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SUMMETH

Sustainable Marine Methanol

Environmental Performance and Provision of Sustainable Methanol for the Smaller Vessel Fleet

Final Seminar
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PROJECT PARTNERS

TRAFIKVERKET SWEDISH TRANSPORT ADMINISTRATION · LUND UNIVERSITY · MARINE BENCHMARK · SCANIA · VTT · Swedish Maritime Technology Forum · SSPA Your Maritime Solution Partner · ScandiNAOS AB

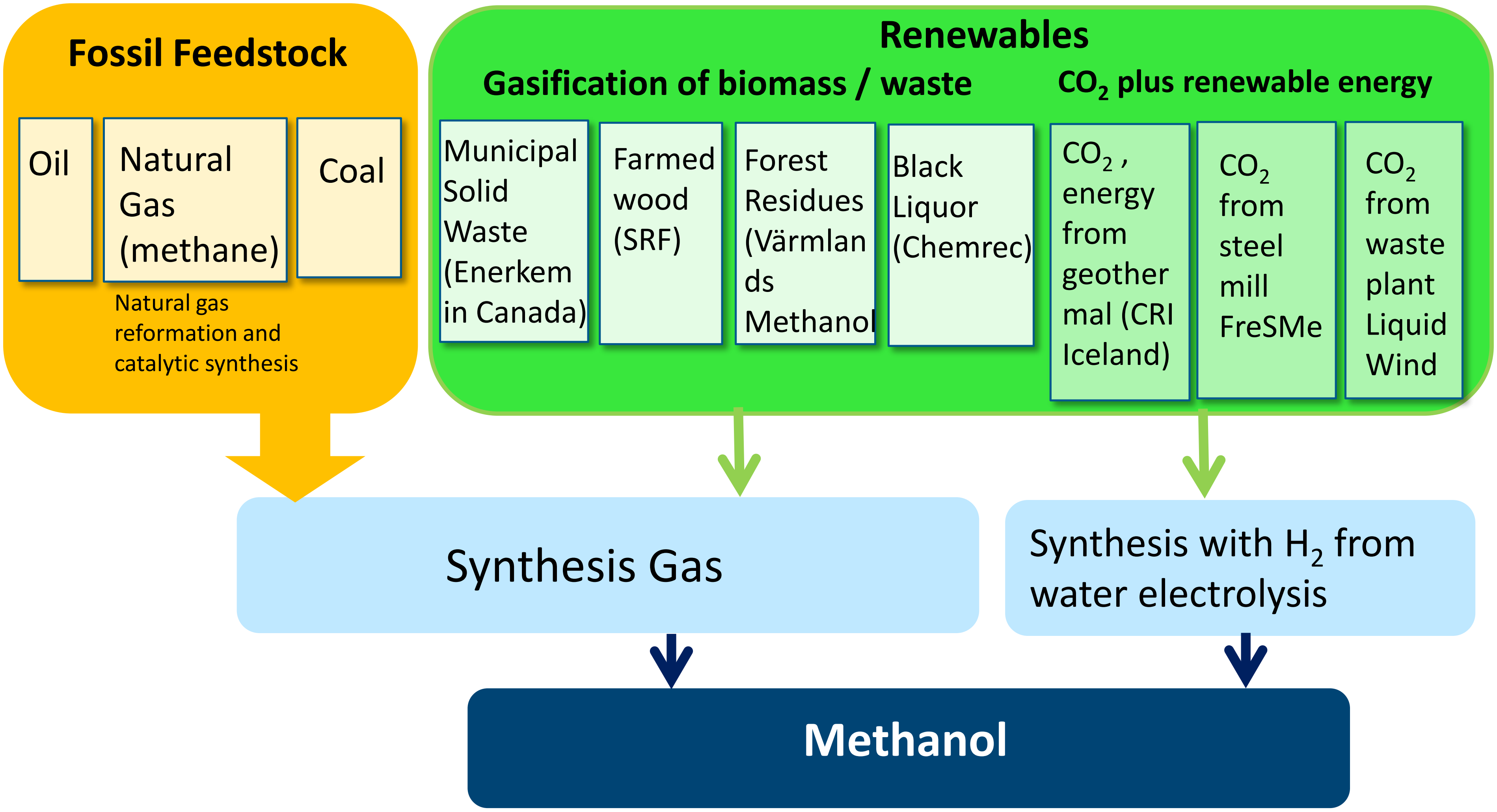
Outline

- Environmental performance
  - Fuel life cycle assessment and comparison
  - Data sources and analysis
  - Results
- Methanol supply chain
  - Production
  - Transport
  - Bunkering
  - Fuel costs

Why is methanol interesting as a fuel from an environmental perspective?

- No sulphur, so is an option for meeting SECA requirements
- Low emissions of particulates and nitrogen oxide, even without exhaust gas after-treatment
- In the event of a spill to water it dissolves, is biodegradable and does not bio-accumulate (GESAMP)
- Can be produced from many renewable feedstocks, including biomass and CO_2 – this can result in significant GHG reductions for fuel use

Methanol fuel feedstock and production – overview



Production locations for methanol

Image: MethaShip project as shown in Ellis, J. and K. Tanneberger. 2015. Study on the use of ethyl and methyl alcohol as alternative fuels in shipping. Report prepared for the European Maritime Safety Agency (EMSA).

