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Biofuels and vehicle compatibility

Task 5.4: Fuel and fuel blend properties in end-use (lead: AALTO)

Michal Wojcieszyk

Aalto University

2nd June 2020

Research Group of Energy Conversion

Aalto University

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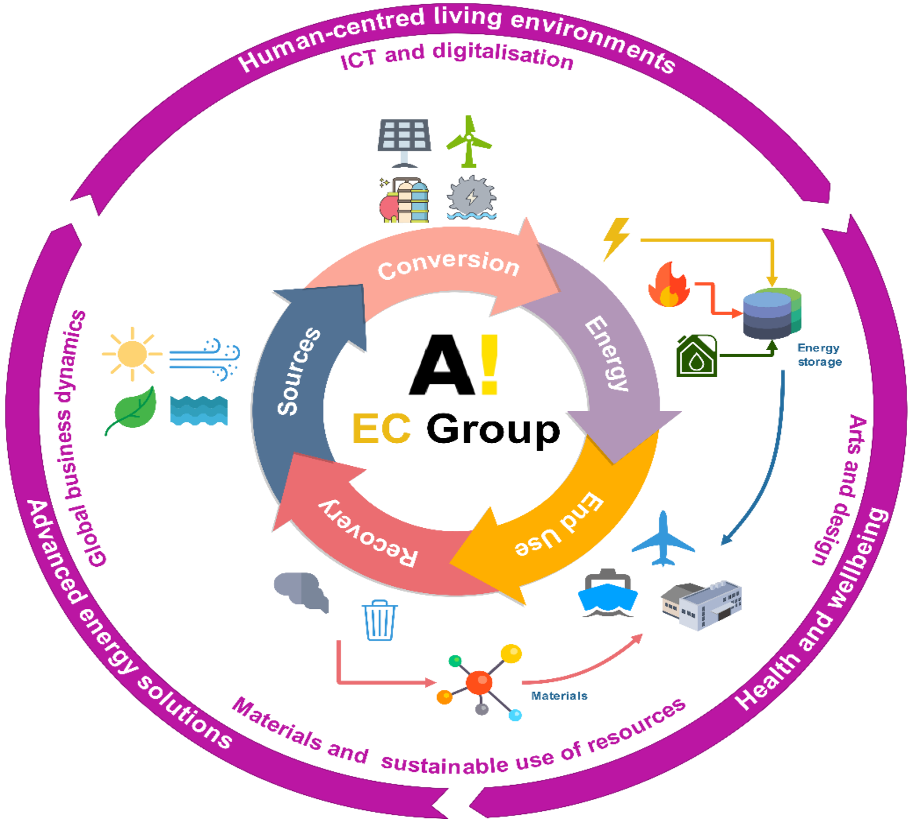
Head
Prof. Martti Larmi

Prof. Annukka Santasalo-Aarnio



Prof. Ville Vuorinen

Prof. Mika Järvinen

https://youtu.be/mK41f24lX1k

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N.° 764799.

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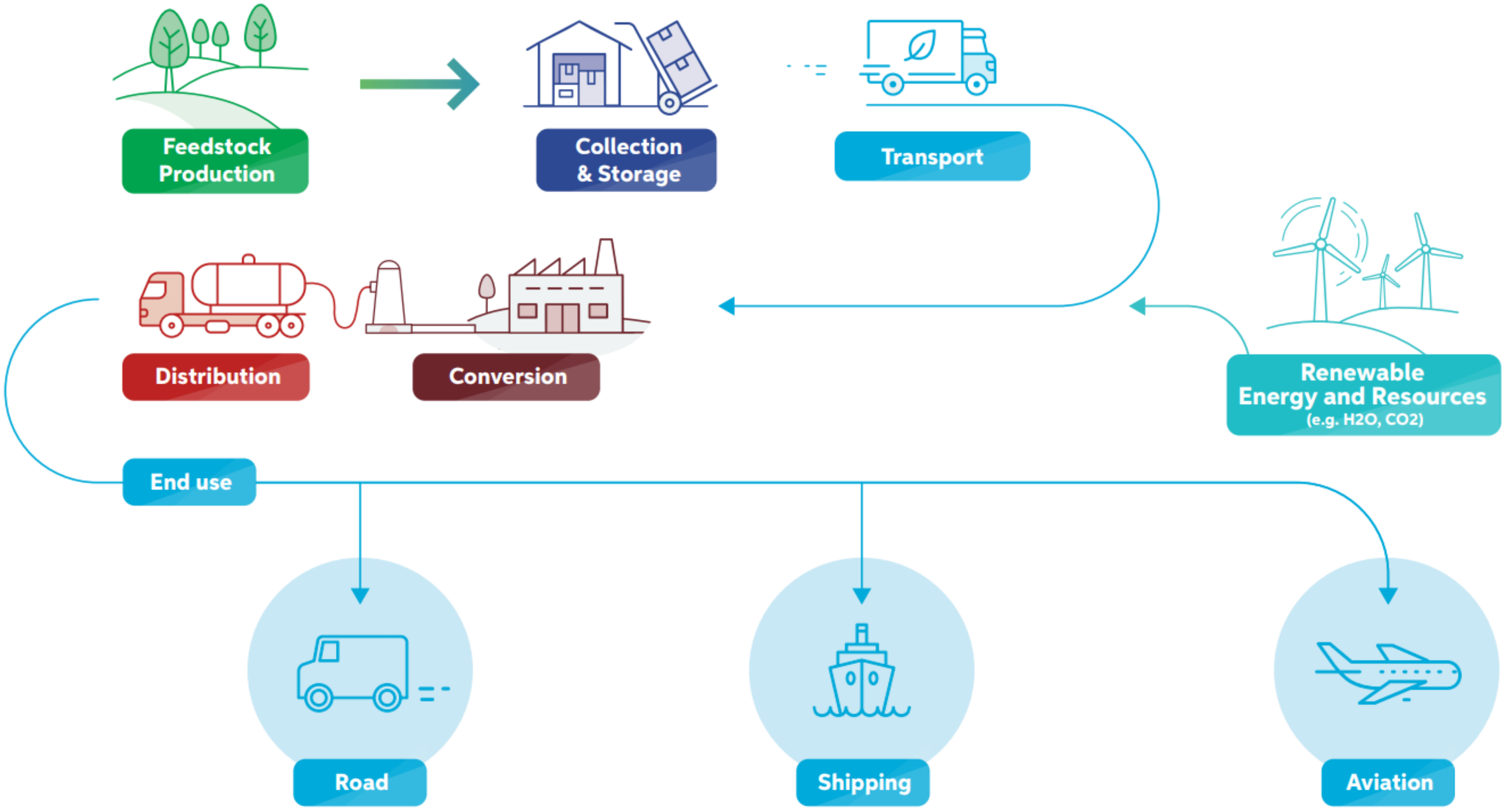

