AdvanceFuel EU-project and Marine Fuels

Martti Larmi, Michal Wojcieszyk, Yuri Kroyan and Ossi Kaario

Aalto University

Graz, September 27, 2019

This Horizon 2020 project has received funding from the European Commission under grant agreement N.º764799

Contents

- AdvanceFuel EU-project
- Fuel property effects in end use
- Modeling methodology
- Study cases: SI LDV and CI LDV and Marine
- Discussion
- Marine fuel research in Aalto

Aalto University
School of Engineering

This Horizon 2020 project has received funding from the European Commission under grant agreement N.º764799

ADVANCEFUEL

- ❑Part of EU Horizon 2020
- ❑Coordination and Support Action of EU Commission
- ❑Facilitating market roll-out of advanced liquid biofuels in transportation sector between 2020 and 2030 and beyond

Partners:

FNR – Fachagentur Nachwachsende Rohstoffe (Co-ordinator)
Germany

ECN – Energy Research Centre of the Netherlands
The Netherlands

Universiteit Utrecht
Utrecht University
The Netherlands

Imperial College London
Imperial College London
United Kingdom

CHALMERS
Chalmers University of Technology
Sweden

Greenovate! Europe
Greenovate! Europe
Belgium

ATB Leibniz-Institut für Agrartechnik und Bioökonomie
ATB - Leibniz Institute for Agricultural Engineering and Bioeconomy
Germany

Aalto University
Aalto University
Finland

Stakeholders:

NESTE

VOLVO

st1

AVL

http://www.advancefuel.eu/

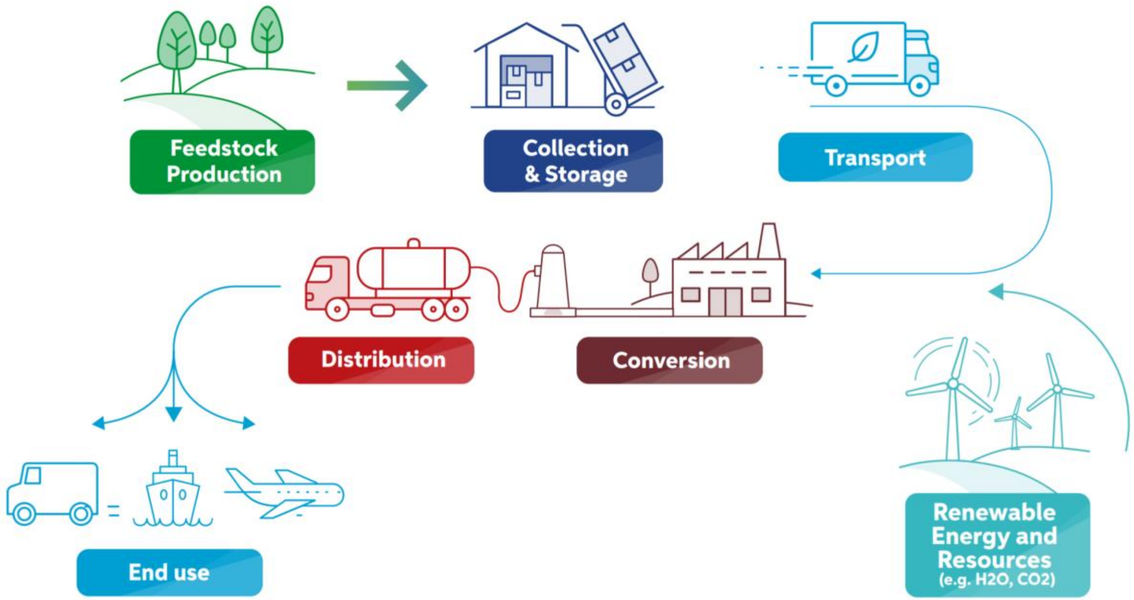
AdvanceFuel value chain

Increased market acceptance and end-use of renewable fuels

Support for decision makers and fuel producers

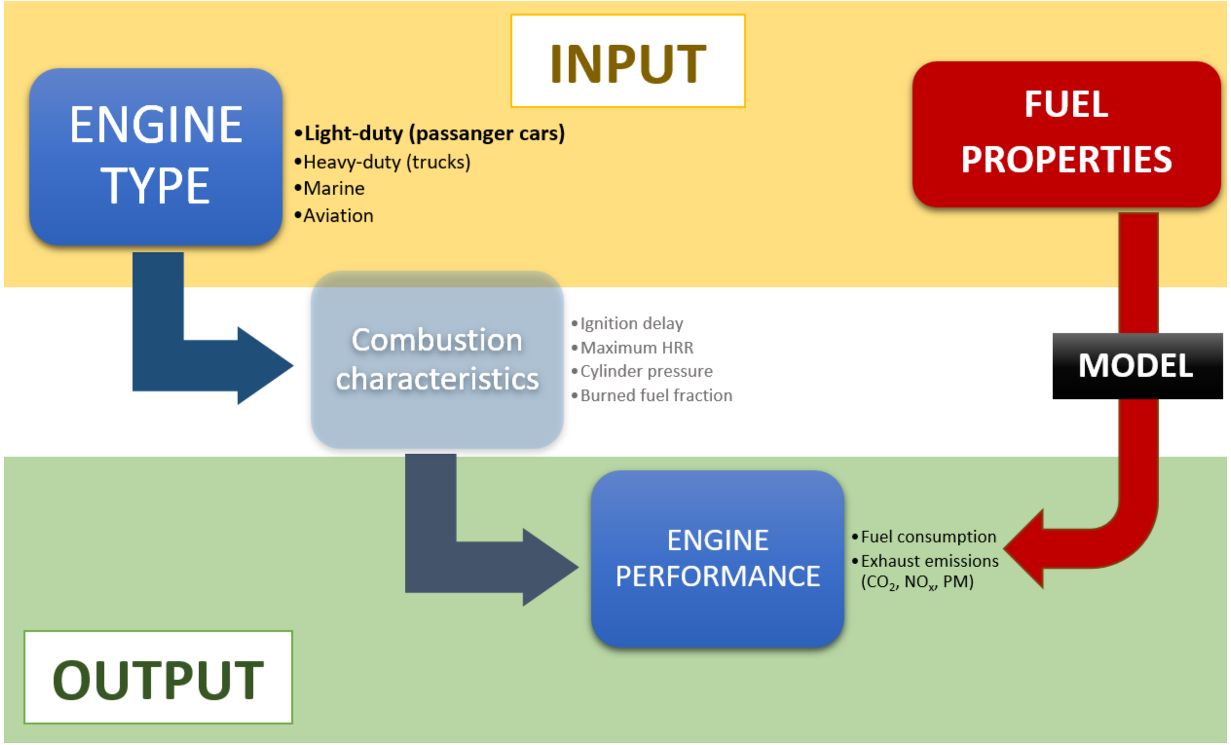
Assessment of future potential of alternative fuels