Fuel Life Cycle Assessment Main Steps

Extraction, cultivation, capture, etc. of primary energy

→

Fuel Production

Ex.: refining (fuel oils), biomass gasification, electrolysis to produce H_2 and CO_2 capture

→

Transport, storage, and distribution of fuel to the ship's tanks
May include several steps (e.g. may be transported to large hub with further feeder transport)

→

Fuel Use

Emissions from fuel combustion on board

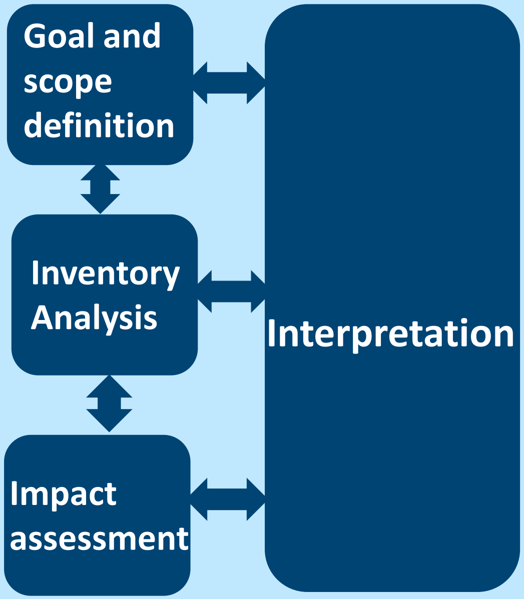
← Well to Tank Chain →

Tank to propeller or ”tank to wake”

Life cycle approach for marine fuel assessment for SUMMETH

- Focus on North West Europe fleet of smaller vessels, case study ferry
- Well-to-tank fuel data adapted from:
  - Fuels in the Baltic Sea (Brynolf, 2014)
  - JEC Well to Tank Study
  - Literature sources

  Adaptation of transport and distribution to reflect supply to smaller vessels
- Tank to wake (combustion) from SUMMETH WP3 and GreenPilot for methanol concepts. Comparison for MGO from published emission factors for marine engines; for road ferry case from measurement data



Main components of an LCA study [ISO 14040] 1997

Impact categories

- Inventory categories for the fuel life cycle comparison:
  - Greenhouse gases (GHGs) (CO_2, N_2O, CH_4)
  - SOx
  - NOx
  - Particulates

Corresponding to impacts:

- climate change
- eutrophication
- acidification
- health effects

Particulate emission impacts

The European Environment Agency 2016 air quality report states that health impact estimates from air pollution attribute PM 2.5 to 467 000 premature deaths in Europe from long term exposure

TRANSPORT & ENVIRONMENT

How do SO2, NOx and particle emissions pose a threat to human health?

Air pollution from international shipping accounts approximately for 50,000 premature deaths per year in Europe, at an annual cost to society of more than €58 billion according tc recent scientific studies. Through chemical reactions in the air, SO2 and NOx is converted into fine particles, sulphate and nitrate aerosols. In addition to the particles directly emittec

Geophysical Research Letters

RESEARCH LETTER

10.1002/2017GL074982

Key Points:
- Lightning is enhanced by about a factor of 2 directly over two of the busiest shipping lanes in the Indian Ocean and South China Sea
- Environmental factors such as convergence, sea surface temperature, or atmospheric stability do not explain the enhancement
- We hypothesize that ship exhaust particles change storm cloud microphysics, causing enhanced condensate in the mixed-phase region and lightning

Lightning enhancement over major oceanic shipping lanes

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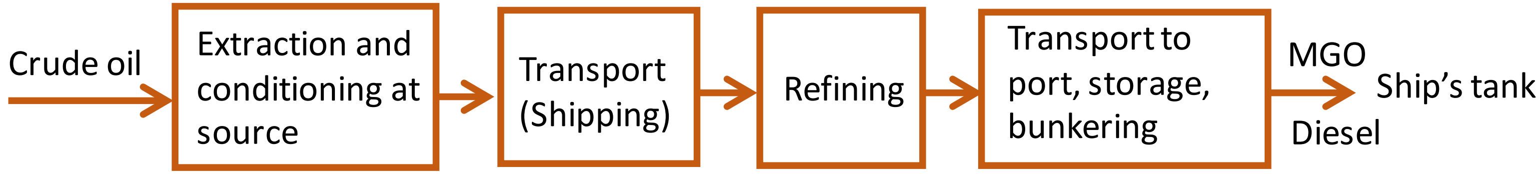
Abstract Using 12 years of high-resolution global lightning stroke data from t Location Network (WWLLN), we show that lightning density is enhanced by up to over shipping lanes in the northeastern Indian Ocean and the South China Sea as co with similar climatological characteristics. The lightning enhancement is most pro convectively active season, November–April for the Indian Ocean and April–Decer

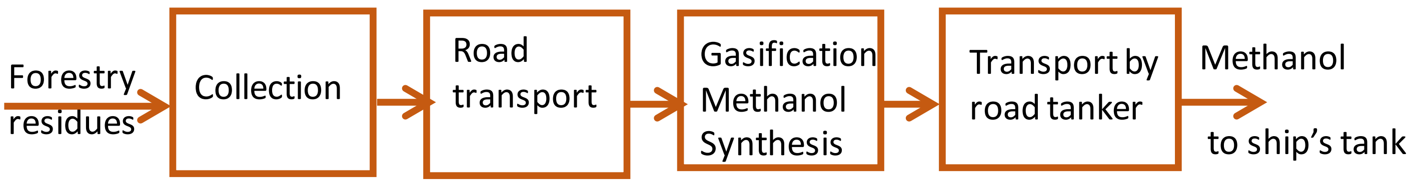
Pathways considered for fuel production - WTT

MGO, Diesel

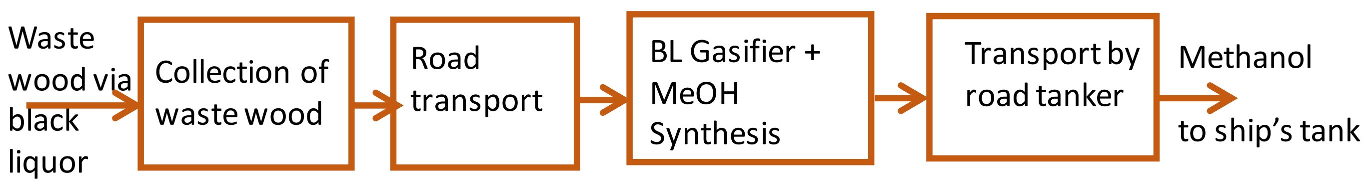


Methanol from natural gas

Methanol from forestry residuals



Methanol from black liquor gasification



Pathways adapted from "Well-to-tank Report Version 4.0", JEC Well to Wheels Analysis" of Future Automotive Fuels and Powertrains in the Automotive Context", 2013, Report EUR 26028

