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### Hydrogen: An enabler for the transition to a fossilfree island?

Dr Björn Samuelsson, Visby November 28 2024

### Gotland – in the middle of the Baltic Sea



- Largest island in Sweden
- 3140 km<sup>2</sup>
- 65,000 inhabitants
- Ca 90 km's from mainland Sweden





# Energy production and consumption

- Electricity consumed: ~ 1 TWh
- 50% imported via cabe from mainland Sweden
- 50% windpower produced at Gotland
- Fossil fuels:  $\sim$  0,9 TWh, (transports 0,6 TWh)
- Good opportunities to increase windpower large-scale offshore wind farms







# Offshore wind farms

- Offshore wind in the surroundings of Gotland could make the island an exporter of energy...
- But...The government and the military have recently stopped all wind farms in the Baltic Sea



Image: PhaseImage: LocationImage: LocationImage: CommissionedProductionCapacityUnder developmentBaltic Sea, outside Öland<br/>and south of Gotland203024 TWh5,5 GW



# Renewable energy

- Renewable energy production is green, but quite volatile
- Hard to to replace all fossil fuels with battery electrification
- Hydrogen can be an interesting solution to both of these problems!
- Would be beneficial with a large off-taker of hydrogen







# Could we run the ferry on hydrogen?

#### **Present operations**

- Distance: 90 nm
- Ferry: Ro-pax, 200m, 1650 passengers, 500 cars (3 ferries)
- Engine: Dual fuel, LNG/LBG, 50 MW
- Speed: 28 knots, 3h15m, 100 MWh per round-trip journey

#### Hydrogen?





# Hydrogen powered ferry

- Gas turbines, in combined cycle with steam turbines
- Long been used in industry, but it is only now that they will be powered by hydrogen.
- A multi-fuel engine; the gas turbines can handle a large variety of fuels
- 24 tonnes of hydrogen stored onboard
- 16 tonnes per round-trip journey
- Provides a unique opportunity to accelerate the transition of shipping.





# Hydrogen supply system

- 16 tonnes of hydrogen per round-trip journey
- 20.000 tonnes annual demand
- Requires ~ 1TWh/yr, 200 MW electrolyser
- Hydrogen production on- or offshore
- Pipeline from production to port
- Surplus of oxygen and heat



Figure 3: Gotland Ferry system layouts



# Wind + Hydrogen

- Hydrogen and renewable energy production = perfect match
- No need for constant hydrogen production
- Hydrogen production can levelize electricity production to the grid
- Hydrogen production can harness otherwise not used wind/sun
- Large-scale hydrogen storage would further improve the system





### In port

- 16 tons in 45 minutes approx. 800 m3
- Cascade filling higher pressure in buffer storage in port
- Temperature will rise Cooling process necessary
- Requires 50 150 tonnes of hydrogen in buffer storage
- Physical space approx. 2 10 000 m<sup>2</sup>
- Security and regulatory
- New refuelling concept needs to be developed







### Economy

- Long term: 5.5 €/kg H2
  - ~€1,5/l diesel
- Utilisation rate, electricity prices
- Short term: 10-20 €/kg H2
- Increased CAPEX ferry
- Need for public support



