

Future Norwegian value chain for liquid hydrogen

Martin Larsen Hirth, 25th of April 2019

GREENSIGHT

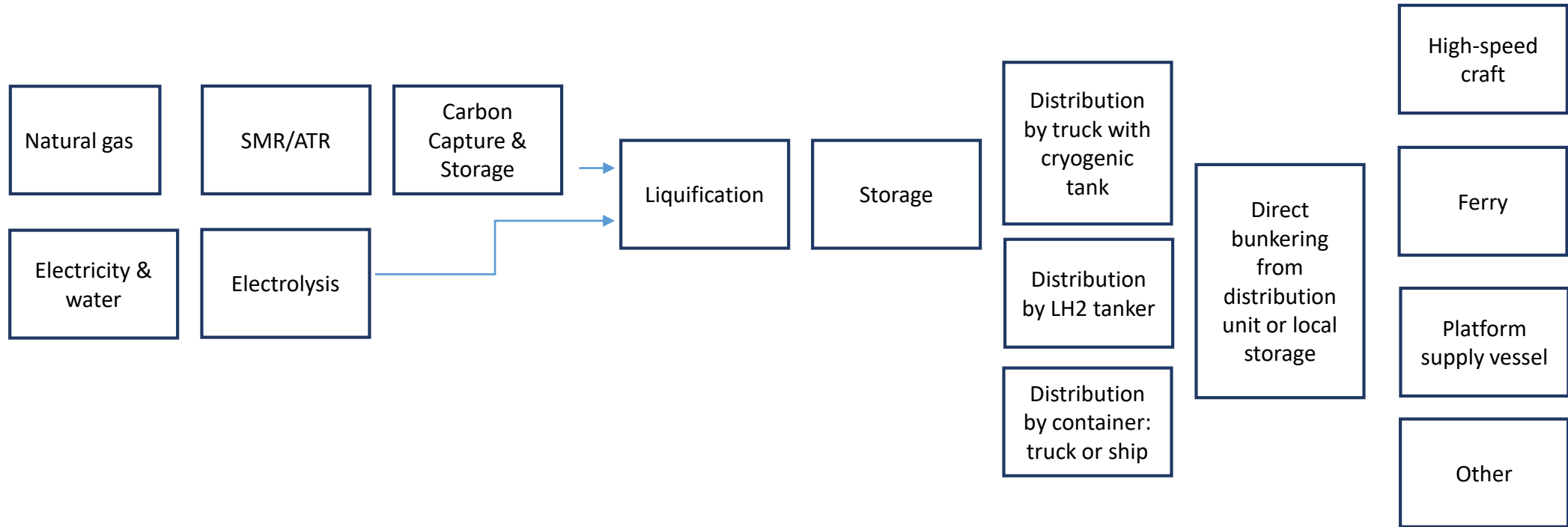


Organization and scope

- What volume of LH₂ is necessary?
- Identify barriers for the introduction of a liquid hydrogen value chain in Norway?
- Vessels: car ferries, high-speed crafts and PSVs
- Geography: Rogaland to Trøndelag