Comparison of emissions per MJ fuel produced (WTT)

Fuels	CO_2 g/MJ	CH_4 g/MJ	N_2O g/MJ	GHGs g CO_2e/MJ	NOx g/MJ	SOx g/MJ	PM10 g/MJ
MGO, 0.1% S	7,1	0,078	0,00017	9,3	0,023	0,041	0,00110
Methanol from natural gas	20,5	0,011	0,00031	20,9	0,051	0,003	0,00063
Methanol, from forest residues	17,0	0,043	0,00021	18,3	0,047	0,046	0,01080
Methanol black liquor	3,1	0,011	0,00835	5,7	-	-	-
*Methanol, from biogenic CO_2, wind energy**	*7,4*	*0,012*	*0,01420*	*11,5*	*0,029*	*0,017*	*0,00239*

* Estimate based on production of methanol from renewable hydrogen and carbon dioxide as described in Matzen and Demeril (2016).

GHG reductions of other methanol production pathways

- Carbon Recycling International – Iceland: certified by the International Sustainability and Carbon Certification system (ISCC) as an ultra-low carbon advanced renewable transport fuel. Stated that the methanol has 75% lower GHG emissions than standard fuel.

- Enerkem: municipal waste to methanol to ethanol. Received lowest ever carbon intensity value issued by the British Columbia government under the renewable and low carbon fuel regulation.

BRITISH COLUMBIA	**Ministry of Energy, Mines and Petroleum Resources** *Issued: July 2013* *Revised: October 2017*	Renewable and Low Carbon Fuel Requirements Regulation **Approved Carbon Intensities** **Information Bulletin RLCF-012**

Previous Fuel Code	Fuel Code	Fuel	Company	Carbon Intensity (gCO_2e/MJ)	Effective Date	Expiry Date
BCLCF224	BCLCF224.0	Ethanol	Pound-Maker Agventures	32.34	Oct. 15, 2015	Oct. 14, 2018
-	BCLCF225.0	Ethanol	Husky Energy	41.87	Jan. 1, 2015	Dec. 31, 2017
-	BCLCF226.0	Ethanol	Husky Energy	10.15	Jan. 1, 2015	Dec. 31, 2017
-	BCLCF227.0	Ethanol	Husky Energy	46.35	Jan. 1, 2015	Dec. 31, 2017
-	BCLCF228.0	Ethanol	Husky Energy	14.63	Jan. 1, 2015	Dec. 31, 2017
-	BCLCF229.0	Ethanol	Husky Energy	71.18	Jan. 1, 2015	Dec. 31, 2017
-	BCLCF230.0	Ethanol	Husky Energy	39.46	Jan. 1, 2015	Dec. 31, 2017
-	BCLCF231.0	Ethanol	Husky Energy	61.63	Jan. 1, 2015	Dec. 31, 2017
-	BCLCF232.0	Ethanol	Husky Energy	29.91	Jan. 1, 2015	Dec. 31, 2017
-	BCLCF233.0	Ethanol	Husky Energy	44.50	Jan. 1, 2016	Dec. 31, 2018
-	BCLCF234.0	Ethanol	Husky Energy	45.56	Jan. 1, 2016	Dec. 31, 2018
-	BCLCF235.0	Ethanol	Husky Energy	60.34	Jan. 1, 2016	Dec. 31, 2018
-	BCLCF236.0	Biodiesel	Cargill Inc.	-3.64	Apr. 1, 2016	Mar. 31, 2019
-	BCLCF237.0	Ethanol	Green Plains Wood River LLC	54.66	May 16, 2016	May 15, 2019
-	BCLCF238.0	Ethanol	Green Plains Fairmont LLC	61.73	May 16, 2016	May 15, 2019
-	BCLCF239.0	Ethanol	Redfield Energy LLC	49.72	July 22, 2016	July 21, 2019
-	BCLCF240.0	Ethanol	Aberdeen Energy LLC	54.55	July 29, 2016	July 28, 2019
-	BCLCF241.0	HDRD	Neste Oil Singapore	26.93	Sept. 7, 2016	Sept. 6, 2019
-	BCLCF242.0	Ethanol	Permolex Ltd.	33.54	Sept. 3, 2016	Sept. 2, 2019
-	BCLCF243.0	Ethanol	Permolex Ltd.	40.11	Sept. 3, 2016	Sept. 2, 2019
-	BCLCF244.0	Ethanol	Enerkem Alberta Biofuels LP	-54.80	Dec. 7, 2016	Dec. 6, 2017
-	BCLCF245.0	LNG	FortisBC Energy Inc.	63.04	Jan. 1, 2017	Dec. 31, 2019
-	BCLCF246.0	Ethanol	Mid America Agri Products/Wheatland LLC	46.87	Mar. 7, 2017	Mar. 6, 2020