End use assessment



Aalto University
School of Engineering

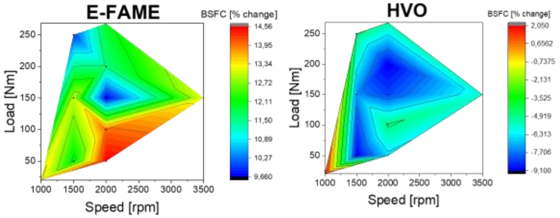
Problem setting of end use assessment



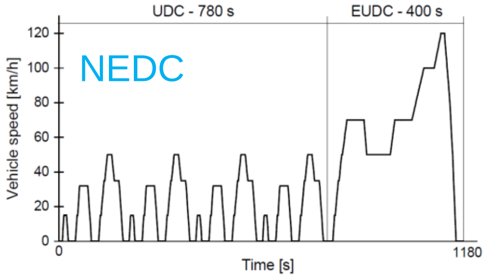
Possible approaches

Impact of fuel properties on engine performance

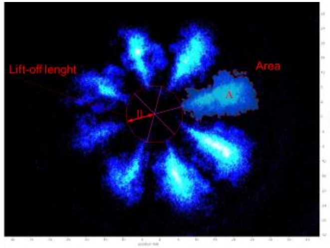
- Steady-state



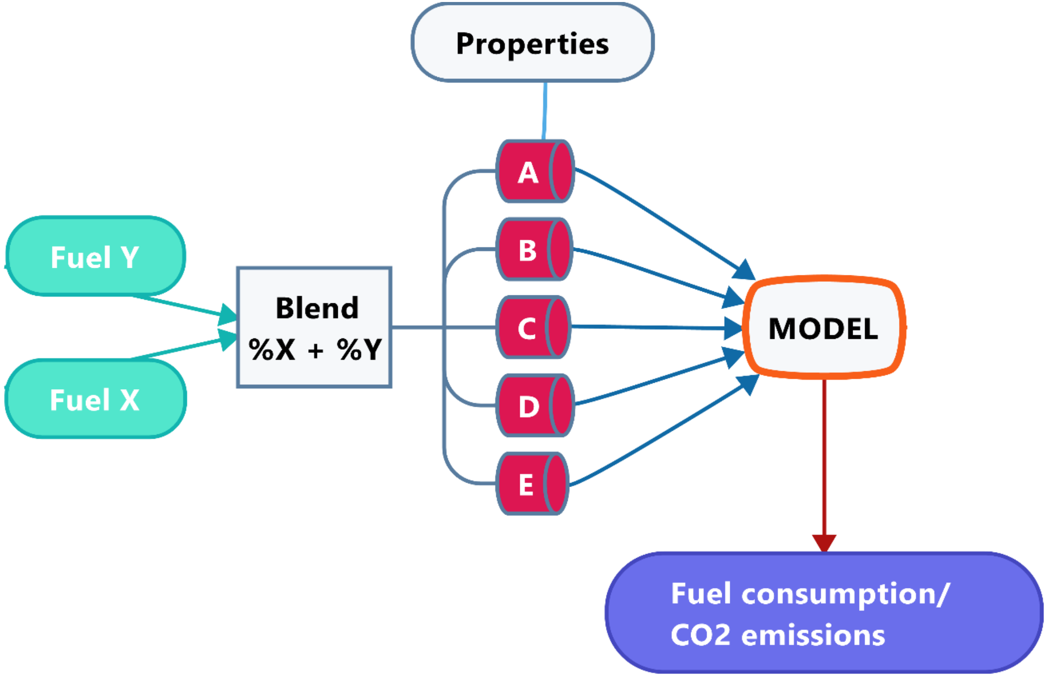
- Driving cycles



- Combustion characteristics



Drop-in fuels are preferable blending as a future solution

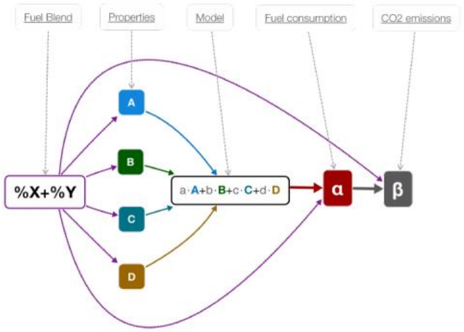


Y – i.e. SVO, HVO, etc.
X – HFO or MDO

A,B,C – i.e. density,
viscosity, etc.

Modeling methodology

- Character of the data: multi input, single output
- Approach: data-driven black-box modeling
- Mathematical methodology: multilinear regression
- Validation: residual analysis and cross-validation



$$\boldsymbol{\alpha} = \boldsymbol{a} \cdot \boldsymbol{A}(\boldsymbol{X}) + \boldsymbol{b} \cdot \boldsymbol{B}(\boldsymbol{X}) + \boldsymbol{c} \cdot \boldsymbol{C}(\boldsymbol{X}) + \boldsymbol{d} \cdot \boldsymbol{D}(\boldsymbol{X})$$

α- fuel consumption [%]
X – alternative fuel concentration [%]
A(X)...D(X) – fuel property [%]
a...d – model coefficients.

