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Marine fuels for short sea shipping

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Background

- The Swedish contribution to Annex 60 – The progress of Advanced Marine Fuels
- The focus for the Swedish contribution was on high-speed engines for short sea shipping
- The objective: to **describe and compare alternative technologies and fuels applicable for short sea shipping and inland waterway use**
- Technologies and fuels suitable for road ferries were of special interest. The aim was to provide an overview of alternatives along with the respective challenges and possibilities of each.
- The study was carried out by consultants (SSPA) in 2021.

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Scope of study

- The study was carried out in 3 phases:
  - Step 1: What technologies exist, how far have they come and what do they cost?
  - Step 2: What are the effects of different technologies (environmental etc.)?
  - Step 3: Regulatory frameworks and policies
- Step 1: Covered eight different fuels as follows:
  - Hydrogenated vegetable oil (HVO)
  - Biogas (compressed (CBG) and **liquefied (LBG))**
  - Ethanol
  - **Methanol**
  - **Hydrogen**
  - Ammonia
  - **Battery electric**
- Step 2-3: 4 fuels selected for deeper analysis

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Scope of this presentation

- Technology readiness
- Costs
- GHG emissions
- Local example – the fleet of the Swedish Transport Administration

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Technology readiness

- To assess and compare the maturity of the different technologies the Technology Readiness Level (TRL)
- To differentiate the fuels that already are in use (and have reached level 9), and to assess the commercialization level of these, the original scale has been extended up to level 12.

12	Established commercial technology
11	Actual system applied in several different vessel types and applications
10	Actual system in operation during longer period
9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)
8	System complete and qualified
7	System prototype demonstration in operational environment
6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
4	Technology validated in lab
3	Experimental proof of concept
2	Technology concept formulated
1	Basic principles observed

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Fuel	TRL
HVO	12
Methanol	10
Ethanol	8
LBG/CBG	12
Ammonia	5
Hydrogen	8
Electricity (batteries)	12

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HVO, TRL 12

- HVO is very similar to fossil diesel and can be used as a drop-in fuel in diesel engines without modifications
- Since 2017, the ferries operated by the Swedish Transport Administration's Road Ferries on the Hönöleden route, located just outside Gothenburg, have been running on HVO
- No major problems – but the cost have been very high during 2022 which has forced STA to pause the use of HVO temporarily

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Methanol, TRL 10

- Two-stroke engines using diesel pilot fuel are available from MAN. They have been installed and are in operation on several vessels, primarily large product tankers intended for methanol transportation.
- Four-stroke engines approved for marine applications are lacking on the market and long-term tests are limited to conversions. However, the technology exists, it's more of a question of "market readiness"
- Since March 2015, methanol has been used in converted dual fuel medium speed four-stroke engines onboard the 240-meter long ferry Stena Germanica (in one of the four engines)
- The conversion has resulted in reduced NOx and particle emissions when the engine is operated on methanol fuel, as well as reduced some need for maintenance.

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Ethanol, TRL 8

- Currently, there are no commercial vessels known to be using ethanol as fuel.
- The technology used for methanol is considered to be adaptable for other alcohols such as ethanol.
- Truck engines using ED95 fuel (95% ethanol with additives) are available.
- Ethanol was tested in a compression ignition engine onboard the pilot boat which was converted to methanol in the GreenPilot project. The test showed that ethanol performed well but the tests were limited and no results from the tests have been officially published.
- So far, methanol is the only alcohol fuel that has been tested and used on ships, as the price of (fossil) methanol is much lower than the price of ethanol.
- Ethanol may replace petrol in outboard engines after minor modifications. This has not been verified through long term tests.

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LBG/LNG – TRL 12

- LBG/CBG can be utilized interchangeably with LNG/CNG. Any utilization of LNG/CBG can therefore be considered as an example of LBG/CBG use.
- LNG is now a well-established marine fuel that is utilized around the world in most ship applications and can therefore be considered a well proven technology. Marine gas engines are available from several manufacturers.
- For more recent installations dual fuel solutions using diesel and LNG dominate.
- The Swedish Transport Administration has been using LNG in the vessels to the island Gotland, around 50% gasoil and 50% LNG.
  - However, LNG is “worse” than gasoil from a GHG perspective

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Ammonia – TRL 5

- The technology for ammonia is still under development and there are no long-term test results.