11 of 12 | Approved Carbon Intensities — Revised: October 2017

Comparison of emissions per MJ fuel combusted

Fuel and Engine Concept	CO_2 g/MJ	CH_4 g/MJ	N_2O g/MJ	GHGs g CO_2e/MJ	NOx g/MJ	SOx g/MJ	PM10* g/MJ
MGO, 0.1% S, High Speed Diesel[1]	74,5	0,00046	0,004	75,4	1,371	0,047	0,011
MK 1 (Diesel), with particle filter, measurements on Göta (Scania)[2]	71,5			71,5	0,781	0,000046	0,00048
MK 1 (Diesel), no particle filter, measurements on Göta (Scania)[2]	72,3			72,3	0,820	0,000046	0,00947
MK 1 (Diesel), with particle filter, lab measurements (by EMTEC, Penta engine)[3]	74,3			74,3	0,635		0,00056
MK 1 (Diesel), no particle filter, lab measuremenets (Penta engine)[3]	74,2			74,2	0,639		0,0054
Methanol, spark ignited, port fuel injection, no particle filter, 64% MCR[4]	70,0			70,0	0,285		1,9E-06
Methanol, PPC, with 3 way catalyst, lab measurements (Lund)[5]	*69,1*			*69,1*	*0,039*		*5,2E-07*
Methanol, DI-SI, lab measurements (Lund)[6]	*69,1*			*69,1*	*0,012*		*< 0,0001*

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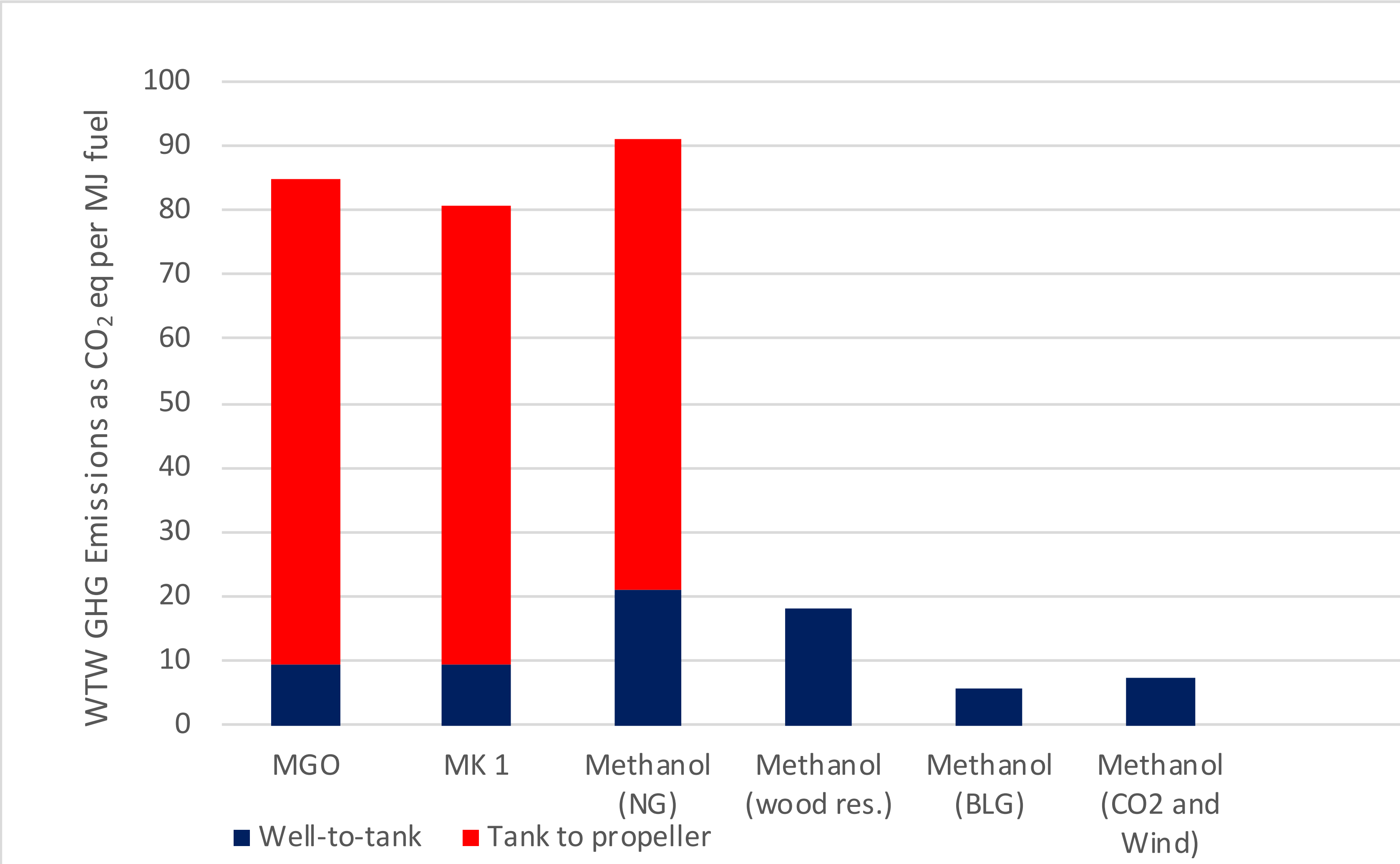
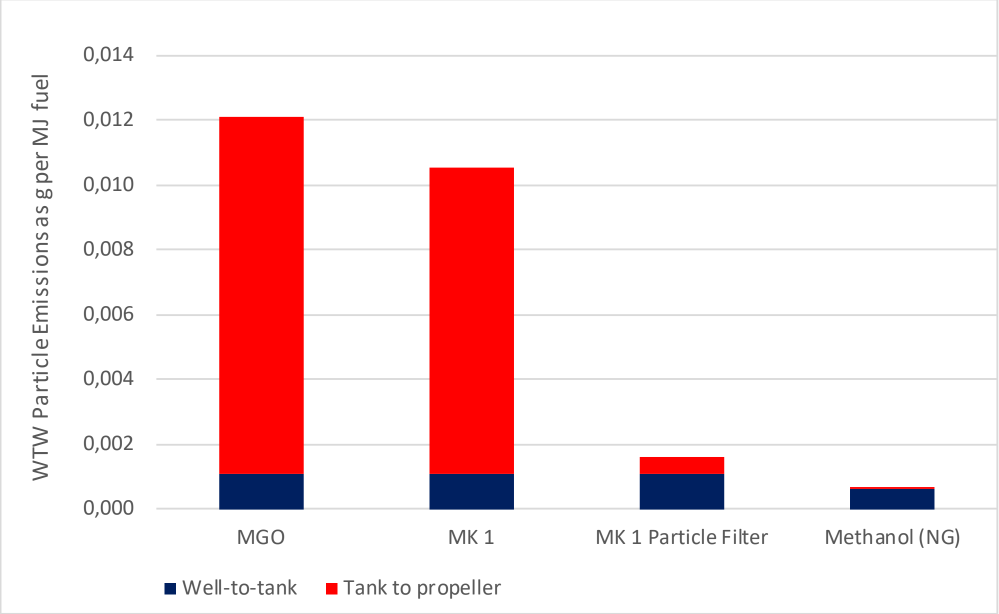
from Cooper and Gustafsson (2004) and Brynolf (2014); [2] Winnes and Peterson, 2012; [3] STT mtec Presentation; [4] Molander, 2017; [5] scaled from Shamun et al. 2016; [6] Björnestrand, 2017. For the methanol spark ignited port fuel injection total particulate matter was measured.

