SUMMETH

SUMMETH – Sustainable Marine Methanol

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Final Report – Summary of the SUMMETH Project Activities and Results

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ABSTRACT

This report provides a summary of the work carried out in the SUMMETH project. A summary of the following SUMMETH technical reports is included:

- market study using automatic identification data to identify number of vessels in the north west Europe area with engines in the 250 to 1200 kW hours, and their fuel usage
- engine technology study including the experimental investigation of several different methanol engine concepts to evaluate performance and emissions for the 250 to 1200 kW engine size range
- conversion design of the case study road ferry and the associated hazard identification study
- report on general recommendations for converting selected categories of smaller vessels to methanol operation
- assessment of environmental, economic, safety, and supply and distribution considerations regarding the use of methanol as a sustainable fuel for smaller vessels.

Project management and dissemination activities carried out over the project duration are also described.

SUMMETH PROJECT SUMMARY

SUMMETH, the **Su**stainable **M**arine **Meth**anol project, is focussed on developing clean methanol engine and fuel solutions for smaller ships. The project is advancing the development of methanol engines, fuel system installations, and distribution systems to facilitate the uptake of sustainable methanol as a fuel for coastal and inland waterway vessels through:

- developing, testing and evaluating different methanol combustion concepts for the smaller engine segment
- identifying the total greenhouse gas and emissions reduction potential of sustainable methanol through market investigations
- producing a case design for converting a road ferry to methanol operation
- assessing the requirements for transport and distribution of sustainable methanol.

The SUMMETH project consortium consists of SSPA Sweden, ScandiNAOS, Lund University, VTT Technical Research Centre of Finland, Scania AB, Marine Benchmark, Swedish Transport Administration Road Ferries, and the Swedish Maritime Technology Forum.

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EXECUTIVE SUMMARY

The Sustainable Marine Methanol (SUMMETH) project was carried out to investigate and develop methanol engine and fuel solutions for smaller ships and to assess the environmental benefits and feasibility of transporting and supplying sustainable methanol as ship fuel.

Methanol engine concepts tested experimentally within SUMMETH included port-fuel injected spark-ignited engines (PFI-SI), methanol-diesel compression ignition of methanol fuel with additive (MD95), partially premixed combustion (PPC), and direct injected spark ignition engine (DI-SI). For the 250 to 1200 kW engine range considered, methanol was found to have a distinct advantage over conventional fuels with regards to emissions, and performance of the different concepts was also found to be good. The conventional PFI-SI engine for lean operation used with an oxidizing catalyst was considered to be the most dependable, clean and affordable methanol concept that could be implemented in the short term. The MD95 (methanol with additive) is another option that likely can be implemented within a short time. For long term implementation a mode-shifting PPC/DI-SI engine with oxidizing catalyst can possibly offer the lowest operating costs and largest reduction of emissions and GHG.

The environmental performance investigation using emissions measurements from the experimental studies showed that methanol fuels resulted in significantly lower particulate emissions and reduced NO_x emissions for the concepts tested. A fuel life cycle comparison with conventional diesel fuels used for smaller vessels showed that the use of renewable methanol from feedstock such as wood residuals and pulp mill black liquor can result in greenhouse gas emissions reductions of 75 to 90%.

A market analysis of smaller vessels within the North West Europe area found that on an annual basis approximately 262,478 tonnes of fuel oil, equivalent to 564,285 tonnes of methanol on an energy basis, is used for main engine propulsion in a fleet of 6167 vessels with propulsion engines with power in the range 250 kW to 1200 kW. The dominant vessel types in terms of fuel use were found to be cargo, fishing, passenger, tanker, and pilot boats.

A design for conversion of an existing Swedish road ferry to methanol operation was developed, demonstrating the feasibility of the concept and that monitoring, serviceability, and safety can meet existing requirements. An overview of other smaller vessel types showed the possibilities for different solutions and system design requirements.

An investigation into marine fuel supply in Sweden found that smaller vessels are typically bunkered by tanker truck, and thus there are no barriers anticipated if methanol is used instead of conventional fuel. Methanol is routinely transported by tanker truck to customers. Within Sweden production of renewable methanol from wood biomass, including gasification of wood residual and gasification of pulp mill black liquor, has been investigated and tested in pilot plants, and the technology is considered mature enough to start larger scale production. Production of methanol from CO_2 is also being tested and planned in Sweden. The only barriers appear to be uncertainty about a market for the fuel, as production cost estimates are currently higher than conventional fuel.

The SUMMETH project shows that methanol can be used efficiently as a fuel in marine diesel engines for smaller vessels. There are significant environmental benefits to be realized from using methanol as fuel, including significantly lower emissions of particulates during combustion, and large reductions in GHG emissions if sustainable methanol is used.

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1 INTRODUCTION

SUMMETH, the **Su**stainable **M**arine **Meth**anol project, was initiated to advance the development of methanol engines and fuel solutions for smaller marine vessels. Previous work, including laboratory studies, testing in heavy duty trucks, and the conversion of the *Stena Germanica* RoPax ferry, have shown the emissions benefits that can be achieved by using clean-burning methanol in a diesel engine. The lack of commercial high speed marine engines for methanol showed the need for more development work to test and optimize combustion concepts for marine diesel applications to allow the smaller vessel segment to benefit from the use of methanol.

Smaller vessels typically spend a large portion of their operating hours close to populated areas, and thus have a greater potential to have an impact on air quality in these areas. A transition to a cleaner fuel such as methanol will lower the impact of shipping on air quality, as waterborne transport is currently a significant contributor to SO_x, NO_x, and particulate emissions. Further, the use of renewable methanol, produced from biomass residuals or CO_2, can result in significantly reduced greenhouse gas emissions compared to fossil fuels. Dependencies on fossil fuel imports can also be reduced.

The Sustainable Marine Methanol (SUMMETH) project had the overall objective of advancing the technological development and providing recommendations for introduction of methanol as an alternative fuel for coastal and inland waterway vessels to reduce their emissions and carbon footprint. Specific aims of the project included:

- testing and evaluating different methanol combustion concepts to identify the best alternative with regards to short, medium and long term perspective for the smaller marine engine segment (about 250 kW to 1200 kW)
- estimating the number of vessels and fuel usage for this engine segment, in the north west Europe area
- identifying the environmental benefits and GHG reduction potential from using methanol as a marine fuel
- developing a case design for a ship conversion of an existing road ferry for diesel to methanol operation
- providing recommendations on conversion needs for smaller vessel types, based on results from the case design and results of the engine development and testing work
- assessing the potential for using sustainably produced methanol as a marine fuel, along with the requirements for transport and distribution to the smaller vessel segment.

The SUMMETH project focussed on the north west Europe area for the market study and Sweden for the case study and assessment of renewable methanol supply to smaller vessels.

Technical reports produced within SUMMETH and summarized in the following chapters are shown in Table 1.

Table 1 Technical Reports Produced for the SUMMETH Project

Report Number	Title	Lead Partner
D2.1	Market Study	Marine Benchmark
D3.1	Engine Technology, Research, and Development for Methanol in Internal Combustion Engines	LTH / VTT / ScandiNAOS
D4.1	General Arrangement Road Ferry Case Study Conversion Design	ScandiNAOS
D4.1b	Hazard Identification Study for the M/S Jupiter Case Study Methanol Conversion Design	SSPA
D4.2	Report on general recommendations for conversions of specific ship types	ScandiNAOS
D5.1	Expected benefits, strategies, and implementation of methanol as a marine fuel for the smaller vessel fleet	SSPA

2 MARKET STUDY

The market analysis work carried out within the SUMMETH project identified all vessels within the North West Europe market area, shown in Figure 1, with propulsion engines with power in the range 250 kW to 1200 kW. This range was divided into four categories for analysis as follows:

- 250 to 450 kW
- 450 to 600 kW
- 600 to 900 kW
- 900 to 1200 kW.