Hydrogen – TRL 8

- Hydrogen is relatively new as a marine fuel and has mainly been tested as fuel onboard smaller vessels. Thus there are no results from long term operation. The technologies are under development and there are several ongoing projects testing the technology onboard vessels.
- Hydroville was launched in 2017 and was the first certified passenger shuttle ferry to use hydrogen in an internal combustion engine. The shuttle is mainly used as a platform to test hydrogen technology for commercial sea going vessels
- In July 2021, “the world’s first liquid hydrogen-powered ferry” MF Hydra was delivered to the Norwegian ferry operator Norled. The ferry is 82.4 meters long with a capacity of up to 300 passengers and 80 cars. The ferry is equipped with fuel cells and with an 80 m3 tank for liquid hydrogen storage.

Electricity (batteries) – TRL 12

- Electricity has seen a big increase in use over the last decade and can be considered a proven technology.
- The main limitations is range and provision of shoreside charging infrastructure.
- In Norway, there are several road ferries operating on batteries, where E/S Ampere is considered a pioneer vessel. It has been in operation since 2014.

Investment costs

	Reference Diesel		HVO		Methanol		Ethanol		LBG/CBG		Ammonia		Hydrogen		Electricity (batteries)	
Investment costs (ship)	0	Reference	0	Same as conventional propulsion, no modifications required	+	Increased investment costs due to additional systems and requirements for low flashpoint fuels	+	Increased investment costs due to additional systems and requirements for low flashpoint fuels	+	Increased investment costs due to additional systems and requirements for low flashpoint fuels and cryogenic storage (probably higher than those for alcohol fuel).	++	High investment cost due to high requirements on safety with regard to toxicity and technology development.	++	High investment costs due to additional systems and requirements for low flash point fuels and for suitable storage tanks either for compressed or liquified hydrogen.	+(+)	High investment costs for batteries.
Infrastructure	0	Reference	0	Infrastructure for diesel can be utilized	+	May require intermediate storage tank for bunkering or more frequent truck delivery	+	May require intermediate storage tank for bunkering or more frequent truck delivery	+	May require intermediate storage tank for bunkering or more frequent truck delivery	+	May require intermediate storage tank for bunkering or frequent truck delivery	++	May require intermediate storage tank for compressed hydrogen or liquified hydrogen and eventually liquification unit. Alternatively, it would require more frequent truck delivery.	0/+	Dependent on grid capacity, may require extension of grid which may be associated with high costs. Additional costs if fast charging is required.

Fuel cost

	Reference Diesel		HVO		Methanol		Ethanol		LBG/CBG		Ammonia		Hydrogen		Electricity (batteries)	
Current Fuel price [SEK / kWh]	0.479/ 0.400	Diesel Mk 1/ Eldningsolja E10 From bunker supplier	1.30	Based on actual cost for Färjerederiet	1.430	Price estimate from producer of biomethanol (Södra), incl. transport	1.461	Price estimate from producer, incl. transport	0.641	Based on information from bunker supplier, incl. transport.	*(1.273)*	*Production cost for green ammonia*	2.7	Price at filling station for vehicles	About 1.0	Based on current electricity price in Sweden.

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Fuel cost adjusted for energy efficiency

	Diesel MK1 (ref)	Hydrogen	Methanol	LBG/LCG	Electricity from grid
Efficiency range (ICE - Medium speed engine)	37%-44%	28%-44%	39%-46%	37%-49%	-
Efficiency range (Excluding ICE)	-	34%-59%	-	-	86%-95%
Relative fuel consumption [9]	0 (reference)	-25% to +32%	-5% to -4%	-10% to 0%	-57% to -54%
Fuel cost [SEK/kWh] (see Table 2.4)	0.479	2.7	1.43	0.641	1.00
Energy cost adjusted for technology efficiency [SEK/kWh] [10]	0.479	1.32 – 3.57	1.36 – 1.37	0.58-0.64	0.43-0.46