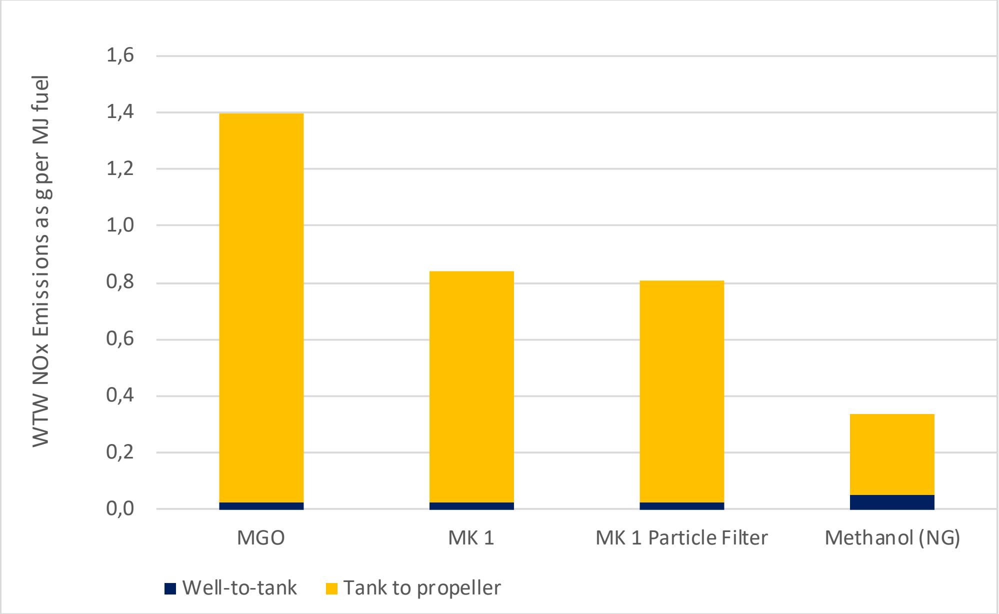
Comparison of emissions per MJ fuel Well to Propeller



Particulate and NOx Emissions

- Significant PM reductions with methanol (no particle filter needed)
- NOx – majority of emissions occur during the ”tank to propeller” phase; methanol combustion results in significantly lower NOx emissions





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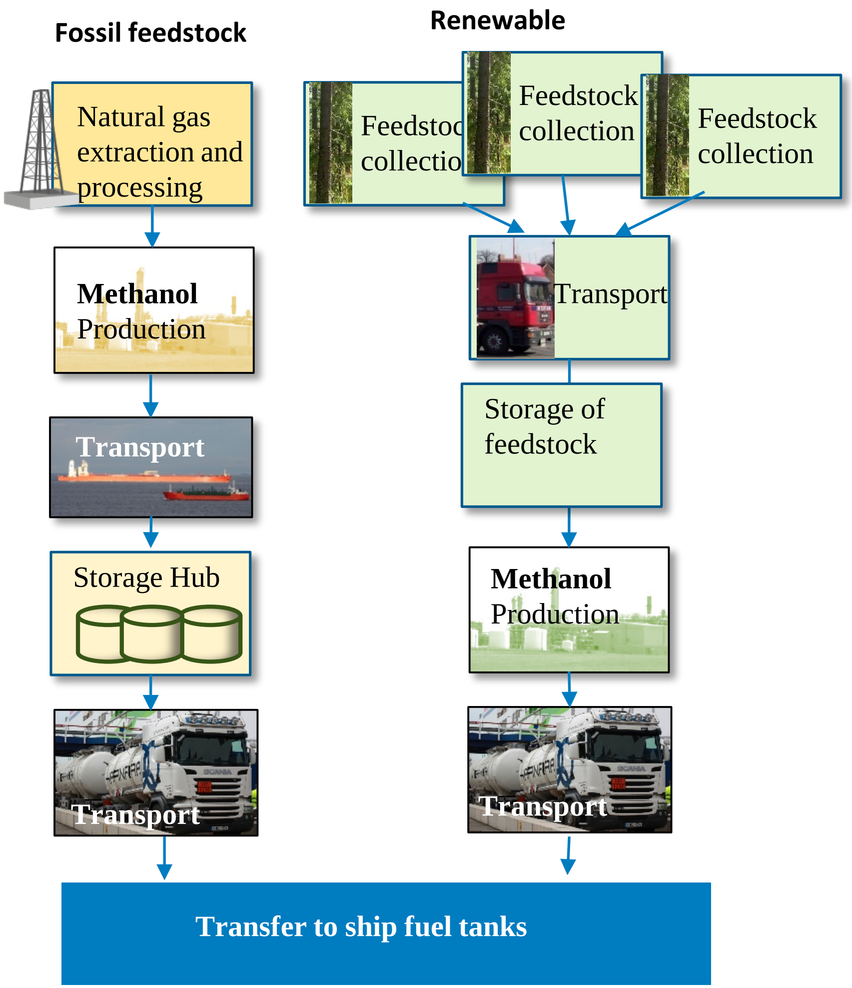
Methanol supply and distribution to the smaller vessel segment