- Input and output parameters represented as relative (%) changes in reference to standard diesel/gasoline.

Current status and future scope

Literature study → Data collection → Methodology development → Modelling and validation → Final models ready → Publishing

Road

- **SI LDV - Published**
- **CI LDV - Published**
- SI HDV - data collection
- CI HDV – data collection

Off-road

- SI engines - data collection
- CI engines – data collection

Marine

- **Preliminary model published**

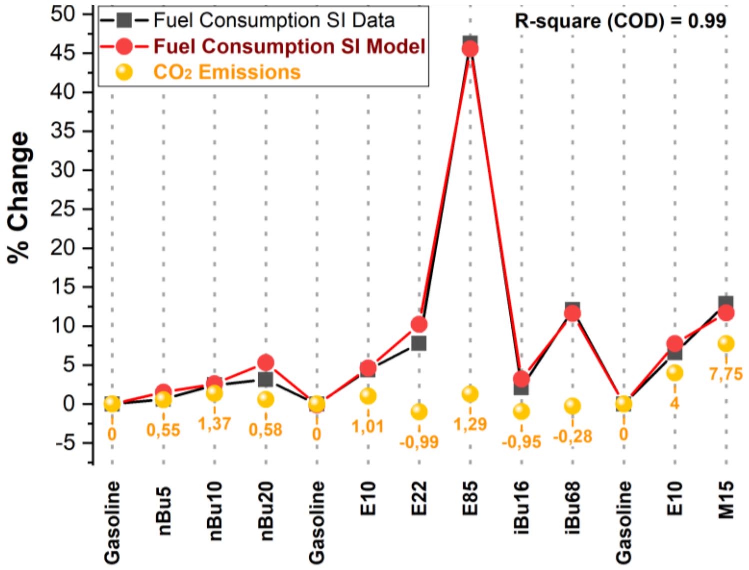
Aviation

- **Data collection**
- **Methodology development**

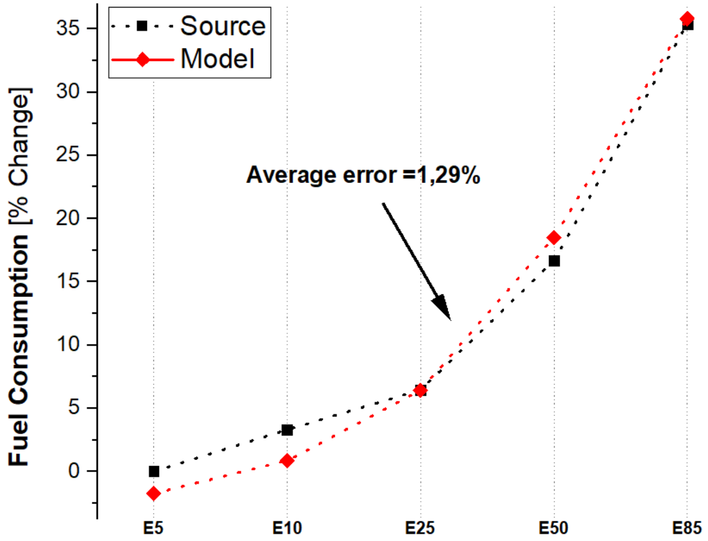
Model - end-use performance in SI LDV engines

