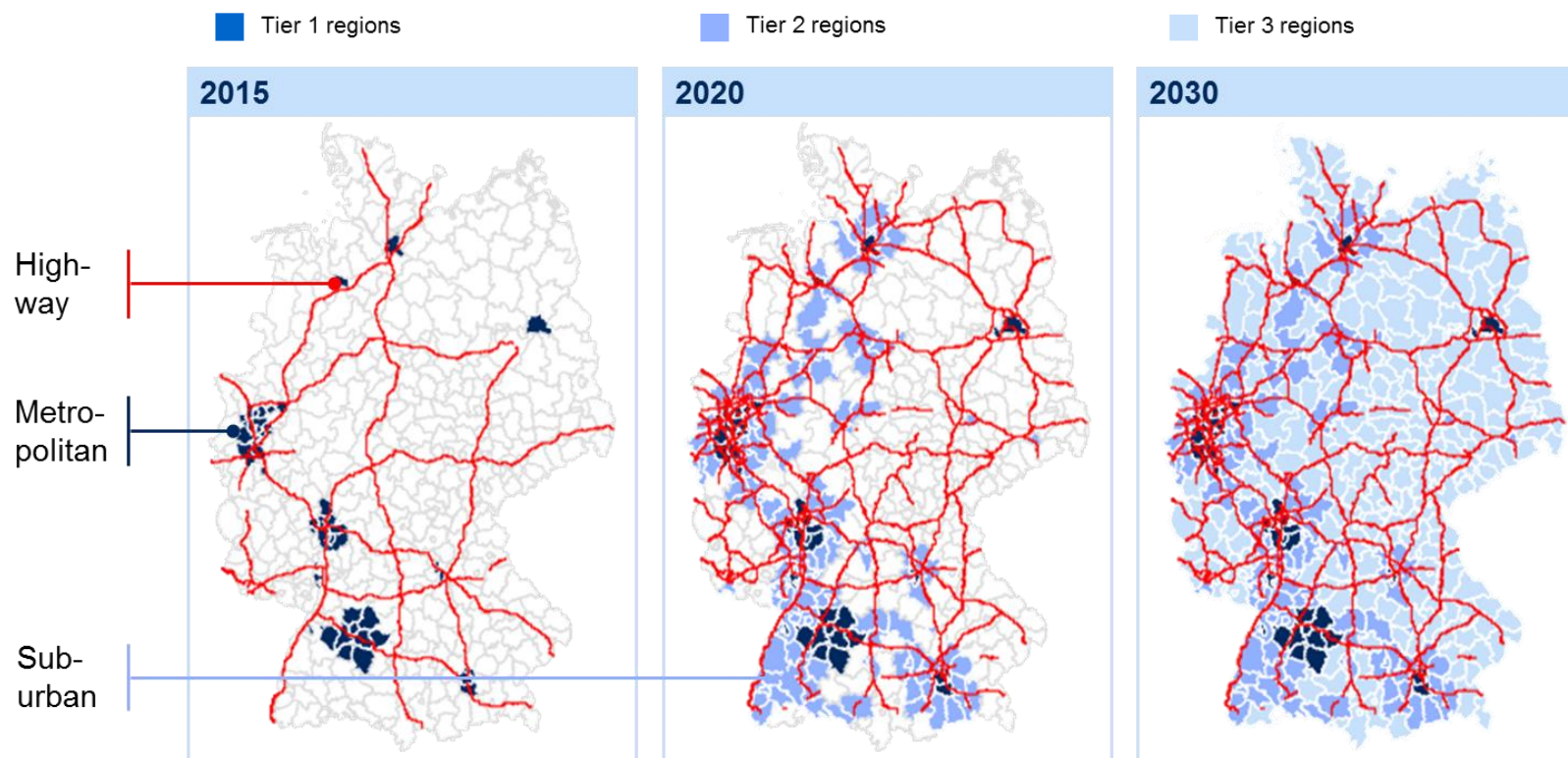


- existing HRS
- HRS under construction / locations determined
- Locations per federal state by end of 2015
- metropolitan area

Source: German Transport Ministry 2012



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



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

- 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:

Four A-70 MPa HRS's in only 12 months
H2Station® from H2 Logic A/S



Location	Date
Holstebro (DK)	June 2011
Oslo (NO)	Nov. 2011
Polar Circle (FI)	Jan. 2012
Lilleström (NO)	June 2012



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