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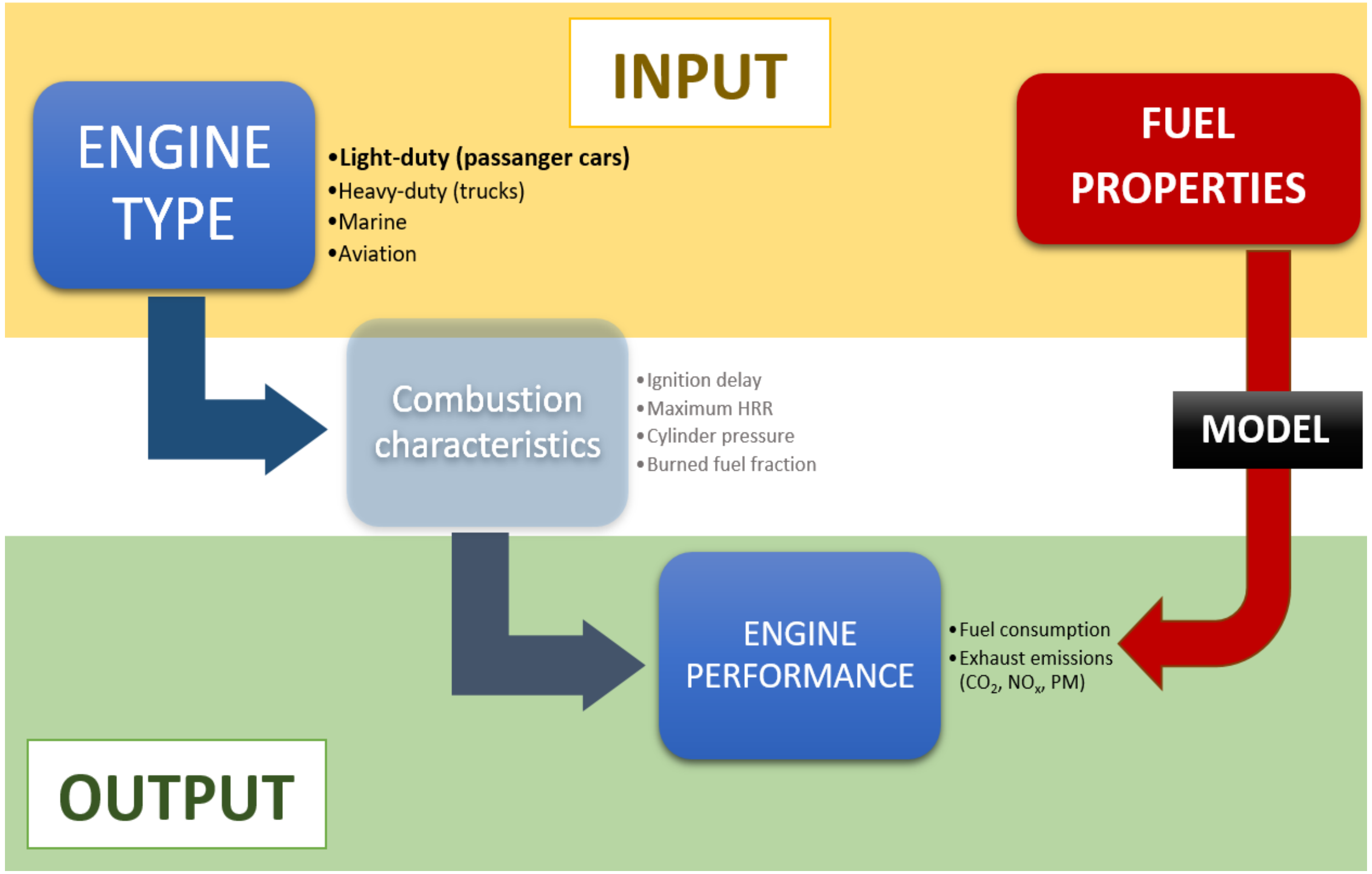
Structure of the problem

- Analysis of RESfuels in the context of their properties -> high impact on end-use!