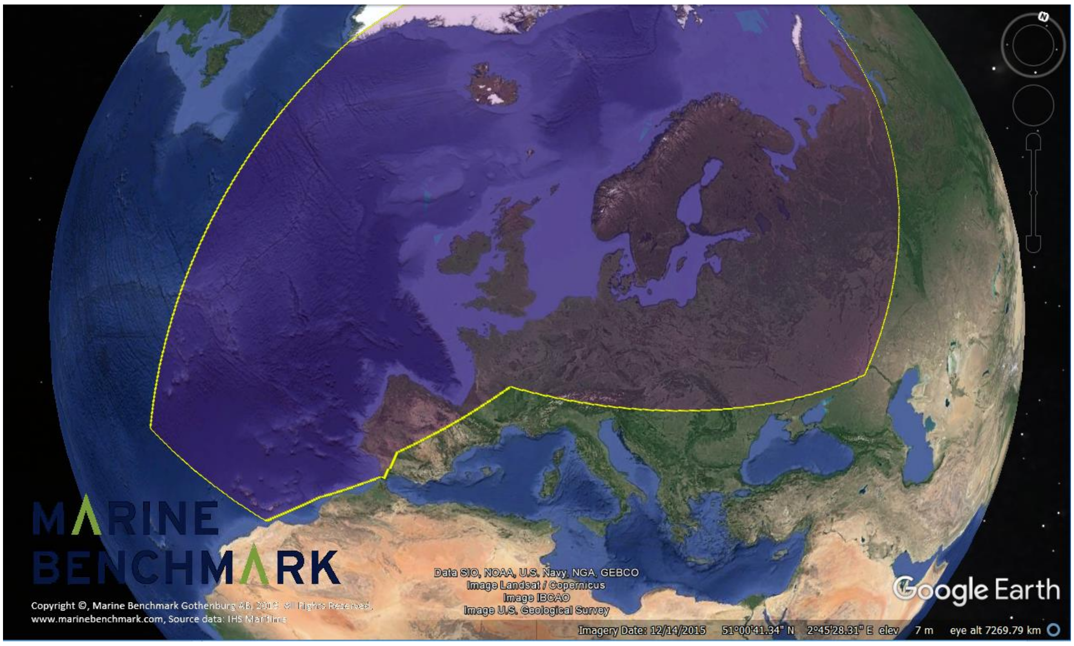

Figure 1 North west Europe area included in the market study

The ship operational profile (time at different speeds and kW load) for all identified vessels with propulsion engines in this range was captured from automatic identification system (AIS) data to enable a calculation of fuel use. The vessels with the highest fuel consumption per installed power were identified, as these would be cases with the best potential for investment in methanol engines if methanol prices were to revert to levels below MGO.

The market study used 2 billion AIS records sampled every 10 minutes globally for the time span of 6 months (1 Mar to 31 Aug 2016). The ID of in total 370 000 vessels was captured, and after the AIS data was sorted, 50 800 vessels were identified for further analysis. Out of these 50 800 vessels there were 14 200 vessels that had IMO number and engine data from the IMO register, and 36 600 vessels without engine data. The method to allocate engine size and service speed for these vessels was to use engine and speed data from the known 14 200 vessels divided into ship type / vessel dimension groups and make a model for engine size and service speed to populate the speed and engine size for the unknown 36 600 vessels.

A total of 10916 vessels with a main engine for propulsion in the size range 250 kW – 1200 kW were identified, and this group was further analysed to identify the vessels that had been moving more than 150 hours during the six-month period selected for the analysis. The resulting 6167 vessels are shown by vessel type and length in Table 2.

Table 2 Vessels with main engine in the 250 – 1200 kW range, moving more than 150 hours during the 6-month period 1 March to 31 August 2016.

	Vessel length groups									
SimpleShipType	no length	A_0 - 19 m	B_20 - 39 m	C_40 - 59 m	D_60 - 79 m	E_80 - 99 m	F_100 - 119 m	G_120 - 139 m	H_140 - 159 m	
	31	179	158	42	7	4	1			422
AntiPollution		2	1							3
Cargo	8	50	289	350	134	232	22		1	1,086
Diving		12	9	1						22
Dredger	2	17	18	23	14	6	1			81
Fishing	48	788	958	81						1,875
HSC	1	53	10							64
LawEnforcement		31	38	8						77
Military		6	9							15
NonCombat		1	1							2
OtherType	14	176	310	79	14	7	2	1		603
Pass	4	117	552	90	8	3		1		775
Pilot		123	24	3						150
Pleasure		132	48	4						184
PortTender	1	19	4	1						25
Rescue		49	5	2	1					57
Sailing		212	93	34	8	2	2			351
Tanker	1	8	59	61	29	51	34			243
Tug	3	72	46							121
WIG	1	2	6	1	1					11
	114	2,049	2,638	780	216	305	62	2	1	6,167

Fuel consumption for this group of vessels is shown in Table 3. A total of 131,229 tonnes of fuel oil was estimated to be consumed during a six month period in 2016 – on an annual basis the consumption would be 262,478 tonnes of fuel oil. If methanol was used for the entire fleet, the total annual fuel requirement would be 564,285 tonnes for main engine propulsion, as methanol has a lower energy density (with a lower heating value of 20 MJ/kg as compared to 43 MJ/kg for marine gasoil).

Table 3 Fuel consumption in tonnes during the 6-month period from 1 March to 31 August 2016, for vessels with main engines in the 250 – 1200 kW range moving more than 150 hours during the period

	Vessel length groups									
SimpleShipType	no length	A_0 - 19 m	B_20 - 39 m	C_40 - 59 m	D_60 - 79 m	E_80 - 99 m	F_100 - 119 m	G_120 - 139 m	H_140 - 159 m	
	349	1,332	2,129	978	193	523	30	0	0	5,534
AntiPollution	0	20	3	0	0	0	0	0	0	23
Cargo	248	735	3,846	8,660	11,131	32,641	2,739	0	30	60,030
Diving	0	122	103	22	0	0	0	0	0	247
Dredger	18	219	305	514	766	454	104	0	0	2,380
Fishing	604	6,782	12,746	1,429	0	0	0	0	0	21,561
HSC	13	908	199	0	0	0	0	0	0	1,120
LawEnforcement	0	396	506	144	0	0	0	0	0	1,046
Military	0	68	131	0	0	0	0	0	0	199
NonCombat	0	17	9	0	0	0	0	0	0	26
OtherType	168	1,806	4,138	1,322	370	354	27	21	0	8,207
Pass	67	1,156	8,134	1,576	146	163	0	51	0	11,293
Pilot	0	2,524	615	71	0	0	0	0	0	3,211
Pleasure	0	582	298	21	0	0	0	0	0	901
PortTender	5	315	86	23	0	0	0	0	0	430
Rescue	0	361	77	41	18	0	0	0	0	496
Sailing	0	1,208	806	477	121	39	145	0	0	2,795
Tanker	13	89	707	2,167	2,592	2,470	1,372	0	0	9,410
Tug	68	932	1,170	0	0	0	0	0	0	2,170
WIG	15	24	92	5	17	0	0	0	0	153
	1,568	19,594	36,100	17,451	15,353	36,643	4,417	73	30	131,229

The top ten types of vessels in terms of total fuel consumption are shown in Table 4 along with the number of vessels in each category. The top ten vessel types together consumed 88% of the total fuel used by vessels with main engines in the 250 – 1200 kW range. Cargo was the dominant vessel type for fuel consumption, while fishing vessels represented the largest number of vessels.