Herizon X			Production capacity (incl. slack)	111,1 100/3	4h				Source CAPEX	Source OPEX	CAPEX	OPEX	
Max demand H2/24 h	100	500	Efficiency	59%		Electrolyzer	90	6.NW	3	6	352 763 291	7 055 2	
lotal demand/year	25.000	ton	Electricity/kg	55,9 kWh		Desalination	30,6	6/L(H20)/h	4	4	3 881	3	
			Electrolyser power	259 MW		Pipeline	4,660*2+0,82*D+0,45	MC/km	5	4	32 700 000	654 0	
Other offtake/yr		ton	Water demand	1111 ton		Compressor	2440	CAW .	6	6	2 440 000	974	
ack (minimum stack in capacity)	10	76	Distance cable	50 km		Storage	740	C/kg	7	7	74 000 000	3 700	
had production y	25.000	500	Distance pipeline	50		Fuelling	Estimated lumpsum	6	estimate	estimate	25 000 000	1 250	
			Diameter pipeline	0.2									
			Compressor	5 MW				Total investment (C)	486 907 173 6				
			Storage	100 ton				Operational cost (Cyr)				12 757 1	
			Utilization	62%				Loan	204				
								Interest	10%				
								Years	15				
								Depriciation (years)	25				
								Common investments					
								Horizon specific investment					
								Shareholder	30%	146 072 152			
								Annual capital cost			- 34 083 507 6		
								Cost per lat H2			1.344		
								Compared of	-	-			
								Price/kWh (óre/kWh)	40				
								Electricity cost/kg H2			r	. 1	
										_			
								Total cost per kg H2			- 3,77¢		
								Corresponding diesel price			- 1,08-C		
Sources: 1. Xiadling Zhao, Yao Liu, Jiawei Wi Slobal Energy Interconnection, Vol 2. IRENA, Green hydrogen cost red	u, Jinyu Xiao, Ji ume 3, Isoue 2 uction: Scaling	nning Hou, Jing 2020, Lup electrolyse	hui Gao, Libheng Zhong, Technical and econor Is to meet the 1.5cc climate goal, 23 https://w	mic demands of HNI www.irena.org/, 202	C submarine ca	bie te chnology for Global Ene	ngy Interconnection,						
3.8 A France P. Baptista, R.C. Neto, S. Ganiha, Assessments of Biading asthways for wind-powered offshore hydrogen production: Energy and economic analysis, Applied Energy 286 (2021)								H2-price (6/kg)	5,5				
4.A.Strigttou, 20th gaint, Challwalleads, Onshow, althouse on Latine electrolysis. Techno-economic evenues of alternative integration designs for greenhydrogen production into offshore electrolysis.								Sold H2 (ton)	25 000				
powerhubs, Renewable and Susta	in able Energy	hansition 1 (20)	21) Main D. Britter für berechten stelle internet	and the second in second second		singling interactions interaction	and so of the second of the day ways						
Energy 38 (2013)	on approved	CHONEDBELL-F	Have, p. Sidden, pris-based scenar or calebration	ins for a mationwide (	in the state of th	ppears in an unit and, men	nacional Journal di Hydrogen	Revenue	137 500 000 €	_			
6. T. Taribux, C. Bauer, R. McKenna, M. Mazortii, Laga-scale hydrogen-productionvia water electrolysis: a ltechno-economic and environmental assessment. Energy & Environmental Science 15 (2022)								Capital cost	- 34 083 502 ¢	_			
7. DanishEnergyAgency,Technologydata-energystology, https://www.dk/en/loar-services/technology-catalogues, 2020.								Operational cost	- 12757163 C	_			
8. D.JangK. Kim, KH. Kim, S. Kang T	achno econor	ricanalysisandr	nontecarlosimulation forgreenitychogen produ	ution using offshore	wind power plan	t, Energy Conversion and Ma	nagement 263 (2022)	Overhead	- 500 000 €				
								Electricity	- 47 400 172 €				
								Depriciation	- 194762876				
								Profit before tax	23 282 876 €				
								Tax (20%)	<ul> <li>4656-575€</li> </ul>				
								Profit after tax	18 626 301 ¢				
								Between on camital	125				



## Hydrogen as an enabler for the green transition

- Large-scale production for the ferry system enables other hydrogen soilutions
- Heavy trucks
- Agriculture machines
- Sustainable fertilizer production









# Renewable $\implies$ Hydrogen $\implies$ Electricty?

- Use hydrogen as energy storage
- Islands with volatile energy production, Wind or solar power
- De-centralized electricity production
- Requires cost-efficient large-scale hydrogen storage
- Enables a fossil-free renewable electricity system





# Some challenges

#### Technical:

- Refuelling and handling in port
- Large-scale storage

#### Financial/political:

• Support front-runners

#### **Political:**

• Support offshore wind farms



### Contact info

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# Thank you!