M. Wojcieszyk, "Modeling the impact of fuel properties on compression ignition engine performance," **Master Thesis**, Aalto University, 2018.

Properties	SI	CI	Jet	Fuel-cell	Marine
RON	x				
MON	x				
Octane sensitivity	x				
CN		x			x
Heating value	x	x	x	x	x
Density	x	x	x	x	x
Viscosity		x	x		x
Lubricity		x	x		x
Distillation characteristics	x	x	x		
Vapor pressure	x				
Vapor Lock Index	x				
Heat of Evaporation	x				
CFPP		x			x
Cloud point		x			x
Pour point					x
Freezing point			x		
Flash point		x	x		x
Oxidation stability	x	x			x
Purity of the fuel	x	x	x	x	x
Acidity and copper corrosion	x	x	x		x
Conductivity	x	x	x		

M. Wojcieszyk, Y. Kroyan, M. Larmi, O. Kaario, A. Bani, "End-use performance of alternative fuels in various modes of transportation", **D5.5. report**, ADVANCEFUEL, May 2020.

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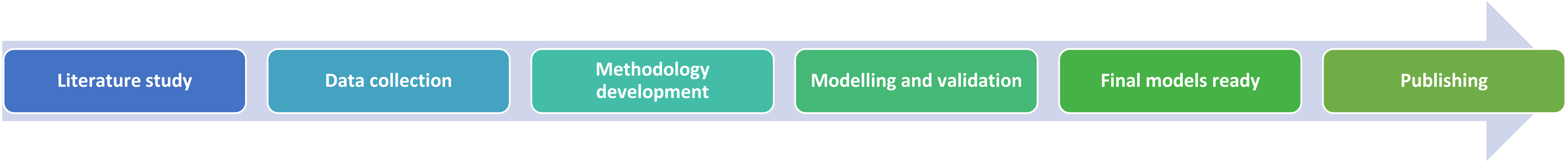
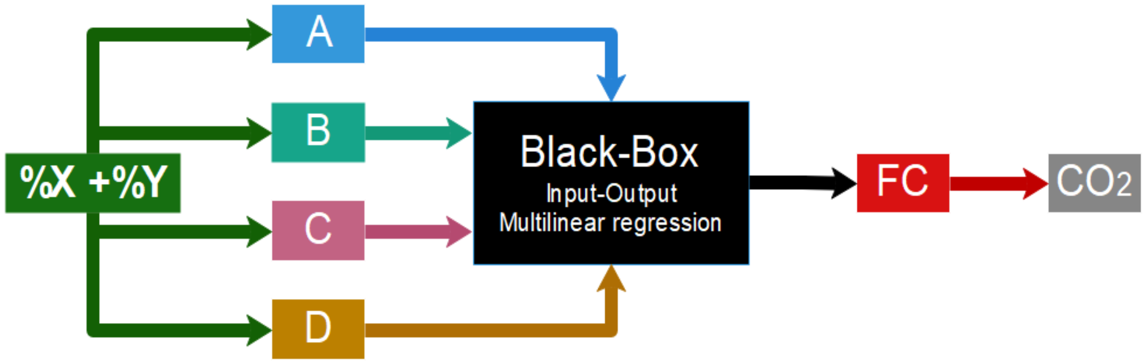
Developed methodology



Modeling approach



Y. Kroyan, M. Wojcieszyk, M. Larmi, O. Kaario, and K. Zenger, “Modeling the Impact of Alternative Fuel Properties on Light Vehicle Engine Performance and Greenhouse Gases Emissions,” in ***SAE Technical Paper Series***, 2019, doi: 10.4271/2019-01-2308.

- Input: important fuel properties (i.e. LHV, density), output: end-use (i.e. fuel consumption)
- Relative changes approach (fossil fuel as a reference)
- Outcome: correlation between set of fuel properties and end-use performance