Table 4 Top ten vessel types in terms of annual fuel consumption for vessels with main engines in the 250 kW to 1200 kW range, based on data from 2016.

Vessel Type	Number of vessels	Annual Fuel Consumption (tonnes)
Cargo	1086	120060
Fishing	1875	43122
Passenger	775	22586
Tanker	243	18820
Pilot boat	150	6420
Sailing	351	5592
Dredger	81	4760
Tug	121	4340
HSC	64	2240
Law Enforcement	77	2092
Total of above 10 types	**4823**	**230032**
Total of all vessels (including other and unspecified)	**6167**	**262478**

The number of vessels and fuel consumption in the four engine power segments 250-450 kW, 450-600 kW, 600-900 kW and 900-1200 kW, shown by vessel type and length, are included in the SUMMETH market report (Rydbergh and Berneblad, 2017). The report also shows the vessel tracks and the hours at speed for the six-month study period (2016-03-01 to 2016-08-31) for the top 25 vessels in each of the four engine power segments.

3 ENGINE TECHNOLOGY, RESEARCH, AND DEVELOPMENT FOR METHANOL IN INTERNAL COMBUSTION ENGINES

Experimental investigation of several different methanol engine concepts in the range of 250 to 1200 kW with respect to performance and emissions was carried out in SUMMETH Work Package 3. The concepts investigated within SUMMETH were compared with each other and also with other methanol engine concepts to rank the merits and challenges. The objective of the work was to identify the best engine concept for methanol operation in internal combustion engines for rapid market introduction and implementation in a long term perspective, considering cost and energy efficiency together with minimised environmental impact.

Concepts studied within SUMMETH included conventional methanol engine concepts such as port-fuel injected spark-ignited engines (PFI-SI) and advanced methanol engine concepts such as Methanol-Diesel compression ignition of methanol fuel with additive (MD95), partially premixed combustion (PPC) and direct injected spark ignition engine (DI-SI). The work is described in detail in the D3.1 Report "Engine Technology, Research, and Development for Methanol in Internal Combustion Engines" (Tuner, Aakko-Saksa, and Molander, 2017). A short summary is provided below.

3.1 USE OF NEAT METHANOL IN SPARK-IGNITED AND PPC ENGINES

Engines tested with neat methanol had a capacity of around 13 liters and can provide power outputs in the range of 250 kW to 700 kW. Experimental studies with a conventional PFI-SI methanol engine were conducted by project partner ScandiNAOS. Testing with advanced methanol engines such as DI-SI and PPC was conducted by Lund University.

3.1.1 DISI and PPC engines

Experimental setup

Three engines were used at Lund engine laboratories. Most of the research was conducted on a Scania D13 engine modified for single cylinder operation to facilitate control and measurement of the operating conditions with greater detail. The single cylinder engine was used with two different cylinder heads: one standard D13 cylinder head for PPC and also methanol diffusion combustion and one specifically designed and built by Lund University for the SUMMETH project for DI-SI operation (Björnestrand, 2017). To investigate the characteristics of direct injected methanol combustion, another single cylinder Scania D13 engine with optical access to the combustion chamber was used. A complete six-cylinder Scania D13 engine adapted for PPC operation was used to measure power and emissions for the complete operating range with gasoline. These results were used to scale the performance of methanol PPC from the single cylinder engine. All engines were connected to emission analysers for quantification of NOx, particulate matter, CO and HC. For the advanced particulate characterization studies a cooperation was performed with Aerosol-technology at Lund University and DTU in Denmark.

Performance

PPC provides the highest recorded indicated efficiencies (>53%) that we are aware of for a methanol engine (Shamun et al., 2017). The indicated efficiency of methanol PPC is thus exceeding those of the best diesel engines, by around 2 percentage points (Tuner 2016). The combustion characteristics of methanol PPC show a very rapid combustion that, however, can be controlled with split injection strategies or through late injection diffusion combustion (Shamun et al., 2016, 2017). Although the PPC experiments with a complete engine demonstrate high efficiency and low emissions throughout the load and speed range, the PPC concept is still at a level of a research concept that lacks maturity. Cold starting is one of the challenges (Shamun et al. 2017).

DI-SI can be run either homogenous premixed through early injection or through stratified late injection. Stratification provides very high indicated efficiencies (>51%) but has a narrow range between knock and misfire where stable operation can be achieved (Björnestrand, 2017). The heat release characteristics for stratified DI-SI are beneficial with a moderate increase and very quick ending which offers a more silent combustion and also an increased time for expansion that improves efficiency (Björnestrand, 2017). DI-SI offers better options than PPC for near time implementation.

Emissions

It was demonstrated that neat methanol operation does not form any carbon-based soot and that the particulate levels are 3-4 orders of magnitude lower than for diesel engines (Svensson et al., 2016; Shamun et al., 2016; Shamun et al., 2017; Tuner, 2016). Stratified DI-SI operation with EGR does not soot either and can provide low emissions of NOx with reasonable levels of HC and CO (Björnestrand, 2017). The emissions advantage is not as strong as for PPC but good enough for SECA regulated areas. It is possible to run DI-SI with stoichiometric operation to enable a three-way catalyst (TWC) for even lower emissions than reported for PPC.

3.1.2 PFI-SI methanol engines

Experimental setup

Two engines were converted to run on 100% methanol in a pilot boat, which had tanks, piping, and safety systems adapted within the GreenPilot project (a parallel project to SUMMETH). One Weichai, originally CNG powered, and one Scania, originally diesel powered. Both engines have been modified to run as SI (spark ignited) and PFI (port fuel injected). Both are six cylinders with total cylinder volume of 12-13 L. Emission measurements were performed for the modified Weichai engine, which produces a rated output power of 313 kW and is optimised for high efficiency, combined with a rating for long life. Emissions measurements on the Scania engine will be carried out in early 2018 as part of the GreenPilot project and will be reported later in the year.

The Weichai engine was run in a dyno and installed in the pilot boat. NOx measurements were carried out in the dyno while NOx and PM/PN measurements were done onboard. Four load points were logged: 1400 RPM, 1800 RPM, 2000 RPM and 2200 RPM. These load points correspond to 31%, 64%, 91% and 100% of MCR (maximum continuous rating). The load points correspond to the prescribed procedure for an emission measurement according to the ISO 8178 E3 – cycle.

Emissions

The lowest recorded NOx emission, 1 g/kWh, was measured at full load (313 kW). In a certification procedure four of the load points are weighted and summed together according to prescribed procedure. Calculated according to IMO standard the NOx emission factor is 1.38 g/kWh. Calculated according to EU procedure, the emission factor is 1.77g/kWh.

Engines with NOx emissions under 1.96 g/kWh fulfil IMO Tier III NOx limit and under 1.8 g/kWh the engine also fulfils the upcoming EU regulations on inland waterways.

Particle mass is regulated in upcoming EU regulations. The limit is 0.015 g/kWh. Recorded and weighted particulate mass is 0.0000282 g/kWh meaning that emissions regulation is fulfilled with a margin of 99.99%.