Value chain



Volume of liquid hydrogen

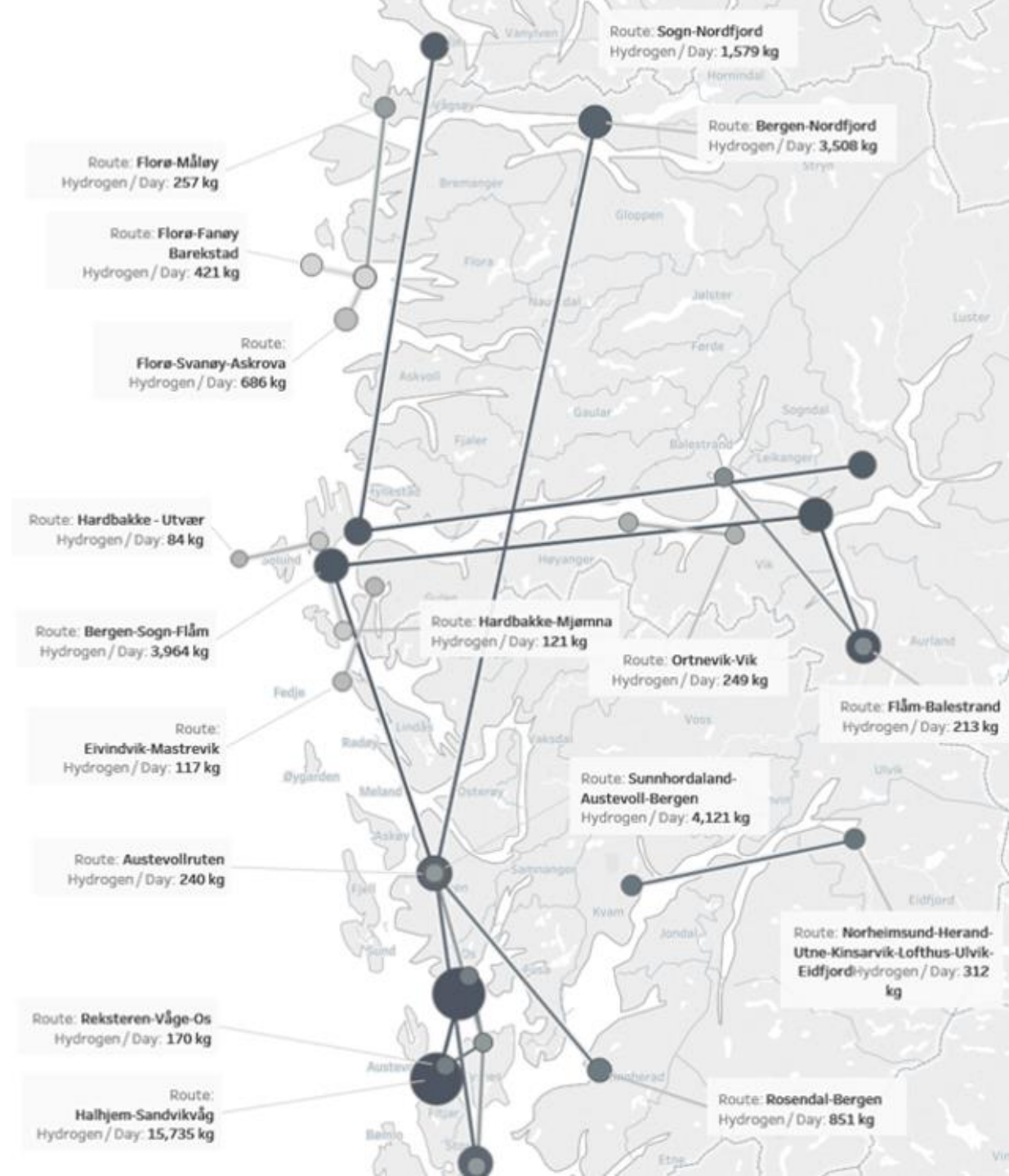
Scenario	100 % conversion to LH2		50 % conversion to LH2		25 % conversion to LH2	
	t/year	t/day	t/year	t/day	t/year	t/day
Trøndelag						
Møre og Romsdal						
Sogn og Fjordane						
Hordaland						
Rogaland						
Total						

Volume of liquid hydrogen

Scenario	100 % conversion to LH2		50 % conversion to LH2		25 % conversion to LH2	
	t/year	t/day	t/year	t/day	t/year	t/day
Trøndelag	2 131	6	1 066	3	533	1,5
Møre og Romsdal	13 577	37	6 789	19	3 394	9
Sogn og Fjordane	23 870	65	11 935	33	5 968	16
Hordaland	39 439	108	19 720	54	9 860	27
Rogaland	25 888	71	12 944	36	6 472	18
Total	104 905	287	52 454	144	26 227	72