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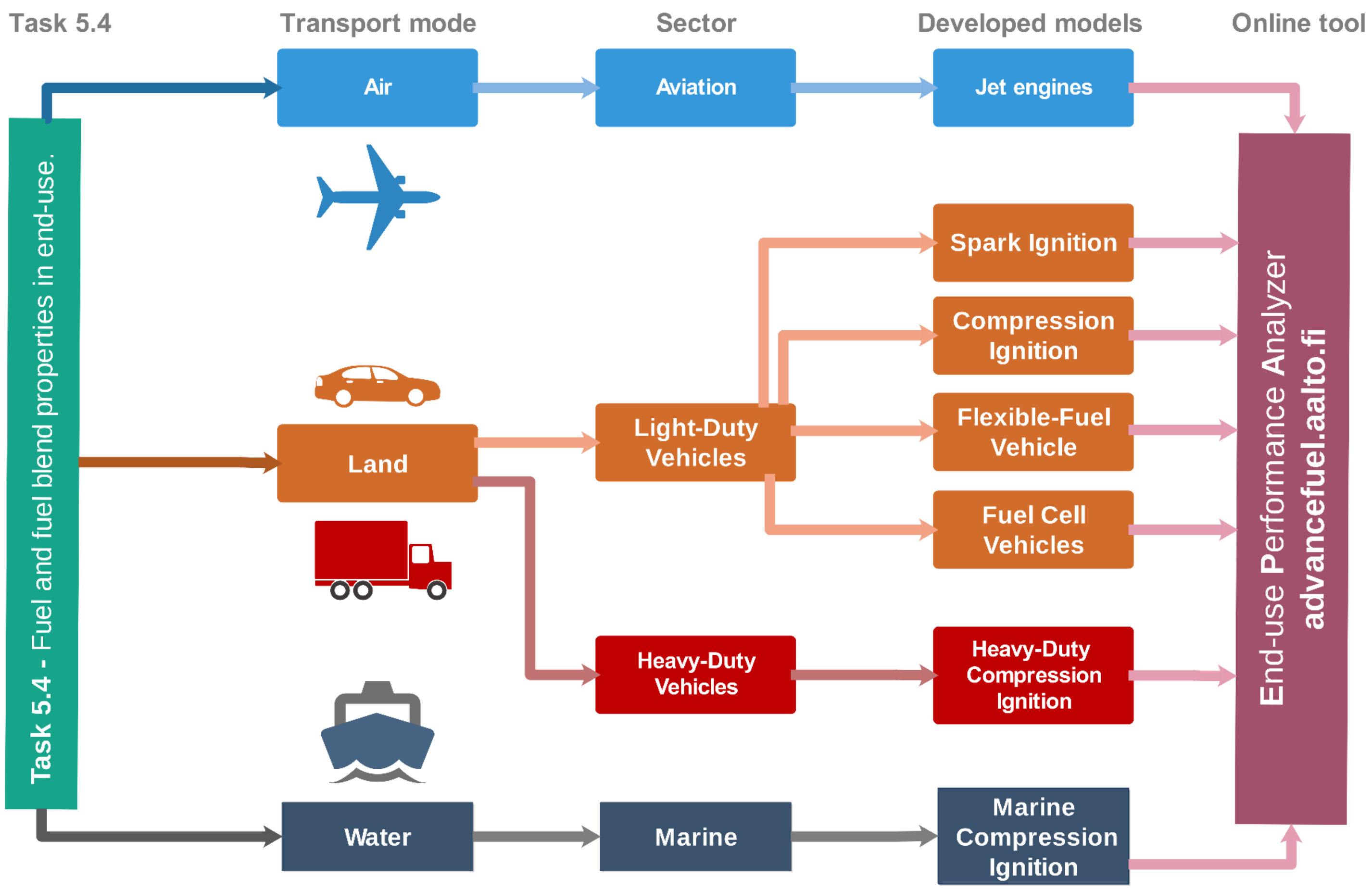
Task 5.4: Results



- Various modes of transportation considered
- Different engine technologies needed depending on the final application
- Engine modifications possible in many cases but still drop-in fuels preferable

M. Wojcieszyk, Y. Kroyan, M. Larmi, O. Kaario, A. Bani, "End-use performance of alternative fuels in various modes of transportation", **D5.5. report**, ADVANCEFUEL, May 2020.

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Highlights from modeling work and recommendations

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Energy Journal, accepted May 2020

Modeling the end-use performance of alternative fuels in light-duty vehicles

Yuri Kroyan[a], Michal Wojcieszyk[a], Ossi Kaario[a], Martti Larmi[a], Kai Zenger[b]

[a]*Aalto University, School of Engineering, Department of Mechanical Engineering, The Research Group of Energy Conversion. P.O.Box 14300, FI-00076 Aalto, Finland.*
[b]*Aalto University, School of Electrical Engineering, Department of Electrical Engineering and Automation. P.O.Box 14300, FI-00076 Aalto, Finland.*

2019-01-2308 Published 19 Dec 2019

SAE INTERNATIONAL

Modeling the Impact of Alternative Fuel Properties on Light Vehicle Engine Performance and Greenhouse Gases Emissions

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

Citation: Kroyan, Y., Wojcieszyk, M., Larmi, M., Kaario, O. et al., "Modeling the Impact of Alternative Fuel Properties on Light Vehicle Engine Performance and Greenhouse Gases Emissions," SAE Technical Paper 2019-01-2308, 2019, doi:10.4271/2019-01-2308.

2019-01-2230 Published 19 Dec 2019

SAE INTERNATIONAL

Effect of Alternative Fuels on Marine Engine Performance

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

Citation: Wojcieszyk, M., Kroyan, Y., Larmi, M., Kaario, O. et al., "Effect of alternative fuels on marine engine performance," SAE Technical Paper 2019-01-2230, 2019, doi:10.4271/2019-01-2230.

Modeling the impact of fuel properties on compression ignition engine performance

Michal Wojcieszyk

School of Engineering

Thesis submitted for examination for the degree of Master of Science in Technology.
Espoo 25.04.2018

Modeling the impact of fuel properties on spark ignition engine performance

Yuri Kroyan

School of Engineering

Thesis submitted for examination for the degree of Master of Science in Technology.
Espoo April 26, 2018

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End-use performance of alternative fuels in various modes of transportation