- Supply chain approach to compare fuels from different feedstocks and assess feasibility
- Some considerations for renewable feedstocks
  - Economies of scale of production vs diseconomies of scale of acquiring larger volumes due to longer distances
  - Feedstock storage required due to seasonal issues – size optimisation
  - Optimising location and size of production facility to minimise feedstock and product transport costs
  - Integration: using both feedstock (the by-products) and residual heat from the processes



Methanol Supply

Methanol (from fossil feedstock) imported by ship to depots in Malmö and Södertälje

Renewable methanol:

Methanol from electricity and CO_2:

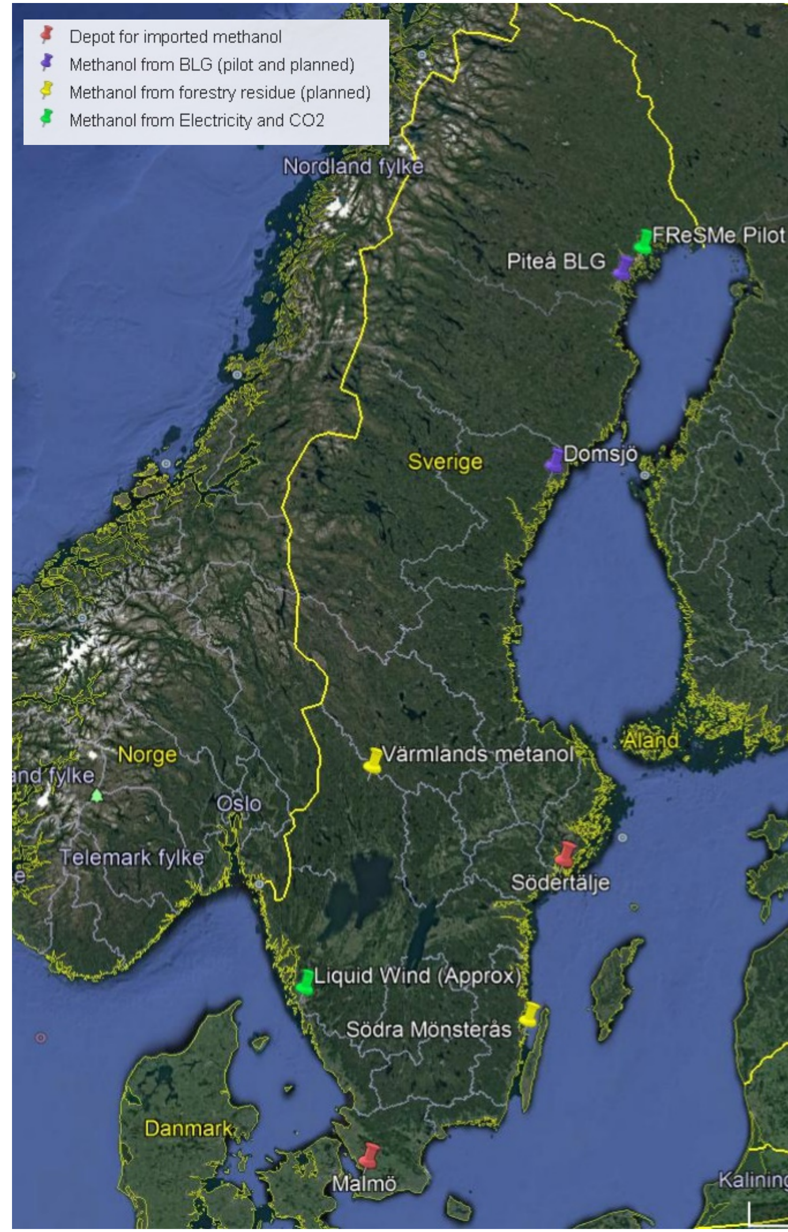
- FReSMe – pilot plant, H2020 Project underway
- Liquid Wind: Feasibility study completed May 2017, work is continuing

Methanol from Forestry Residue:

- Värmlands Methanol: designed 2012; on hold due to uncertainty re biofuels tax
- Södra Mönsterås: started 2017, est. completion 2019, production 5000 tonnes annually

Methanol from black liquor gasification:

- Piteå (Chemrec) – pilot plant operated more than 25,000 hours
- Domsjö (Chemrec): industrial scale, extensive planning, not built