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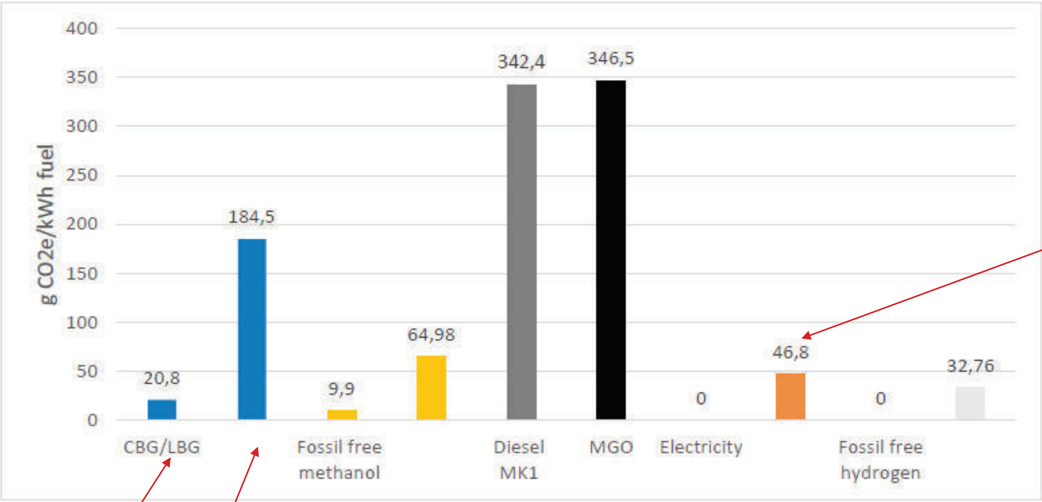
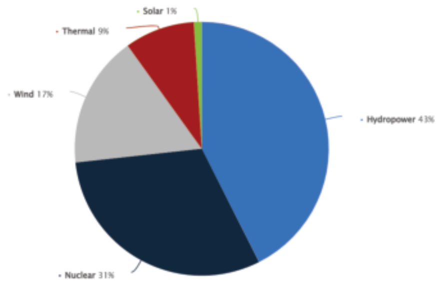
GHG emissions for ”green” fuels (WTW)



Low High

LNG: could be higher than diesel/MGO for dual fuel medium speed due to methane slip

Swedish electricity mix:



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Local example: Swedish Transport Administration (STA)

- STA is responsible for the overall long-term infrastructure planning of road, rail, sea and air transport.
- Our assignment also includes the construction, operation and maintenance of state roads and railways.
- The Swedish Transport Administration (STA) operates 68 road ferries on 40 routes throughout Sweden, one million calls are made annually

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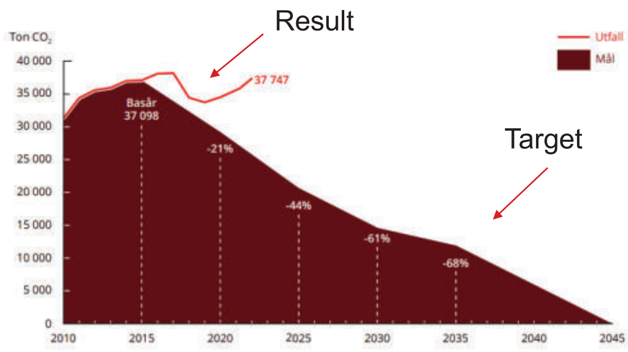
Net zero emissions by 2045

- STA must achieve a climate-neutral ferry operation by 2045 at the latest. In line with the Swedish national target of “net zero emissions” by 2045.
- In 2022 the emissions rose due to changing back from HVO to fossil diesel – too expensive



CO_2-utsläpp Färjerederiet. Utsläppen ökade under 2022 beroende på att färjornas motorer har gått på diesel istället för förnyelsebar diesel. Skälet till detta var det rådande marknadsläget med minskad tillgång på HVO och höjda priser.

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Electrification the main way forward

- In 2022, contracts were signed for four new electric ferries for delivery in the years 2024-2027
- This is the beginning of an extensive new construction program that includes a total of 20 electric ferries over the next 20 yeas.
- Also conversion of 30 of our 70 existing ferries for electric operation.
- Another 15 of our existing ferries are adapted for environmental operation (where the choice of fuel is not decided today).
- However, we have chosen to do not unilaterally rely on electricity but retain the possibility of running the ferries on renewable energy fuel as back-up for example power failure.
- Energy storage on land is an option (charged during the ferry is at sea and which provides sufficient power for charging)

Conclusions – short sea shipping

- Several available options for short sea shipping today
- But the system perspective is important:
  - the technology has to be available
  - the fuels have to be available and distributed to the ferries
  - the costs need to be ”acceptable”
- Electricity seems to be a competitive option – at least in some applications!

Thank you!