Performance

Results indicated braked fuel efficiency of 38 to 40% for higher loads. The engine performance was similar to a conventional diesel with respect to efficiency and torque output. Emissions of NOx and particulates are low compared to diesel engines.

3.2 USE OF ADDITIZED METHANOL IN A DIESEL ENGINE

Several MD95 fuel concepts with different additives and recipes were studied by VTT in a Scania engine (Scania EEV Ethanol DC9 270 hp) in a standard configuration on a test bench, and tests with the intake manifold injection to reduce the need for an ignition improver. Cylinder pressure parameters, engine performance and emissions were measured to enable rating of different development paths. The details of work are provided in Aakko-Saksa et al. (2017).

Fuel blending Four ignition improvers were selected, as well as two esters and three oxygenates. The selection was based on previous work and literature studies. Solubility tests were conducted, and the ignition characteristics of fuel blends were preliminarily screened using a constant volume combustion chamber (AFIDA in ASG). Three methanol blends were selected for the engine tests: MD-1 (with additive A), MD-2 (with additive C and FAME), MD-3 (with additive C+FAME+ether). ED95 was studied as a reference. For actual wet blends FAME separated at least partially, which was not seen in the solubility testing with dry methanol. The intake manifold injection study was conducted with MD-4 and MD-5 having low concentrations of additives. MD-6 contained nitrate additive.

Emission measurements using the ESC test cycle showed differences between the test fuels. The CO emission was substantially lower for all MD candidates than for the ED95 fuel, and also lower aldehyde emissions were observed for methanol than for ethanol blends. Unburned alcohol was present in exhaust both for the MD and ED fuels. NOx emissions were slightly lower for the MD fuels than for ED95. Flame temperature of methanol is lower than that of ethanol (Piel, 1990), which probably explains this difference. By default, methanol fuels without carbon-carbon bonds do not enhance soot formation. In these tests material was observed on the PM filters, but it was not black. This material on the filters with alcohol fuels indicated presence of unburned additives. Earlier experience has shown that this kind of semivolatile liquid constituent can be easily removed by oxidation catalyst (Aakko et al., 2000). Particle number emissions were relatively high for the MD-fuels – a catalyst may also reduce these emissions. With nitrate-based additive in MD-6 fuel, the engine did not start.

Cylinder pressure analysis and intake manifold injection tests were also carried out and are described in Aakko-Saksa et al. (2017).

Overall, several MD95 methanol blends were clean burning, and combustion was good in the Scania EEV Ethanol DC9 270 hp. The best performance was observed for the same type of ignition improvers as used in the ED95 concept. For both fuels, MD95 and ED95, high masses on particulate filters were observed and concluded to originate from the unburned additives. This "liquid PM" is assumedly removed by the oxidation catalyst that belongs to the commercial Scania alcohol engine concept. Catalyst may also reduce particle number emissions that were elevated for the alcohol fuels. When fuel was injected in the intake manifold, concentration of ignition improver additive can be reduced. However, the system needs improvement and optimisation to show the potential of the concept. Overall, the results show that the MD95 concept can be a potential solution to introduce environmentally friendly renewable methanol for smaller ships on the condition that engine materials and other related issues are handled.

3.3 DISCUSSION AND COMPARISON

An estimation of the relative merits and challenges with the various methanol engine concepts versus conventional diesel engines is shown in Table 5.

One of the benefits with diesel engines is the extreme ruggedness. Although methanol engines can be expected to be robust enough, none of them are expected to match a conventional diesel engine, except maybe for the DI-Dual-Fuel concept (used on *Stena Germanica*). Fully premixed engines such as PFI-SI and Dual-Fuel are more exposed to in-cylinder corrosion if the engines are used frequently with start-stopping without proper warming up. The PPC engine is still a research concept and has poor low load operation quality which currently ranks it worst in terms of robustness.

Retrofitting refers to modifying an existing on-board diesel engine to operate on methanol. The on-board conversion of the *Stena Germanica* engines is a good example of retrofitting (Haraldson 2015). The motivation to retrofit an engine is to limit cost but if the engine is too old or the modification expensive it might be more cost effective to replace the complete engine, especially for smaller engines. All the concepts introduce challenges when it comes to retrofitting. How severe the challenges are, depends also on the generation of the engine to be modified. Apart from that the fuel system with tank, pumps, injectors, etc. needs to be upgraded, MD95 requires different pistons, while PFI-SI, DI-SI need new pistons and cylinder heads adapted for spark plugs. The dual-fuel concept also needs adaption with new pistons and a secondary fueling system, while the DI-Dual-Fuel might get away with a secondary fueling system and advanced fuel injectors thus leaving the base engine intact. PPC is possibly the closest to use diesel engine hardware, but needs an EGR system and an advanced fuel injection system, and considering the immaturity of the concept the requirements for retrofitting are currently quite uncertain.

Table 5. Comparison of various methanol engine concepts 250-1200 kW. DICI Diesel is the reference technology. All other technologies in the table use methanol and are compared with DICI Diesel.

Engine type	Robustness	Efficiency	Power	Noice	HC	CO	NOx	soot
DICI Diesel	0	0	0	0	0	0	0	0
DICI Diesel with particulate filter / SCR	0	-	0	0	0	0	++	++
MD95 with oxidation catalyst	-	0	-	0	0	0	+	+
MD95 with particulate filter / SCR	-	-	-	0	0	0	++	++
PFI-SI Lean burn	-	0	-	++	-	-	++	++
PFI-SI TWC	-	-	0	++	++	++	++	++
DI-SI Lean burn	-	+	-	+	-	-	+	++
DI-SI TWC	-	0	0	+	++	++	++	++
Dual-Fuel	(-)	--	-	+	--	--	0	+
DI-Dual-Fuel	0	0	0	0	-	-	+	+
PPC	--	++	0	-	0	0	++	++

0 = similar performance with methanol as with DICI Diesel

– *= worse performance with methanol than with DICI Diesel*

+ = *better performance with methanol than with DICI Diesel*

Diesel engines are known for their high efficiency and thus low fuel consumption. Methanol engines can be even more efficient than diesel engines, but since hardly any are used commercially there is little long term operation data to depend on (Tuner, 2016; Björnestrand, 2017; Shamun et al., 2017). Direct injected lean operated concepts such as DI-SI, DI-Dual-Fuel and PPC are estimated to have similar or higher efficiency as diesel engines while concepts running at stoichiometric conditions to accommodate a three-way catalyst for ultra-low emissions are expected to have lowest efficiency (Tuner, 2016; Björnestrand, 2017).

Cost of operation depends mainly on the fuel consumption of the engine and considering the uncertainty of the relative price between diesel fuel and methanol fuel the comparison is only done between the methanol engines. PPC has demonstrated the highest efficiency in laboratory conditions and if this materializes in a commercial engine it will probably have the lowest operating costs. Both DI-SI and DI-Dual-Fuel have good potential for low operating costs. Additives needed for the MD95 increases fuel price to some extent, however, this effect could be minimized using the intake manifold injection.

The power levels are expected to be similar to those of diesel engines but with some limitations for the MD95 concept due to the very high compression ratio and for the PFI-SI engine due to risk of knock.

Diesel engines are quite noisy, while especially PFI-SI engines are known to be quite silent. DI-SI and the Dual-fuel concepts can be more silent than diesel engines while PPC typically has a more aggressive combustion that can be noisy.