Potential for methanol production from biomass in Sweden

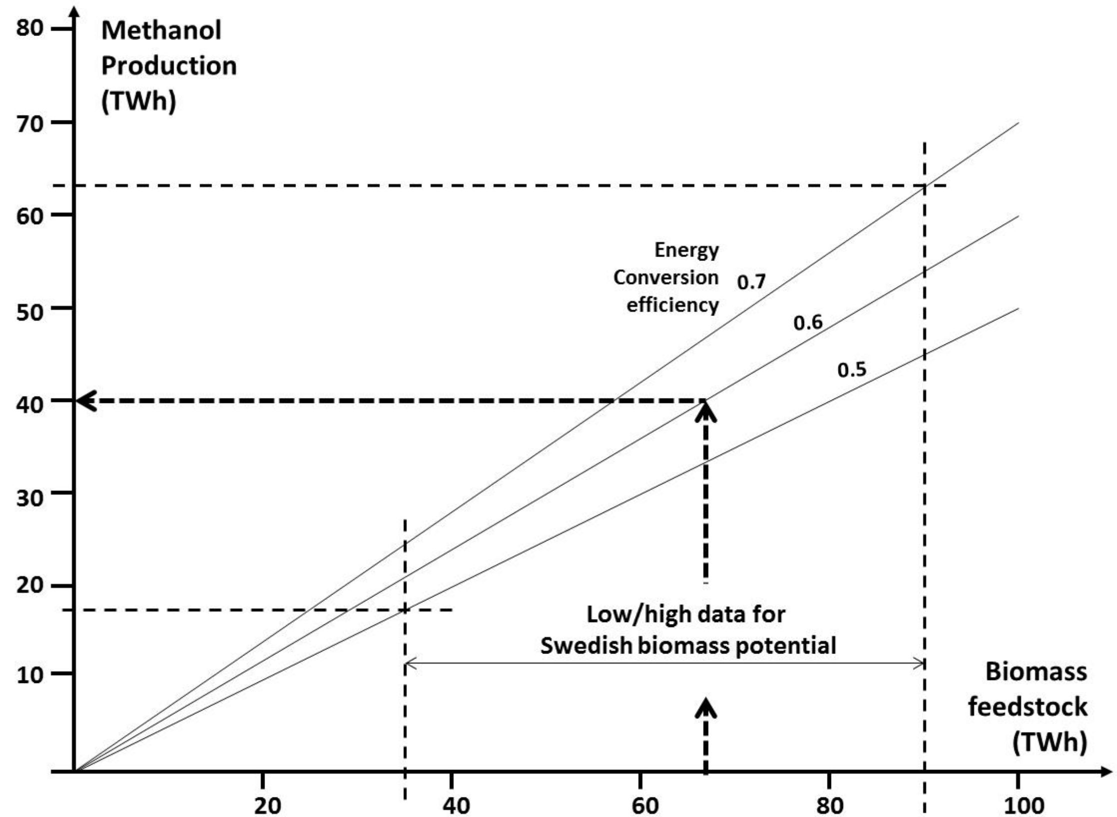
40 TWh of methanol = 7.2 million tonnes

Marine Fuel Use – annual (examples)

North West Europe, vessels with ME 250 kW – 1200 kW: 525 000 t

Swedish Icebreaker Atle: 990 t

Jupiter Road Ferry: Est. 700 t



Methanol production as a function of biomass potential for different conversion efficiencies

Source: Landälv, I. 2017. Methanol as a renewable fuel – a knowledge synthesis. Report No. f3 2015:08. The Swedish Knowledge Centre for Renewable Transportation Fuels (f3)

Potential for methanol production from black liquor gasification in Sweden

Approx. 12 TWh of methanol = 2.2 million tonnes methanol

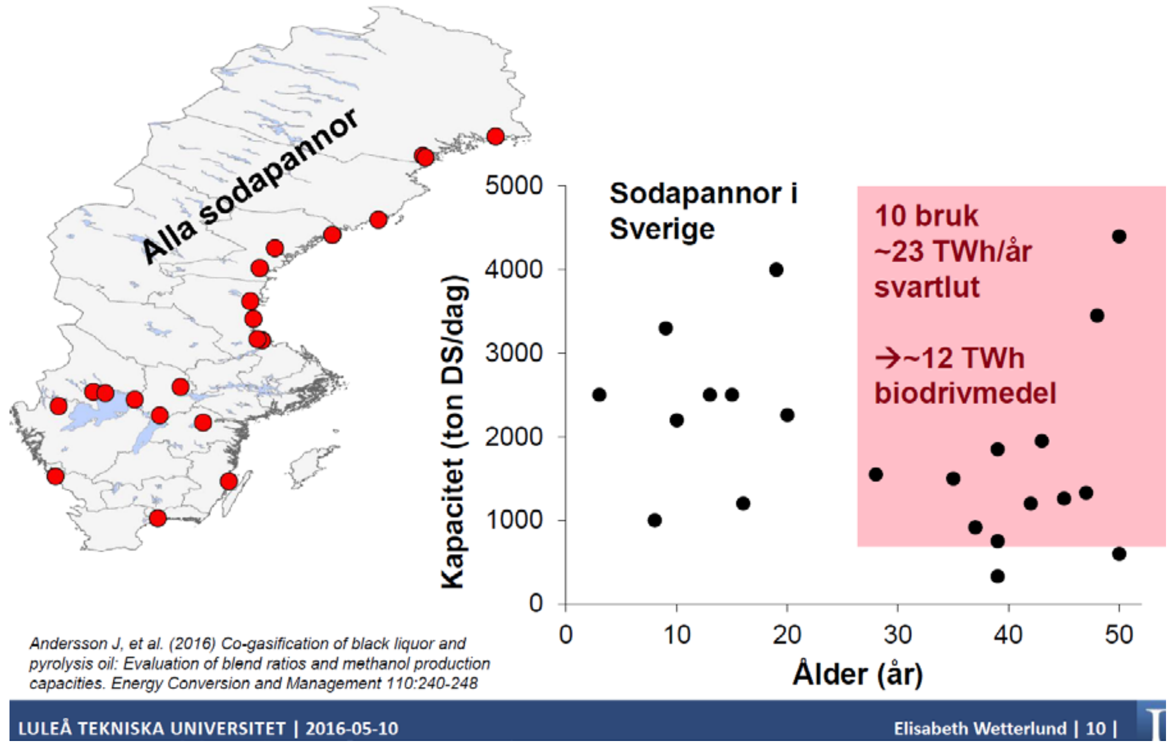
Marine Fuel Use – annual (examples)

North West Europe, vessels with ME 250 kW – 1200 kW: 525 000 t

Swedish Icebreaker Atle: 990 t

Jupiter Road Ferry: Est. 700 t

Swedish Road Ferries (all) 10 295 t



Recovery boilers at Swedish kraft pulp mills by age and capacity
Source: Andersson, J. et al. 2016. Co-gasification of black liquor and pryolysis oil: Evaluation of belnd ratios andmethanol production capacities. Energy Conversion and Management 110:240- 248.