D5.5 report

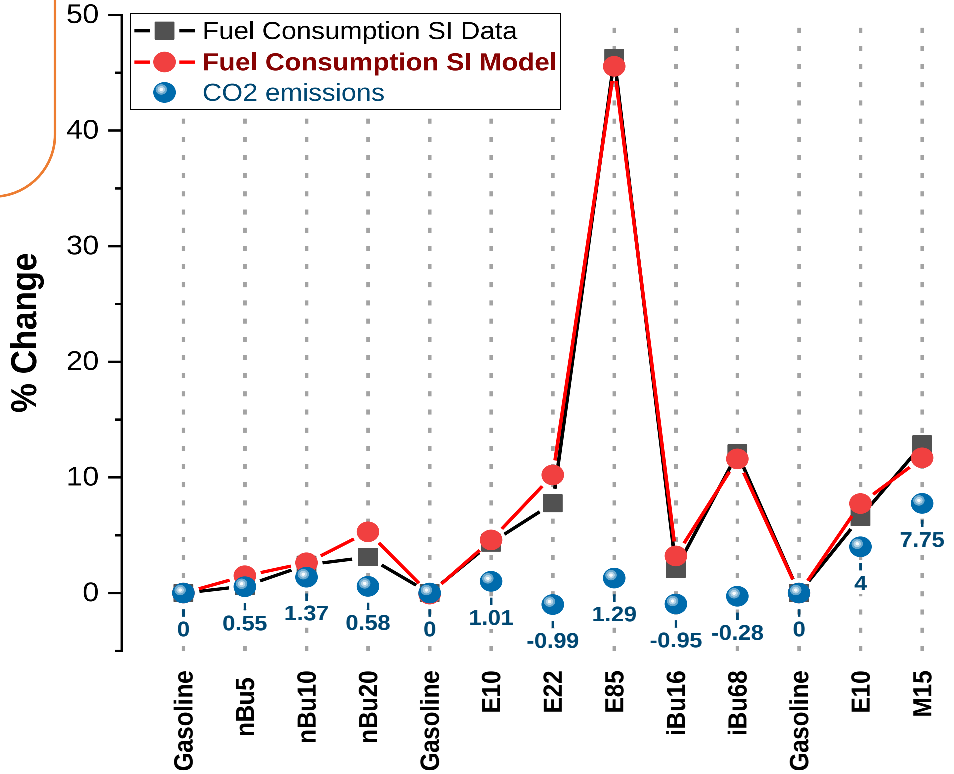
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N.° 764799.

Example 1: Light-duty vehicles (spark-ignition engines)

$$FCvol = 2.75 \cdot Density - 2.39 \cdot LHV - 0.47 \cdot RON - 1.0 \cdot O2,$$

where *FCvol* – % change of volumetric fuel consumption for RESfuel (compared to reference gasoline),
Density – % change of density for RESfuel (compared to reference gasoline),
LHV – % change of lower heating value volume-based for RESfuel (compared to reference gasoline),
RON – % change of research octane number for RESfuel (compared to reference gasoline),
O2 – oxygen content (wt. %) in the fuel.

- Various alcohol blends considered
- Higher fuel consumption but potential for lower GHG emissions and better efficiency



2019-01-2308 Published 19 Dec 2019

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Modeling the Impact of Alternative Fuel Properties on Light Vehicle Engine Performance and Greenhouse Gases Emissions

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

Citation: Kroyan, Y., Wojcieszyk, M., Larmi, M., Kaario, O. et al., "Modeling the Impact of Alternative Fuel Properties on Light Vehicle Engine Performance and Greenhouse Gases Emissions," SAE Technical Paper 2019-01-2308, 2019, doi:10.4271/2019-01-2308.

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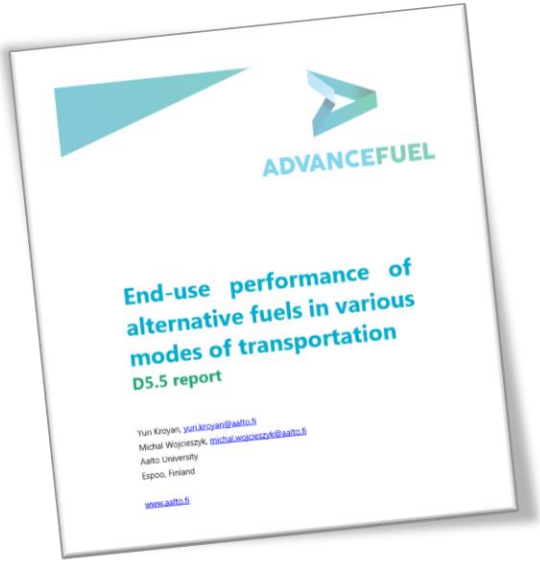
Example 2: Heavy-duty vehicles (compression-ignition engines)