When it comes to the emissions, methanol has a distinctive advantage compared to most fuels. The high oxygen content of methanol means that neat methanol fuel will not produce carbon based soot in engine combustion. This feature can also be exploited to operate methanol engines in a way to suppress other emissions. Dual-Fuel and DI-Dual-Fuel depend on diesel pilot, which leads to some soot emissions, but still far lower than for conventional diesel engine operation. For MD95, there are no soot emissions, but some unburned additives are seen on particulate filters. DI-Dual-Fuel and MD95 concepts can reduce NOx down to approximately 2 g/kWh. Even lower NOx can be achieved by the use of lean operation, EGR or aftertreatment devices. For current SECA regulations, lean operation will be sufficient, which relaxes the need for expensive EGR or aftertreatment devices. HC and CO emissions will be produced for engines that depend on premixed or partially premixed operation. Levels can be acceptable with engine control strategies or with the use of low-cost oxidizing catalysts.

For a short term implementation, the conventional PFI-SI engine for lean operation and with an oxidizing catalyst is probably the most dependable, clean and affordable concept. The MD95 is another option that likely can be implemented within a short time. Dual-Fuel and DI-Dual-Fuel concepts would probably need longer introduction time for this engine size class. PFI-SI with stoichiometric operation and TWC (M85) is also a proven technology that can be applied for neat methanol use, but due to lower engine efficiency is probably not preferred as such for ships. For long term implementation a mode-shifting PPC/DI-SI engine with oxidizing catalyst can possibly offer the lowest operating costs and strongest reduction of emissions and GHG.

4 ROAD FERRY CONVERSION CASE STUDY

A conversion design for the Swedish Transport Administration Road Ferries vessel *M/S Jupiter* was developed based on existing regulations for low flashpoint fuels in combination with experience from other methanol conversions and conclusions from risk analysis and hazard identification studies. The chemical properties of methanol motivate some practical changes as compared to conventional oil fuels, and special considerations are necessary to achieve a corresponding level of safety.

4.1 DESIGN AND GENERAL ARRANGEMENT

The *M/S Jupiter* operates on a route between Östano and Ljusterö in the northeast area of Stockholm's archipelago. It has a length overall of 86 metres, a breadth of 15 metres, and the capacity to carry 60 passenger cars and 397 passengers. The ferry is equipped with four main engines – two located in a forward engine room and two aft. The engine couple in each end mechanically drives thrusters in each side. In addition to the propulsion engines each engine room is equipped with gensets. The aft engine room has a diesel burner for a thermal oil heating system.

The Jupiter conversion design includes modification of the aft diesel tank to hold methanol, and the surrounding tank room is converted to a methanol storage area, as shown in Figure 2.

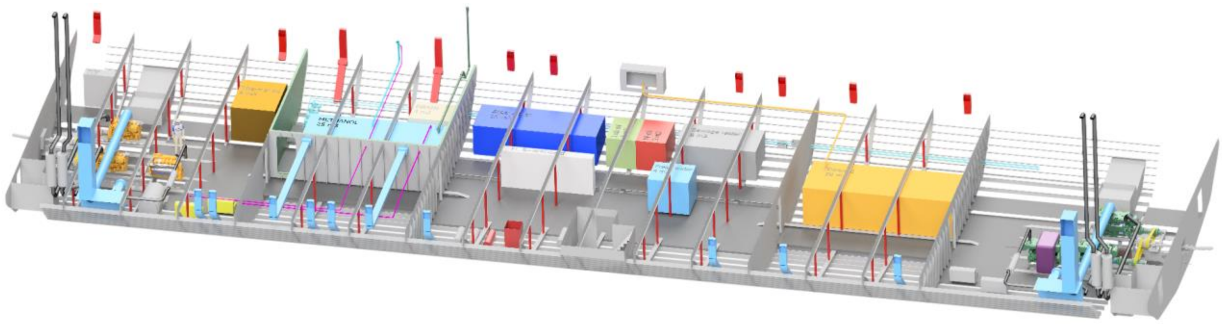

Figure 2 Arrangement of the compartments below deck. From left the aft engine room, new methanol tank room, tank room 2, tank room 3 (diesel tank room) and the forward machinery room. Entrance is from the stair in tank room 2 with emergency exit past each engine room

The new compartment is equipped with mechanical ventilation, methanol vapour detection and has special procedures for safe operation. The four main engines are changed to methanol operation while the electrical generators and diesel burner are kept on diesel. At a later stage the forward diesel tank can be modified and the remaining diesel consumers changed to methanol counterparts. Full details of the methanol conversion design, including the general arrangement plan, the hazardous area plan, and the system coordination diagram are provided in SUMMETH report D4.1 (Bomanson and Ramne, 2017). The design philosophy and general principles of the methanol systems are described in the following sub-sections.

4.2 DESIGN PHILOSOPHY

In terms of regulations for using methanol as fuel the IMO is working on developing the IGF code (International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels) to include technical provisions for methanol as fuel for ships covered by the SOLAS convention. The classification societies DNV-GL and Lloyd's Register have also published class rules. For vessels in national traffic there are no particular rules for the use of methanol. When the SUMMETH project started the Swedish Transport

Agency TSFS 2014:1 statute did not allow for use of fuels with lower flashpoint than 43 °C, similar to the requirements in SOLAS of minimum flashpoint of 60 °C. Similar to SOLAS TSFS 2014:1 also have provisions for alternative designs where risk analysis is used to show that the alternative design is as safe or safer than the prescribed design.

From 1 June 2017 new national statutes entered in to force, TSFS 2017:26. The new statutes are function based and have no formal requirements on the fuel used on board. Instead the rules require an adequately safe design with little guidelines on actual requirements. As risk assessment is already a big part of the methanol system design the new statutes do not have a major impact other than removing the formal process of having an *alternative* design. Prescriptive rules are still used in a sense as the class rules are used as reference in the design process together with experience from the conversion design for both *Stena Germanica* and the pilot boat conversion of the parallel project GreenPilot.

4.3 General functionality and Principles of the methanol system

The general principle of the methanol fuel system is similar to any conventional fuel system. The special requirements on the fuel piping such as double walled and limitation on joints are aimed at minimizing the possibility of leakage. The double walled piping is used to provide an outer protective barrier to contain any methanol in case of rupture of the inner pipe.

The methanol fuel tank is located in the aft tank room, which is modified with a longitudinal bulkhead to create a new compartment. The fuel pumps are separated from the engines and located in a new pump room together with the equipment that is most likely to cause leakage if failing during operation or during maintenance. All electrical equipment in the new pump room is EX-approved.

The aft tank is modified and a new longitudinal bulkhead is installed in the existing tank room, thus insulating the new methanol tank room from the ordinary passage way to the engine room. The new methanol tank room is also used as the methanol pump room.

In addition to the fuel supply system other modifications include upgrading the safety systems. Both for early detection in case of any methanol leakage and for suppression of danger in case any such scenario would develop. More details are provided in SUMMETH report D4.1 (Bomanson and Ramne, 2017a).

4.4 Hazard Identification Study

A hazard identification study was carried out for the *M/S Jupiter* road ferry methanol conversion design. The study identified hazards through two structured hazard identification meetings and a review of historical accident and incident data for free sailing road ferries. The hazard identification sessions covered the main areas affected by conversion to methanol operation, including methanol bunkering, storage, the pump area, and fuel transfer to the engine. Hazard scenarios identified as part of the work were ranked according to frequency and severity and all were considered to be in the “low risk” or “as low as reasonably practicable” (ALARP) risk area. Safeguards and follow-up areas were identified for the ALARP risks. Results are reported in SUMMETH Deliverable report 4.1b (Ellis and Bomanson, 2017).