$$FC = -0.47 \cdot RON + 2.75 \cdot Density - 2.39 \cdot NCVvol - 1.0 \cdot O$$

Internal validation



External validation

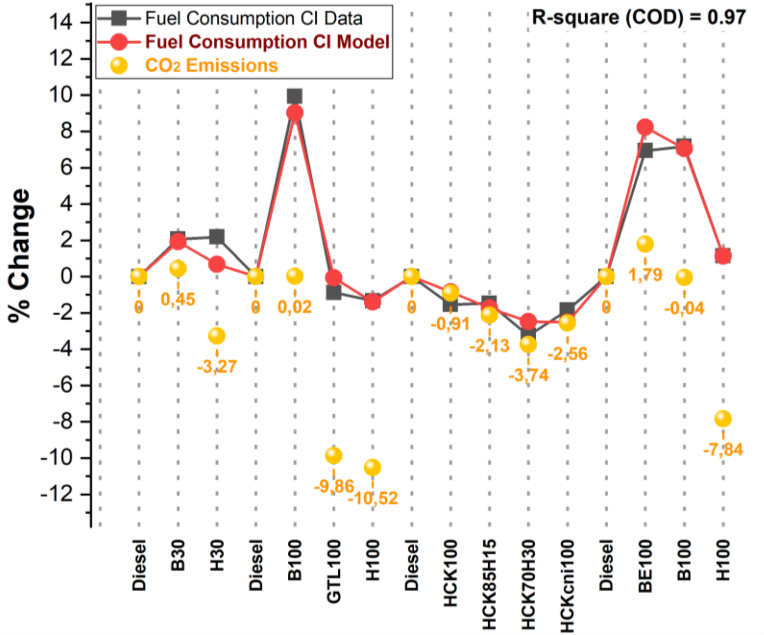


Aalto University
School of Engineering

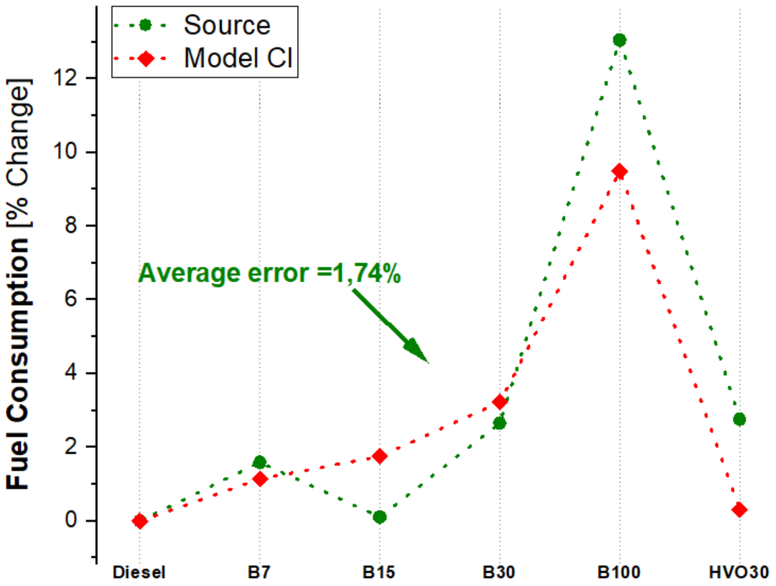
Model - end-use performance in CI LDV engines