$$FCvol = 0.415 \cdot Density - 0.881 \cdot LHV + 0.075 \cdot CN,$$

where *FCvol* – % change of volumetric fuel consumption for RESfuel (compared to reference diesel),
Density – % change of density for RESfuel (compared to reference diesel),
LHV – % change of lower heating value volume-based for RESfuel (compared to reference diesel),
CN – % change of cetane number for RESfuel (compared to reference diesel).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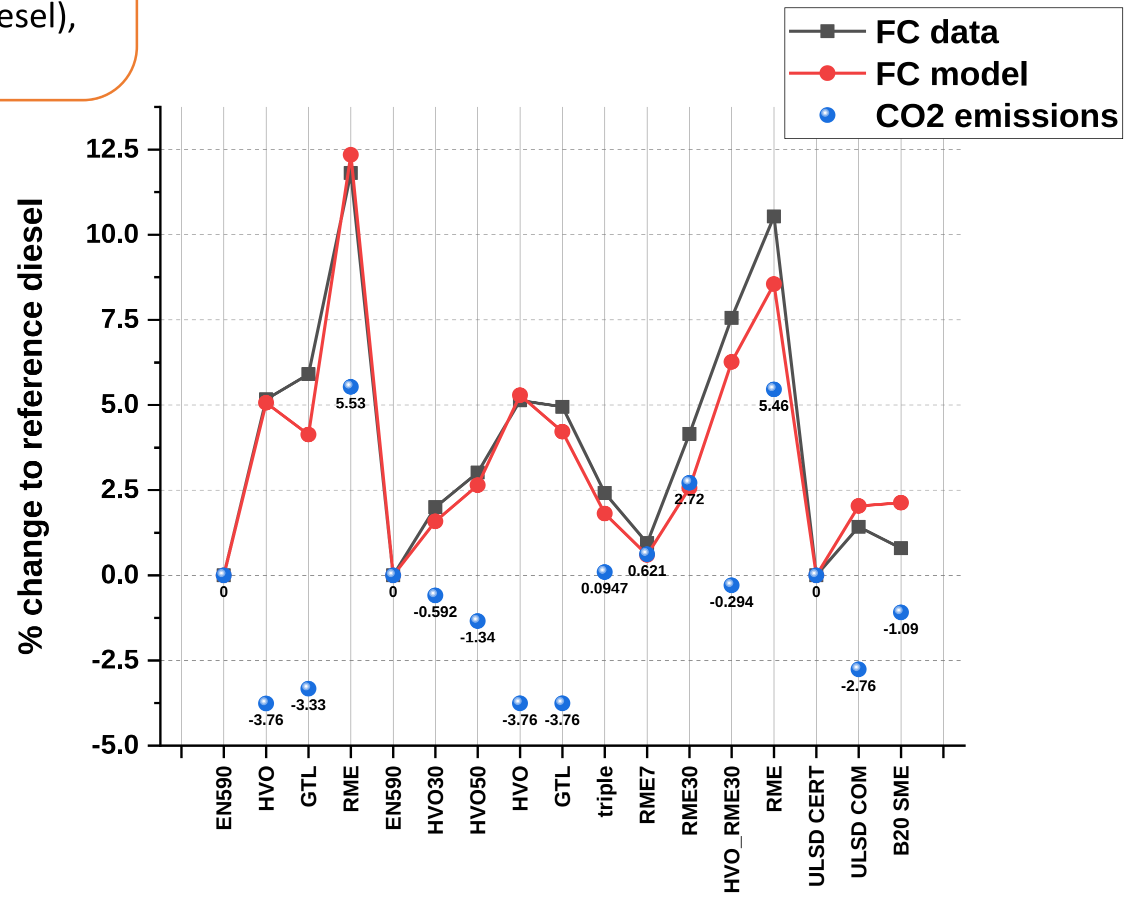
End-use performance of alternative fuels in various modes of transportation

D5.5 report

Yuri Kroyan, yuri.kroyan@aalto.fi
Michal Wojcieszyk, michal.wojcieszyk@aalto.fi
Aalto University
Espoo, Finland

www.aalto.fi

- High quality paraffinic diesels (BTL, HVO) with lower GHG and local emissions
- Limits or blending wall for traditional biodiesel (FAME-type fuel)



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Example 3: Marine engines

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- Methanol as a potential marine fuel
  - Need for dedicated engine technology
- Biocrude from hydrothermal liquefaction (HTL)
  - After upgrading process potential drop-in fuel

2019-01-2230 Published 19 Dec 2019

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Effect of Alternative Fuels on Marine Engine Performance

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

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Fuel	*Advantages*	*Disadvantages*
SVO	+Reduction of GHG +Improved lubrication properties +Low SO_x emission +Lower PM emissions	-Long-term storage and water separation challenges -Lower energy content of approximately 10% -Microbiological growth increased -Higher acidity and risk of damage to certain rubber materials
FAME	+Reduction of GHG +Improved lubrication properties +Possibility of blending with MDO or HFO	-Long-term storage and water separation challenges -Lower energy content of approximately 10% -Microbiological growth increased
HVO	+High quality paraffinic fuel +No blending wall, easily mixable with MDO +Commercially available	-Higher price than fossil diesel -Limited feedstock when using only vegetable oils
Methanol	+Can be produced from lignocellulosic feedstock (TRL reaches 8th level) +Feasible in dual fuel concept	-Major production from natural gas (currently) -Low flashpoint -Toxicity
Pyrolysis oil & HTL biocrude	+Potential substitute for HFO and also as a blending component (no need for retrofit is expected) +Abundant feedstock	-Not yet certified for use -Fuel stability not known completely -Relatively low TRL (5/6), first commercial plant expected after 2025

"Application of synthetic renewable methanol to power the future propulsion", Santasalo-Aarnio et al., submitted to SAE, April 2020.