4.5 Discussion

Converting a road ferry to methanol is a realistic undertaking. The arrangements on board with space available below the deck allows for a safe design and also arrangements that should satisfy all requirements on monitoring and serviceability. Auxiliary systems have been kept to a minimum but with the overall goal to ensure safe and reliable operation on methanol.

From a technical point of view all parts of the design should be able to work with few problems during installations. The major question mark for commercial operation on methanol at this point is the availability of engines but from a technical point of view methanol does not provide a huge challenge.

Efficiency wise similar efficiency as a conventional ferry should be expected, resulting in bunkering methanol about twice as often to compensate for the lower heating value of the fuel. The ferry is designed with two independent engine rooms, each equipped with two main engines mechanically connected to a propeller pod. During normal operations all engines are often running on very low load, resulting in poor efficiency and high relative emissions. Efficiency wise running on fewer engines is better but will also result in less redundancy.

5 GENERAL RECOMMENDATIONS FOR CONVERSIONS OF SPECIFIC SHIP TYPES

For large ships, regulations and procedures for using methanol as fuel is available from two class societies and regulations from IMO are under way. The requirements are to a large extent based on requirements for LNG and provide a safe design for converting a large ship to methanol. For smaller ships, such as road ferries and fishing boats, not all requirements in the available rules are suitable. Arrangement wise it may not be possible to fulfil the rules, nor are many of the automation requirements suitable for a smaller ship with more limited on board systems. In order to design a safe and reliable system the design requirements in the available rules can be used as reference when scaling back to a reasonable level for smaller boats.

General recommendations on how to convert smaller ships in different categories to methanol are presented in SUMMETH Report D4.2 (Bomanson and Ramne, 2017b), and the major requirements for using methanol as a marine fuel according to the current regulations are described along with their applicability to specific ship types. For a general overview possible ships are divided in four categories based on size and regulatory differences:

- Type 1 - Large ship with SOLAS certificate
- Type 2 - Smaller ship with national speed certificate (road ferries, fishing vessels, local transport ferries are typical in this category)
- Type 3 - Smaller ship/working boat (typical examples are pilot boats, police boats, small transportation boats and some working boats).
- Type 4 - Small working boat/recreational craft (some of these vessels may currently use gasoline, and there are special requirements for this that also have applicability to methanol)

A general assessment on the system design requirement for the different types of vessels noted above is presented in report D4.2. The results are general and for a conversion the specific ship still needs to be analysed. Area of operation, number of passengers and general arrangements will be key areas of interest when looking at the individual ship to determine what is safe and what is not.

In general, special arrangements for methanol will be less for smaller vessels. In particular the smallest category where gasoline is today an alternative to diesel requirements would be very similar to requirements for gasoline. For larger ships diesel fuel is the alternative, consequently the requirements on a methanol installation will be higher to account for the much lower flashpoint. As requirements on safety systems in general are higher for larger ships as a result of larger consequences in case of failure, so are the requirements on the methanol systems.

Each ship is different; many factors will influence the final design and recommended systems for the individual ship. The conclusions on necessary systems and design choices presented in the report are very general in nature and are based on previous work, discussions and risk analysis done for a small number of ships in different sizes. The results should not be viewed as definitive requirements but rather a possible general level of system complexity for different sizes of ships. Many different aspects will influence the design and requirements other than size such as operational profile, area of operation and passenger arrangements.

6 EXPECTED BENEFITS, STRATEGIES, AND IMPLEMENTATION OF METHANOL AS A MARINE FUEL FOR THE SMALLER VESSEL FLEET

The potential of methanol as a fuel for smaller vessels, with main engines in the size range 250 kW to 1200 kW, was assessed through analysis of the following main areas:

- Environmental impacts including production and supply of methanol (fossil and renewable), combustion emissions, and impacts resulting from accidental spills to the marine environment
- Costs
- Safety and regulations applicable to smaller vessels
- Production, availability, and distribution of fossil and renewable methanol.

Both benefits and potential barriers were identified and comparisons made with the conventional fuels currently used for this vessel segment. Detailed information is provided in SUMMETH project report D5.1 (Ellis and Svanberg, 2017).

6.1 ENVIRONMENTAL PERFORMANCE

Use of methanol as a fuel in smaller vessels results in fewer environmental impacts overall as compared to marine gas oil and diesel fuels currently used. A fuel life cycle comparison of methanol and conventional fuels showed that methanol produced from renewable feedstock such as wood residuals and pulp mill black liquor can result in greenhouse gas emissions reductions of 75 to 90%, as shown in Figure 3. Methanol produced from fossil feedstock results in a slightly higher GHG emission than conventional petroleum fuels.

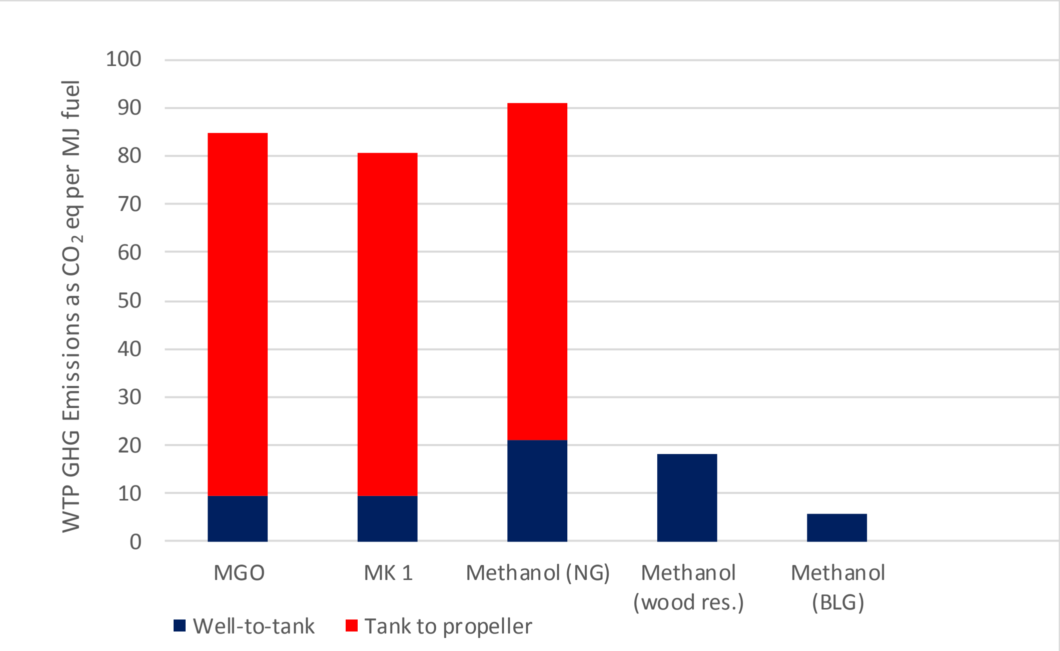

Figure 3 GHG emissions per MJ fuel for methanol from natural, wood residues, and black liquor gasification (BLG) as compared to marine gasoil and MK 1 diesel.

Methanol fuels resulted in significantly lower particulate emissions, even as compared to conventional fuels combusted in an engine using a particle filter. NO_x emissions were also reduced for methanol combustion as compared to combustion of diesel fuels. Emissions from methanol were less than half of those for diesel fuel. These values were for combustion without aftertreatment. Impacts of accidental spills of methanol would be less than those of an equivalent fuel oil spill. Thus there are clear environmental benefits for smaller vessels switching to operation on methanol fuels.