$$FC = -0.076 \cdot CN - 1.075 \cdot Density - 1.11 \cdot NCVmass$$

Internal validation



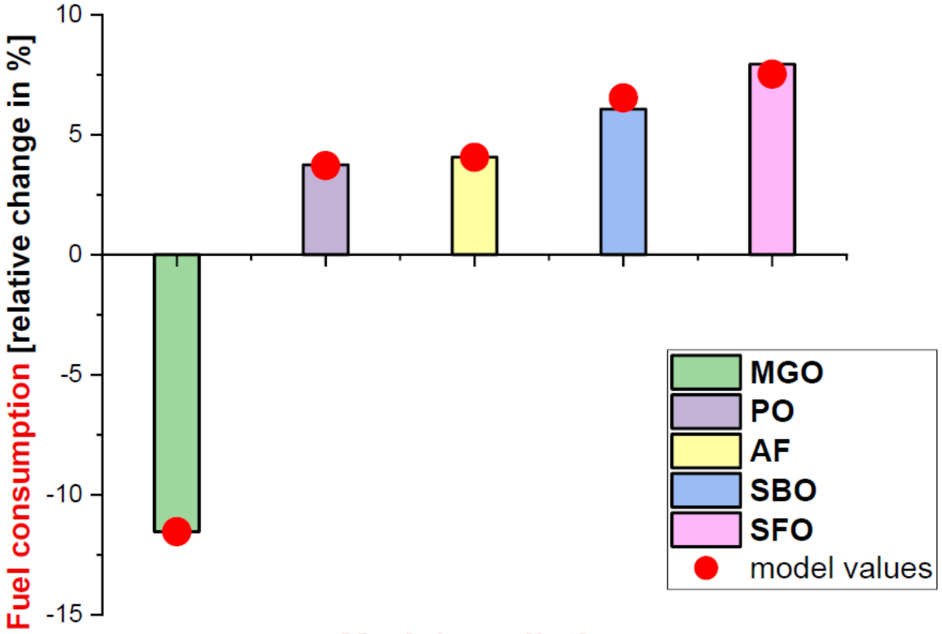
External validation



Aalto University
School of Engineering

Model - end-use performance in marine engines

$$FC = 2{,}09 \cdot Density + 0{,}97 \cdot NCVmass - 0{,}19 \cdot Viscosity$$



Model prediction
for marine engine

Explanation:
MGO – marine gas oil
PO – palm oil
AF – animal fat
SBO – soybean oil
SFO – sunflower oil
HFO – reference fuel

Test setup:
- medium speed marine engine
- 1 cylinder with 320 mm bore
- 75% load @ 750 rpm

US Co-optima as a reference

Co-Optimization of
Fuels & Engines

- 250 M$ and 10 years project established by U.S. DOE
- The main aim is to co-optimize simultaneously fuels and engines
- Collaboration between fuel producers and engine manufacturers
- 9 national laboratories, 13 universities and 77 stakeholders
- To boost research in 2017
  8 universities awarded with extra 7M $

$$Merit = \sum \underbrace{\boxed{\frac{(RON_{mix} - 91)}{1.6}}}_{\text{RON}} - \underbrace{\boxed{K\frac{(S_{mix} - 8)}{1.6}}}_{\text{Octane Sensitivity}} + \underbrace{\boxed{\frac{(S_{L\,mix} - 46[cm/s])}{3}}}_{\text{Flame Speed}}$$

$$+ \underbrace{\boxed{\frac{0.01[ON/kJ/kg](HoV_{mix} - 415[kJ/kg])}{1.6} + \frac{(HoV_{mix} - 415[kJ/kg])}{130}}}_{\text{Heat of Vaporization}}$$

$$- \underbrace{\boxed{LFV_{150}}}_{\text{Distillation}} - \underbrace{\boxed{H(PMI - 2.0)[0.67 + 0.5(PMI - 2.0)]}}_{\text{Particulate Emissions}}$$

The merit function captures the impact of major fuel properties on the efficiency of an advanced SI engine.

Discussion

- Alternative liquid fuels are necessary to decarbonize transportation, especially marine and aviation sectors
- Drop-in fuels or fuel blends are needed for existing fleet
- The black-box modeling of the end-use performance of alternative transport fuels can result in high-quality models (scarcity of data in marine case). A **computational tool for predicting fuel performance** will be released in 2020 by AdvanceFuel project
- Fuel consumption/CO2 emissions of alternative fuel or its blends can be predicted based on known set of fuel properties

Recent SAE papers

JSAE 20199118
SAE 2019-01-2230

Effect of alternative fuels on marine engine performance

Michal Wojcieszyk, Yuri Kroyan, Martti Larmi, Ossi Kaario, Kai Zenger
Aalto University

JSAE 20199100
SAE 2019-01-2308

Modeling the impact of alternative fuel properties on light vehicle engine performance and greenhouse gases emissions