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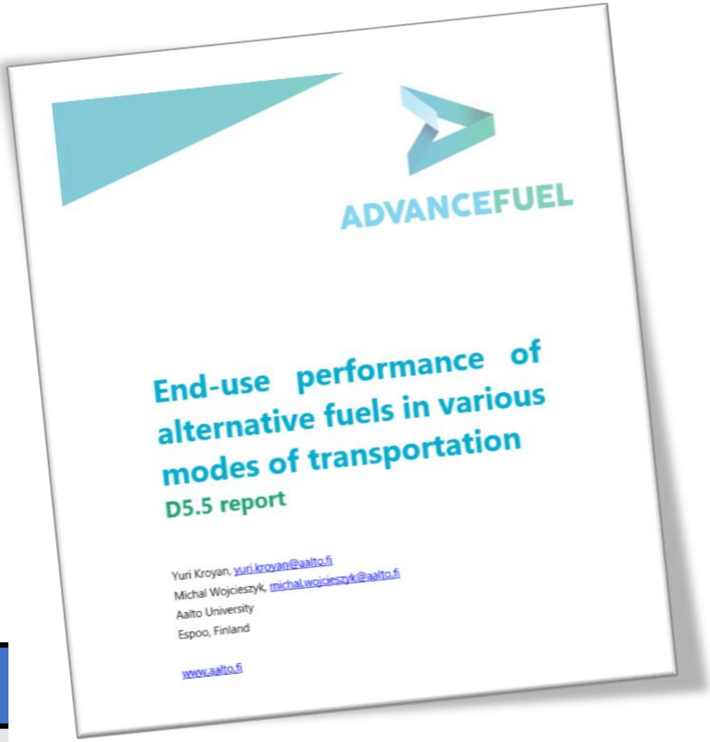
Example 4: Jet engines

Certified Sustainable Aviation Fuels (SAF):

- **Fischer Tropsch (FT-SPK),** i.e. Biomass-to-Liquid (BTL) fuels
- **Hydrotreated Esters and Fatty Acids (HEFA)**
- **Renewable Synthesized Iso-Paraffinic (SIP)**
- **Synthetic paraffinic kerosene with aromatics via Fisher Tropsch (FT-SKP/A)**
- **Alcohol-to-jet (ATJ),** from isobutanol (certified in 2016) and ethanol (certified in 2018)

Fuel	FT-SPK	HEFA	SIP	FT-SPK/A	ATJ
Blending-wall with fossil kerosene	50%	50%	10%	50%	50%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End-use performance of alternative fuels in various modes of transportation
D5.5 report

Yuri Kroyan, yuri.kroyan@aalto.fi
Michal Wojcieszyk, michal.wojcieszyk@aalto.fi
Aalto University
Espoo, Finland

www.aalto.fi

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Conclusion

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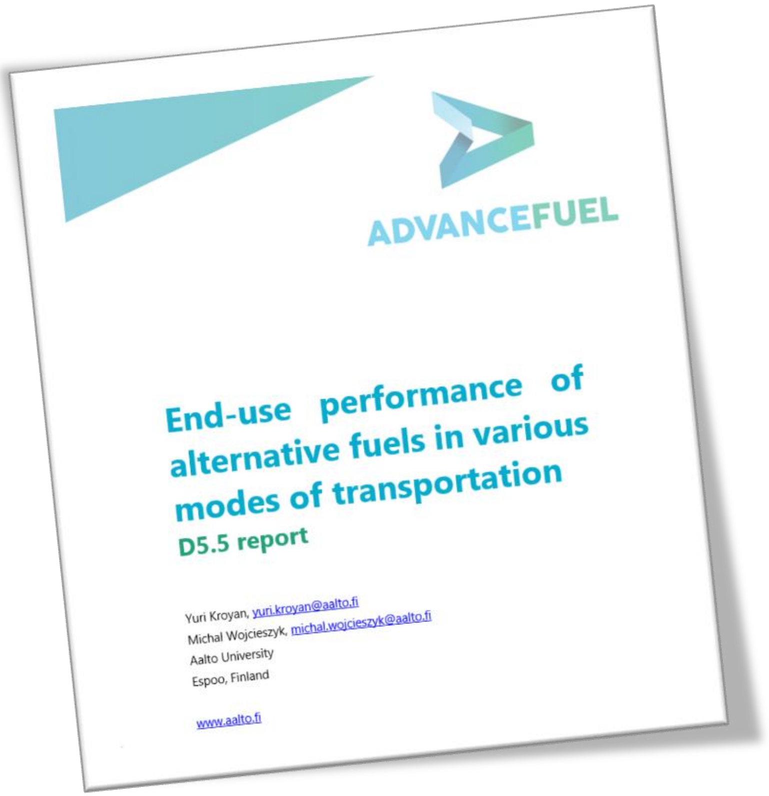
1) **7 developed models** cover various modes of transport

2) Fuel properties are essential in assessing vehicle compatibility

3) Drop-in fuels preferred (compatibility) but engine modifications also feasible (i.e. alcohols)

4) RESfuels with the potential to outperform fossil fuels in terms of GHG and local emissions, thermal efficiency and even fuel economy



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End-use performance (fuel consumption and GHG emissions) of alternative fuels in various modes of transportation.