6.2 Costs

The cost of methanol produced from fossil feedstock has been higher than MGO for most of the period between 2013 and 2017. There is no historical price information for renewable methanol and plants currently in operation are pilot scale or “first of a kind”. Estimates from recent studies show production costs of renewable methanol to be on average higher than prices of MGO and methanol from fossil feedstock, but the low range of the estimates show production costs that are almost competitive. Due to the higher cost of methanol as compared to other fuels, incentives, targets, or other measures are needed to drive its uptake as a marine fuel. Measures such as stricter emissions regulations regarding particulate emissions, or requirements for reduction of GHG from shipping could favour the uptake of methanol, as other measures to meet these goals would also entail higher costs. Another possibility for reducing costs could be using methanol of a lower purity than the 99.85% specified for the chemical industry. Combustion engines have been shown to operate well with purities as low as 90% (Ryan et al. 1994; Stenhede, 2013). Although production of a lower purity “fuel grade” methanol has been considered to be impractical for larger suppliers that are producing for chemical industry customers, it could be a good opportunity for smaller plants producing renewable methanol to reduce their costs, if they have a local fuel market.

6.3 Safety

Safety is not considered to be a barrier for adoption of methanol fuel by smaller vessels. The few large ships using methanol in dual-fuel engines, the *Stena Germanica* and the Waterfront shipping chemical tankers, have undergone safety assessments prior to approval and to date have been operating safely. International regulations for use of methanol as a ship fuel are under development at the IMO and classification societies have developed tentative or provisions rules. Although these international regulations are not necessarily applicable to smaller vessels classified under national regulations they provide guidance and indication of good practice for handling methanol as a marine fuel.

6.4 Production, availability, and distribution of fossil and renewable methanol

Methanol produced from natural gas is imported by ship to Sweden and distributed routinely by road and rail. There are no barriers regarding availability and supply of this methanol to smaller vessels. Sustainable methanol is a particular focus for the SUMMETH project and production and feedstock possibilities within Sweden were assessed. Production of methanol from wood biomass, including gasification of wood residual and gasification of pulp mill black liquor, has been investigated and tested in Sweden. A pilot plant producing methanol from pulp mill black liquor in Piteå has operated successfully, and detailed plans were developed for an industrial scale facility. This has not been built due to uncertainties regarding regulations and taxes for bio-fuels for automotive use. A plant using domestic forest residues as feedstock, Värmlandsmetanol, has been planned and designed, but has not been constructed for the same reason. Work has started on a small plant producing methanol from pulp production by-products at Södra’s pulp mill in Mönsterås (Jacobsson, 2017). These developments indicate that technology is mature enough for production of methanol from biomass in Sweden, with the only barriers being uncertainty about a market for the fuel. Estimates of biomass production potential indicate that there is sufficient feedstock to produce enough methanol to more than meet the needs of the smaller vessel segment.

Production of methanol from CO_2 is also being tested and planned in Sweden. A pilot project to produce methanol from steel mill flue gases was started in 2017. A feasibility study was completed in 2017 for a small to medium scale plant to produce methanol from wind energy and CO_2 of primarily biogen origin (Liquid Wind, 2017).

Regarding distribution of methanol from renewable production plants to smaller vessels, there are no barriers anticipated as many smaller vessels are already bunkered by tanker truck for conventional fuels. There would be minimal changes if they were to switch to methanol fuel, as methanol is routinely transported by tanker truck to customers.

In summary the few barriers identified for use of sustainable methanol are related to the production costs as compared to conventional fuel, and the lack of certainty for producers for an end user market. On the environmental side, there are many benefits to be realized from using methanol as fuel, including significantly lower emissions during combustion, and large reductions in GHG emissions if sustainable methanol is used.

7 PROJECT MANAGEMENT AND DISSEMINATION ACTIVITIES

7.1 PROJECT MANAGEMENT

Project management activities within SUMMETH dealt mainly with administration of the project, including organising and chairing project meetings, monitoring and reporting on progress with respect to milestones and deliverables, and reporting to the project's external co-funders.

Ten project consortium meetings were held during the project duration. Project meeting dates were as follows:

- 2015-12-10 at SSPA in Göteborg
- 2016-03-06 at SSPA
- 2016-06-15 at SSPA
- 2016-08-31 at SSPA
- 2016-11-30 at Lund University
- 2017-02-23 at VTT, Technical Research Centre of Finland, in Espoo, Finland
- 2017-05-03 at Marine Benchmark in Göteborg
- 2017-09-04 at SSPA
- 2017-10-18 at SSPA
- 2017-11-15 at SSPA

In addition several work package meetings were held throughout the project.

Project progress reports were prepared and submitted on 2016-06-30 and 2017-06-30.

7.2 DISSEMINATION

Dissemination activities were carried out throughout the project and included presentations at conferences and shipping industry events, creation of a website, publication of a project brochure, academic publications, marketing through partners' own activities, and organization of a final seminar.

7.2.1 Presentations

The SUMMETH project work was presented at the following conferences and seminars:

- VTI Transportforum 2017, Linköping, 10 January 2017
- Methanol Workshop, Elsfleth, Germany, 7 June 2017
- Methanol Policy Forum, Washington, DC, 13 June 2017
- Shipping as a Guide to Sustainable Transport Seminar, Göteborg, 15 June 2017

The project was also presented on a poster at the Swedish Pavilion of the Nor-Shipping Exhibition, held May 30 – June 2, 2017 in Oslo.

Figure 4. SUMMETH Poster at the Nor-Shipping Exhibition, May 30 – June 2, 2017

7.2.2 Project Brochure

A project brochure was produced and distributed at the Nor-Shipping Exhibition, the Methanol Policy Forum, and the SUMMETH Final Seminar. The brochure is shown in Appendix I.

7.2.3 Publications

Reports for each of the technical work packages were produced as described previously in this report. Academic publications completed or planned for submission in early 2018 include the following:

- A Master's Thesis titled "Efficiencies and Emissions of a Methanol Fuelled Direct Injection Spark Ignition Heavy Duty Engine" was defended by Lee Björnestrand (supervised by A/Prof. Martin Tunér) at the University of Lund in April, 2017. This described tests of direct injection compression ignition and stratified spark ignition combustion of methanol which were carried out at the University of Lund Division of Combustion Engines in early 2017.
- VTT has prepared an article based on their work in WP3 on methanol with additives for diesel engines. This will be submitted to a scientific journal in 2018.
- SSPA has prepared an article based on work carried out in WP5 on the use of renewable methanol in the shipping industry. This will be finalized and submitted to a scientific journal in early 2018.

Partners' own publications about the SUMMETH project include an article published in 2016 in SSPA's newsletter "Highlights", titled "Methanol as an alternative fuel for smaller vessels". The article is available here:

Http://www.sspa.se/sites/www.sspa.se/files/field_page_files/2016_sspa_highlights_62_methanol_as_an_alternative_fuel_for_smaller_vessels.pdf

7.2.4 Project Website

A web page for the SUMMETH project was created in early 2016 at the following address:

http://summeth.marinemethanol.com/

7.2.5 Final Seminar

A SUMMETH final seminar was held December 6th, 2017, in Göteborg. Project results were presented in a full day seminar that was attended by participants from industry, academia, consultants, and end users. The seminar program is included in Appendix II. Presentations from the seminar are available on the SUMMETH web page:

http://summeth.marinemethanol.com/?page=FinalPresentation

8 CONCLUSIONS

The Sustainable Marine Methanol (SUMMETH) project has contributed to the development of the use of methanol as fuel in smaller vessels in the following key areas:

- **Methanol combustion concepts for smaller engines**: Experimental investigations of different methanol engine concepts in the range of 250 to 1200 kW showed that emissions reductions and performance are good. The conventional PFI-SI engine for lean operation used with an oxidizing catalyst is probably the most dependable, clean and affordable concept and could be implemented in the short term. The MD95 (methanol with additive) is another option that likely can be implemented within a short time. For long term implementation a mode-shifting PPC/DI-SI engine with oxidizing catalyst can possibly offer the lowest operating costs and largest reduction of emissions and GHG.
- **Conversion designs**: Development of a case study design for a Swedish road ferry showed that converting a road ferry is a realistic undertaking, and that monitoring, serviceability, and safety can meet existing requirements. An overview of other smaller vessel types showed the possibilities for different solutions and system design requirements.