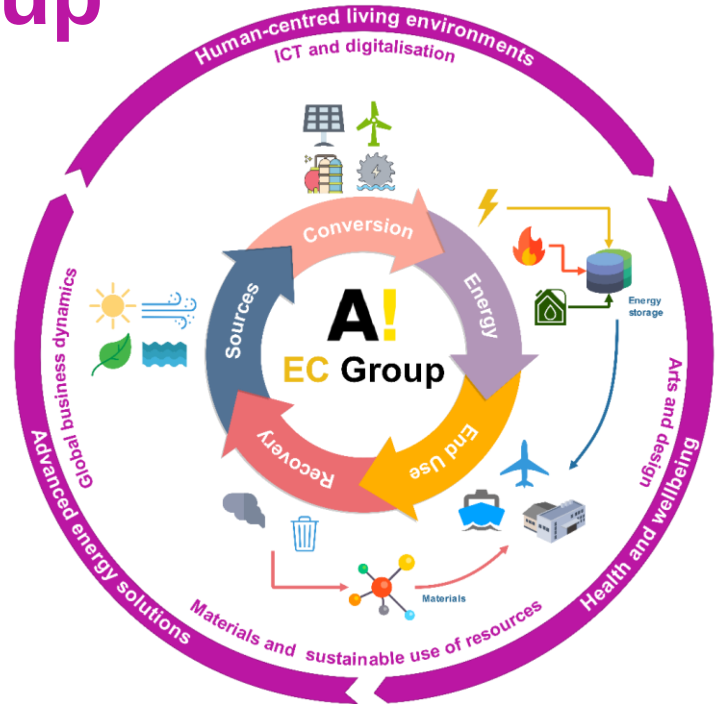
Yuri Kroyan, Michal Wojcieszyk, Martti Larmi, Ossi Kaario, Kai Zenger
Aalto University

AdvanceFuel contacts in Energy Conversion Research Group

Michal Wojcieszyk
Doctoral Candidate
michal.wojcieszyk@aalto.fi

Yuri Kroyan
Doctoral Candidate
yuri.kroyan@aalto.fi

Martti Larmi
Professor
martti.larmi@aalto.fi



https://youtu.be/mK41f24lX1k

Aalto University
School of Engineering

Some future marine fuel options …

1. **Biocrude/Bio-oils to be upgraded from HTL or pyrolysis**
   - Blends in existing fuels
   - Development still needed in fuel conversion technologies
2. **Hydrogen: H_2**
   - Possible in PEMFC, engines and GT
   - Storage and delivery?
   - New engine combustion technology
3. **Methanol: CH_3OH**
   - Possible in engines and GT with non-sooting low NOx-combustion.
   - New engine combustion technology
4. **Methane: CH_4**
   - Possible in engines, SOFC and GT.
   - In engines stoichiometric SI or lean burn pre-chamber SI or DF or GD
   - Still issues with methane slip
5. **DME: C_2H_6O**
   - Excellent "CI fuel", high reactivity and non-sooting also as a DF pilot fuel for CH_4 main fuel
   - Physically close to LPG
6. **Ammonia: NH_3**
   - New technology and infra needed

Sustainability on the high seas
November 20, Scandic Grand Marina in Helsinki

9.00: OPENING

9:30-11:00 SESSION: Marine fuels for today and tomorrow, and role of regulations

- 9:30-10:00 Neste, Merja Kouva
- 10:00-10:30 Traficom, Jorma Kämäräinen
- 10:30-11:00 Aalto University, Michal Wojcieszyk

11:00-12:00 LUNCH

12:00-13:00 SESSION: Engines and new technologies for sustainable shipping

- 12:00-12:30 Wärtsilä, Christer Wik
- 12:30-13:00 ABB, Sami Kanerva
- 13:00-13:30 Aalto University, Martti Larmi
- 13:30-14:00 University of Vaasa, Maciej Mikulski

14:00-14:30 TEA & COFFEE BREAK

14:30-16:00 SESSION: Ship design and energy consumption

- 14:30-15:00 Foreship, Jan-Erik (ship design)
- 15:00-15:30 Aalto University, Janne Huotari
- 15:30-16:00 Aalto University, Antti Ritari

16:00-16.30 DISCUSSION PANEL AND CLOSING REMARKS

Aalto University
School of Engineering