Transport

- Methanol is regularly transported by road and rail
- Class 3 flammable liquid according to the UN dangerous goods classification (same category as many other liquid fuels)
- Transport by road according to ADR-S regulations; by rail according to RID

Bunkering

For conventional fuels:

- Ship to ship
  - only available on the West coast of Sweden and for larger vessels
- Truck to ship
  - Almost all bunkering on Sweden's east coast is truck to ship
  - Swedish road ferries, commuter ferries bunker this way
- Land to ship
  - the Swedish Icebreaker fleet bunkers from tank storage in Piteå (Preem)

For smaller recreational vessels, and some small commercial vessels, fuel (gasoline and diesel) can also be obtained from fuel pumps at harbours and marinas (similar to fuel stations for cars).

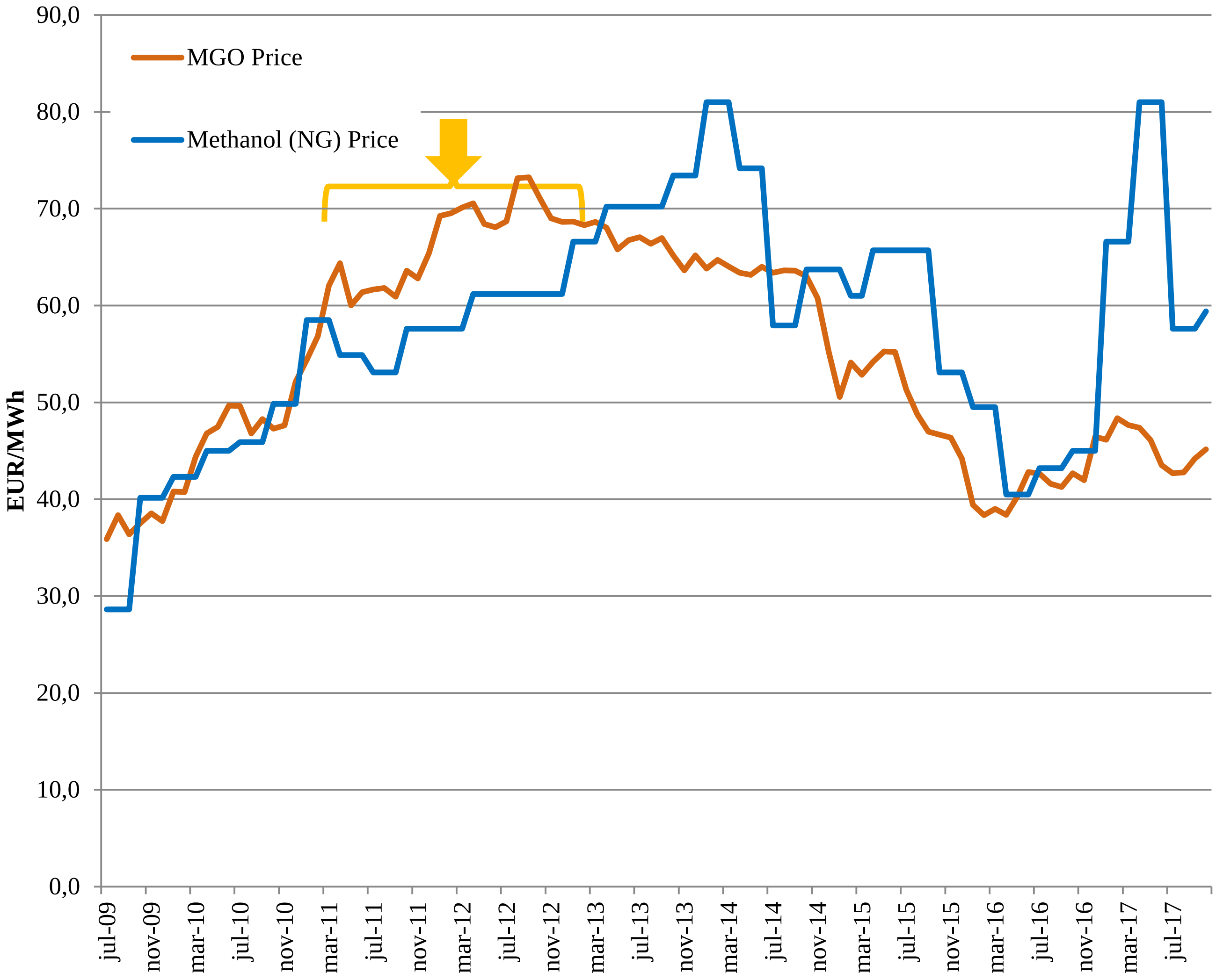
Bunkering

For methanol:

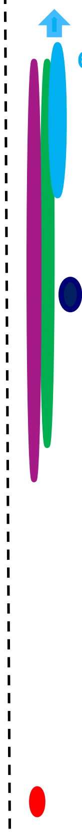
- SPIRETH project bunkered from a truck on deck
- Stena Germanica bunkers from tanker trucks via a pump station on shore

Most smaller vessels as investigated in the SUMMETH project already bunker by truck, thus infrastructure is not a problem.

Fuel Prices / Production Costs



Estimated production costs



e- methanol: 80 - 140

Methanol from wood: 56 -91

HVO: 50 – 90

Methanol from BLG: 69

Methanol from municipal waste (Italian case): 20

Data sources: Bunker Index for MGO, Methanex for Methanol NG (European contract price); Landälv (2017) methanol BLG; Landälv and Waldheim (2017) HVO and methanol from wood; Ianquaniello et al. (2017) for methanol from municipal waste; Taljegård et al. 2015 for e-methanol

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Sustainable Methanol for Smaller Vessels: Summary

Opportunities:

- Significant reduction of GHGs with renewable feedstock
- Large reductions in PM reductions
- Many local feedstocks and production opportunities
- Distribution system essentially in place, no challenges technically

Barriers:

- Economic: Cost for fuel – mechanisms for encouraging the use of renewables

Thank you!