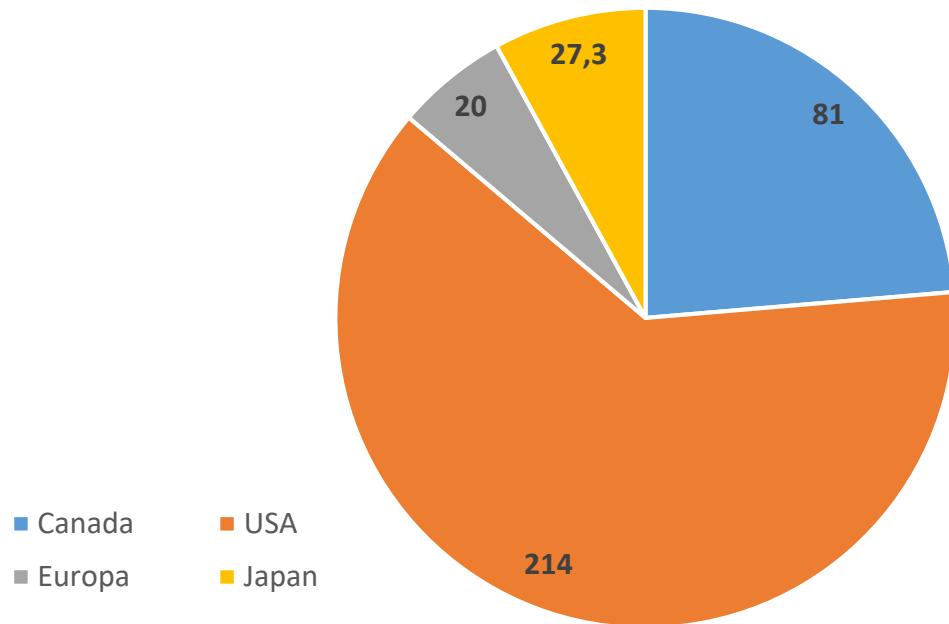
Car ferries and high-speed crafts

- A daily demand of up to 4 tons of LH_2 per day for high-speed crafts
- The car ferry between Halhjem and Sandvikvåg has a daily demand of ca 16 tons of LH_2
- Bergen as a central hub for several crossings.
- Also need for effective distribution of fuel to more remote locations



Need more production capacity for LH2

Global production of LH₂ tons/per day



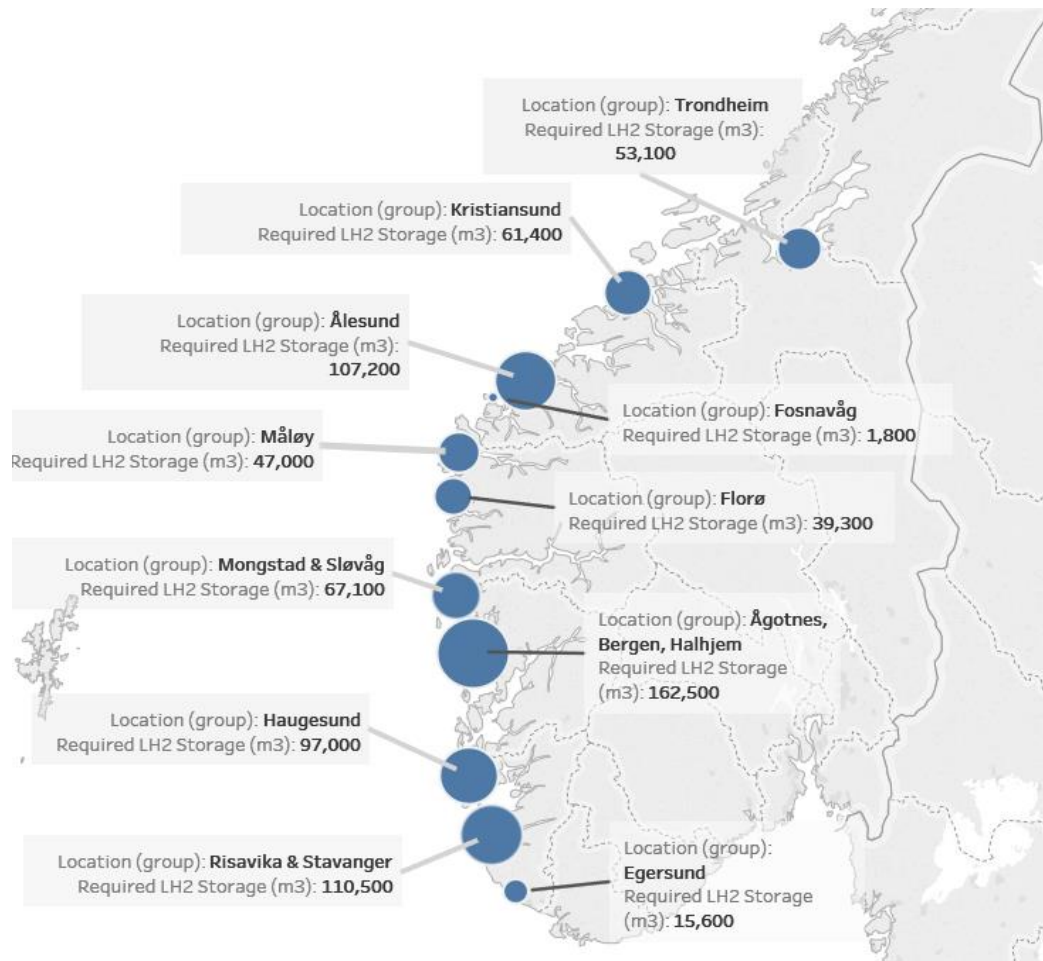
Europe (all SMR without CCS):