Task 5.4: Fuel and fuel blend properties in end use (lead: AALTO)

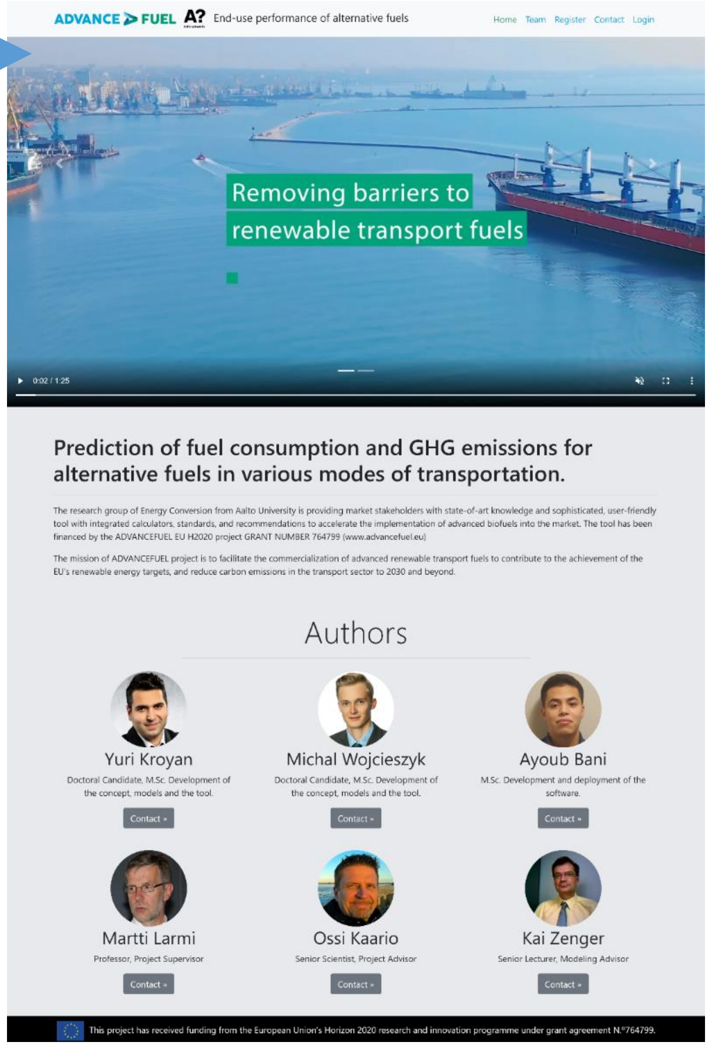
Contact:

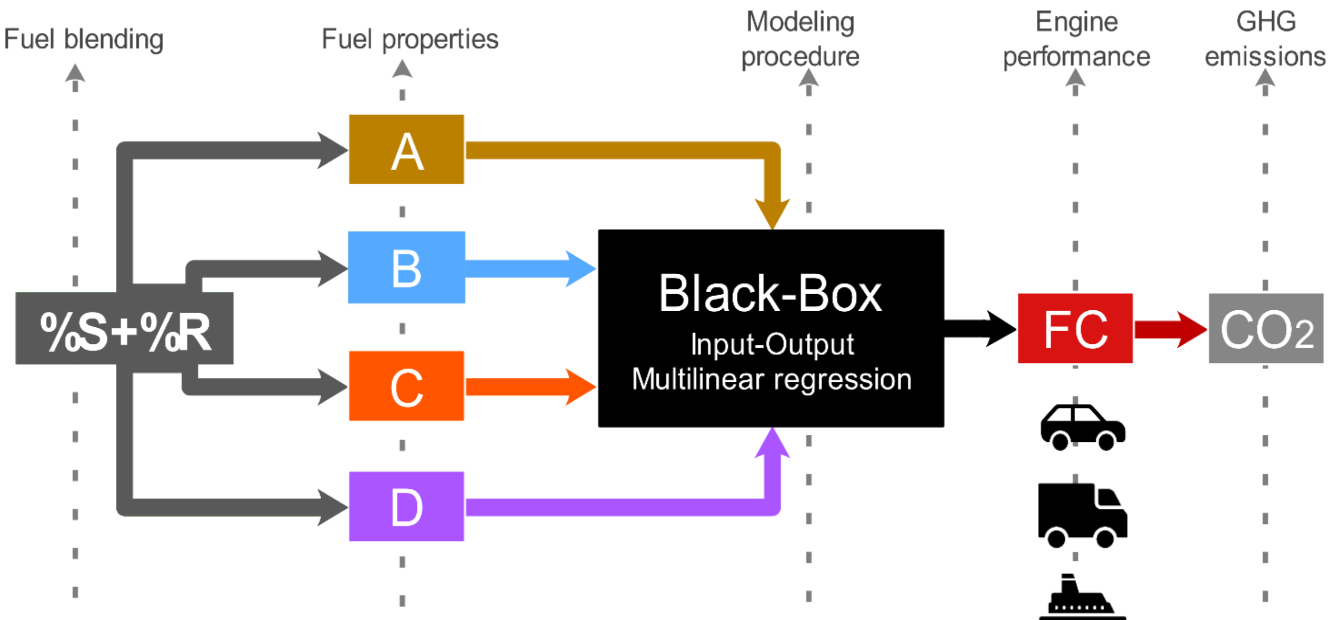
Yuri Kroyan – yuri.kroyan@aalto.fi

Michal Wojcieszyk – michal.wojcieszyk@aalto.fi

THE ONLINE TOOL

http://advancefuel.aalto.fi/





S – Standard fossil fuel (reference)

R – Renewabel fuel

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Together towards sustainable future...

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Thank you for your attention!

Yuri Kroyan
Doctoral Candidate
yuri.kroyan@aalto.fi

Michal Wojcieszyk
Doctoral Candidate
michal.wojcieszyk@aalto.fi

Martti Larmi
Professor
martti.larmi@aalto.fi

Ossi Kaario
Senior Scientist
ossi.kaario@aalto.fi

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