The environmental performance potential for methanol has been investigated with emissions measurements from the experimental studies showing that methanol fuels resulted in significantly lower particulate emissions and reduced NO_x emissions for the concepts tested. A fuel life cycle comparison with conventional diesel fuels used for smaller vessels showed that the use of renewable methanol from feedstocks such as wood residuals and pulp mill black liquor can result in greenhouse gas emissions reductions of 75 to 90%.

Regarding **distribution of methanol** to smaller vessels, there are no barriers anticipated as many smaller vessels are already bunkered by tanker truck for conventional fuels. There would be minimal changes if they were to switch to methanol fuel, as methanol is routinely transported by tanker truck to customers. For **supply of renewable methanol**, within Sweden production of methanol from wood biomass, including gasification of wood residual and gasification of pulp mill black liquor, has been investigated and tested in pilot plants, and a small plant is planned to start operation in 2019. Production of methanol from CO_2 is also being tested and planned in Sweden. The only barriers appear to be uncertainty about a market for the fuel, as production cost estimates are currently higher than conventional fuel.

The SUMMETH project results show that methanol can be used efficiently as a fuel in marine diesel engines, and smaller vessel conversion designs are feasible. There are significant environmental benefits to be realized from using methanol as fuel, including significantly lower emissions of particulates during combustion, and large reductions in GHG emissions if sustainable methanol is used.

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APPENDIX I: SUMMETH BROCHURE

CO-FUNDED BY

SWEDISH MARITIME ADMINISTRATION · REGION VÄSTRA GÖTALAND · METHANOL INSTITUTE · Oiltanking

SUMMETH

Sustainable Marine Methanol

Powering cleaner shipping on coastal and inland waterways

SUMMETH, the sustainable Marine Methanol project, is focussed on developing clean methanol engine and fuel solutions for smaller ships. A transition to a cleaner fuel such as methanol will reduce the impact of shipping on air quality. The use of sustainable methanol will also reduce the carbon footprint of ship operations.

PROJECT PARTNERS

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

SUMMETH

The SUMMETH project is advancing the development of methanol engines, fuel system installations, and distribution systems to facilitate the uptake of sustainable methanol as a fuel for coastal and inland waterway vessels through:

- Developing, testing and evaluating different methanol combustion concepts for the smaller engine segment
- Identifying the total greenhouse gas and emissions reduction potential of sustainable methanol through market investigations
- Producing a case design for converting a road ferry to methanol operation
- Assessing the requirements for transport and distribution of sustainable methanol

The SUMMETH project began in late 2015 and will conclude at the end of 2017.

Read more about the project at:

www.summeth.marinemethanol.com

For more information contact

Project Coordinator SSPA Sweden AB
email postmaster@sspa.se

Technical Coordinator ScandiNAOS AB
email info@scandinaos.com

Using additizied methanol in a diesel engine

Testing methanol in a diesel engine with increased compression and an ignition improver added to the fuel was also carried out. Additives and recipes for methanol fuel blends were developed and evaluated.

Photo: VTT

Blends were tested for solubility and the cetane number and ignition delay were studied. The best blends were evaluated in engine tests where cylinder pressure and emission parameters were measured.

Sustainable fuel for shipping

Methanol contains no sulphur, is clean burning with very low particulates, and can be produced sustainably from many feedstocks. It can even be produced from carbon dioxide emissions, and thus can be a carbon-neutral fuel in the future.

The SUMMETH project will analyse the market for methanol engines for smaller ships and also estimate the emissions reduction that would be possible with a switch to sustainable methanol. The logistics aspects of supplying sustainable methanol to the operators of smaller vessels and fleets will also be investigated.

Designing for methanol

Methanol is considered a low flashpoint fuel by the International Maritime Organization - therefore conventional ship safety and fuel systems need to be adapted. A case study design for the conversion of a Swedish road ferry to methanol has been developed in the SUMMETH project, taking into consideration the ship classification society interim rules and based on experiences from larger vessels such as the Stena Germanica methanol conversion. Experience from the conversion of a pilot boat in the parallel GreenPilot project was also an input to the design. Both the ferry and pilot boat designs show that it is feasible to convert smaller vessels to methanol operation.

Testing marine methanol engine concepts

One of the main goals of the SUMMETH project is to test and evaluate different methanol combustion concepts and methanol fuel additives in a laboratory and to identify the best alternatives for the smaller marine engine segment. The work is focussed on engines with power up to about 1200 kW and both Otto and diesel combustion concepts will be considered.

Evaluating different methanol combustion techniques

Different combustion methanol concepts are being tested in a heavy duty engine to determine how methanol combustion can be optimized. Efficiencies and emissions have been measured and the effects of spark timing, start of ignition, common rail pressure, and exhaust gas recirculation assessed. Tests of direct injection compression ignition and stratified spark ignition combustion of methanol were carried out in early 2017 and indicated gross efficiencies of 54% were found to be possible with methanol. Further testing will focus on a glow plug concept.

Photo Truls Persson

APPENDIX II: SUMMETH FINAL SEMINAR PROGRAM

CO-FUNDED BY

REGION VÄSTRA GÖTALAND

SWEDISH MARITIME ADMINISTRATION

METHANOL INSTITUTE

Oiltanking

SUMMETH

Sustainable Marine Methanol

Agenda

10.00	Registration and coffee		
	Welcome and introduction from one of the co-funders	Joanne Ellis, Peter Peterberg	SSPA, Trafikverket
	Alternative combustion concepts for methanol engines	Bengt Ramne	ScandiNAOS
	How to convert at marine diesel engine to methanol operation	Patrik Molander	ScandiNAOS
	Towards ultra-efficiency and zero-emissions with methanol engines	Martin Tunér	LTH
12.15	Lunch		
	Methanol with additives for diesel engines	Päivi Aakko-Saksa	VTT
	How to convert at road ferry to methanol operation	Joakim Bomanson	ScandiNAOS
	Safety Assessment of Methanol for Smaller Vessels: Road Ferry Case Study	Joanne Ellis	SSPA
14.45	Coffee and cake		
	Market Study - Finding vessels with total installed power between 250 - 1200 kW in North West Europe	Torbjörn Rydbergh	Marine Benchmark
	Environmental Performance and Provision of Sustainable Methanol for the Smaller Vessel Fleet	Joanne Ellis	SSPA
16.00	Wrap up & end of day discussion	Bengt Ramne	ScandiNAOS

PROJECT PARTNERS

TRAFIKVERKET SWEDISH TRANSPORT ADMINISTRATION

LUND UNIVERSITY

MARINE BENCHMARK

SCANIA

VTT

SSPA Your Maritime Solution Partner

ScandiNAOS AB