- Air Liquide: Waziers, Frankrike: 10 tons/day
- Air Products: Rotterdam/Rosenberg, Nederland: 5 tons/day
- Linde: Leuna, Tyskland: 5 tons/day (doubling from 2021)

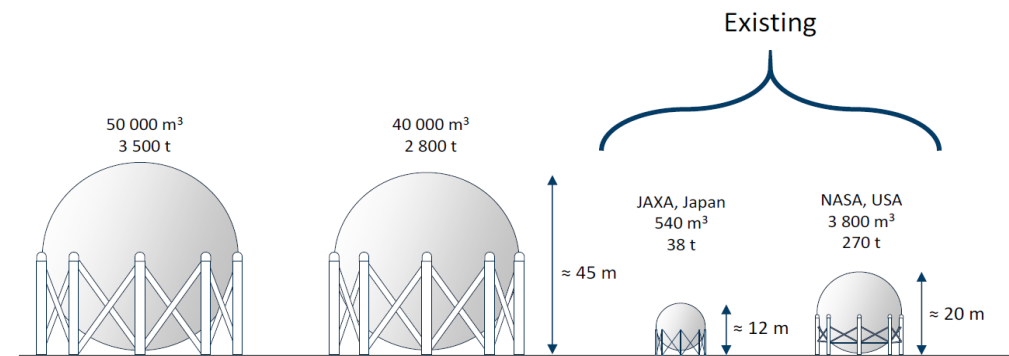
Norge (plans)

- Kvinnherad: 15 tons/day from electrolysis
- Tjeldbergodden: Current surplus of 15 tons/day – large additional capacity using gas reformation

Storage



- Lower energy density than current fuels:
 - LH₂ – 8500 Megajoule/m³
 - LNG – 22 000 Megajoule/m³
 - MGO – 38 000 Megajoule/m³
- Important to implement future land footprint



Distribution

Currently available:

Trucks



Cryogenic tank on RoRo



Future solutions:

Distribution

Currently available:

Trucks

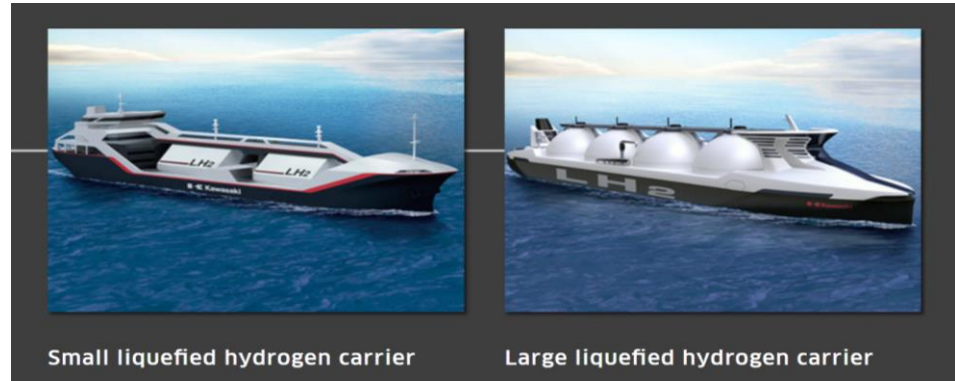


Cryogenic tank on RoRo



Future solutions:

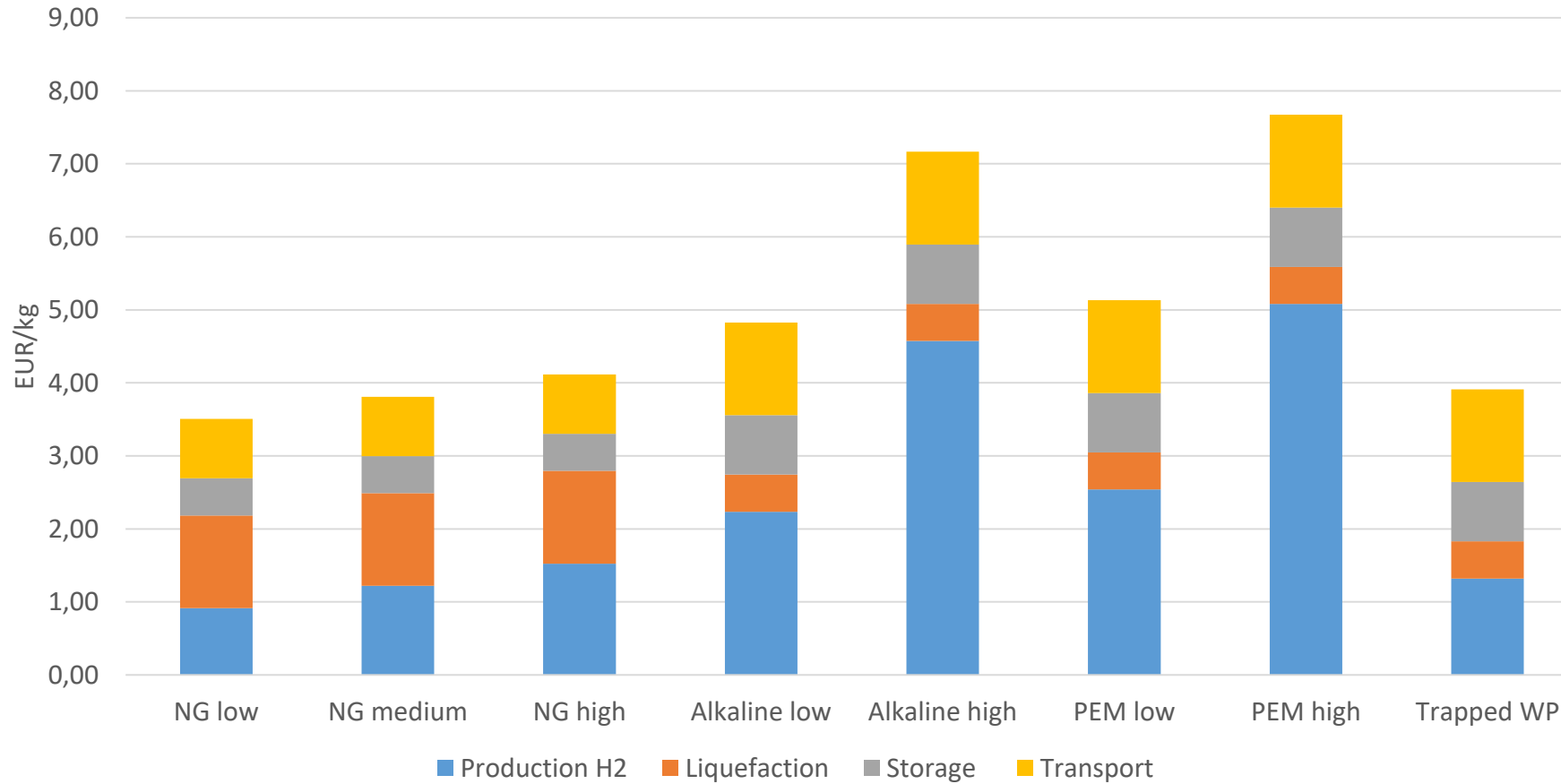
Large scale carriers



Distribution/bunkering vessel



Estimated retail price in 2030



Comparison of fuel cost/kWh to propeller

Fuel	Retail price EUR/kg (ex. vat)	Cost in EUR per kWh	LH ₂ -price to match other fuels
MGO	0,61	0,11	1,9
LNG	0,76	0,14	2,3
Ammonia (fuel cell)	0,51	0,18	3,0
LPG	1,10	0,19	3,2
Ammonia (combustion)	0,51	0,20	3,3
LH₂- Best case NG	3.5	0,21	N.A.
Methanol	0,8	0,25	4,1
Bio-diesel	1,68	0,32	5,3
LH₂- High estimate	7.5	0,45	N.A.

Summary:

- Need:
 - To establish emission free large scale production of LH₂ in Norway
 - To reduce cost for LH₂
 - LH₂-tanker/bunkering vessels for effective distribution
 - To close regulatory gap – especially for bunkering procedure
 - Further engineering and testing to modify existing LNG-equipment for LH₂

