PYROLYSIS OIL PRODUCTION AND UPGRADING TO RENEWABLE MARINE FUELS

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THE MUSIC PROJECT – INTERMEDIATE BIOENERGY CARRIERS

Intermediate Bioenergy Carriers (IBCs) are densified biomass 'energy' – similar to coal and oil. IBCs are easier to store, transport and use than regular biomass.

In the MUSIC project, the market uptake of IBCs is facilitated, by developing feedstock mobilisation strategies, improved cost-effective logistics and trade centres.

A value chain is developed for production of pyrolysis oil in Sweden and Finland, and upgrading to marine biofuels in the Netherlands

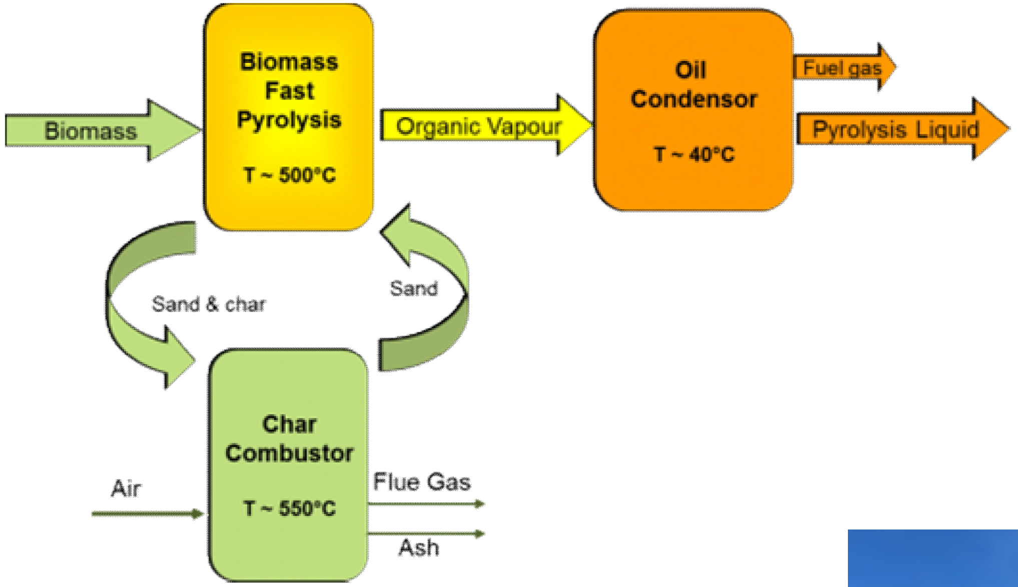
Torrefied biomass

Pyrolysis oil

Microbial oil

PYROLYSIS OIL – A PROMISING ENERGY CARRIER

Pyrolysis oil production process



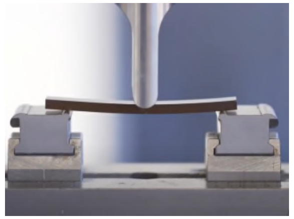
Pyrolysis oil

- Efficient, sustainable process using non-food biomass
- Proven technology: three 24.000 tonne/year plants have been implemented, in the Netherlands, Finland and Sweden
- Upgrading of pyrolysis oil is required to produce marine transport fuel

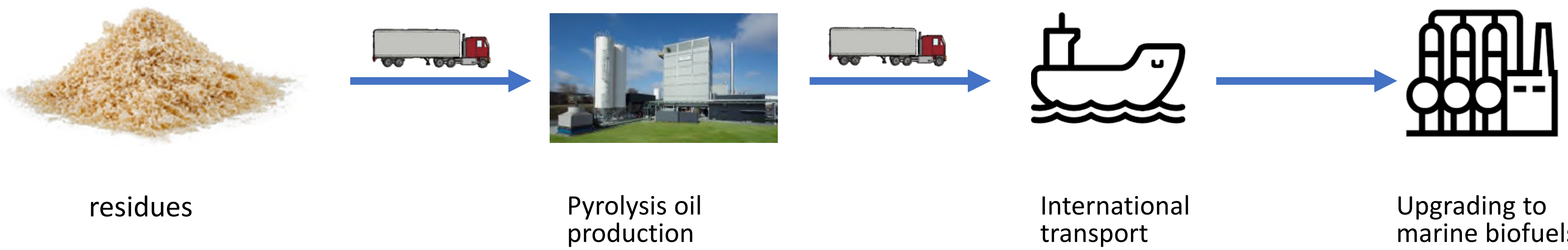
The Empyro Pyrolysis plant in Hengelo (est. 2015)

FROM BIOMASS TO MARINE TRANSPORT FUELS

- Pyrolysis oil can be used to produce heat, electricity, **transport fuels** or biobased products (e.g. foam resins, molding materials, modified wood)

- In this project rationale is to produce pyrolysis oil in places with abundance of biomass and transport it to where the markets for transportation fuels are
- Entire value chain is considered – by market players active in the chain



FROM BIOMASS TO MARINE TRANSPORT FUELS

Pyrolysis plant size is fixed at 24,000 tonne pyrolysis oil per year

Two cases were considered:

- The **Advanced case study** – Three pyrolysis plants (2 in Finland, 1 in Sweden) for ca 72,000 tonne pyrolysis oil per year

- The **Strategic case study** – Eight pyrolysis plants (4 in Finland, 4 in Sweden) for ca 192,000 tonne pyrolysis oil per year

The sailing route determined in the MUSIC advanced case study

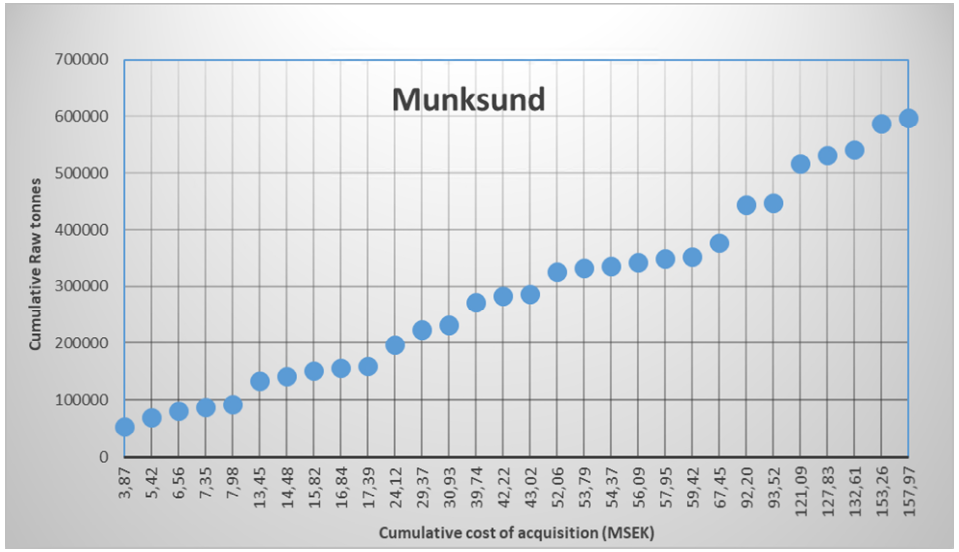
PRODUCTION OF PYROLYSIS OIL

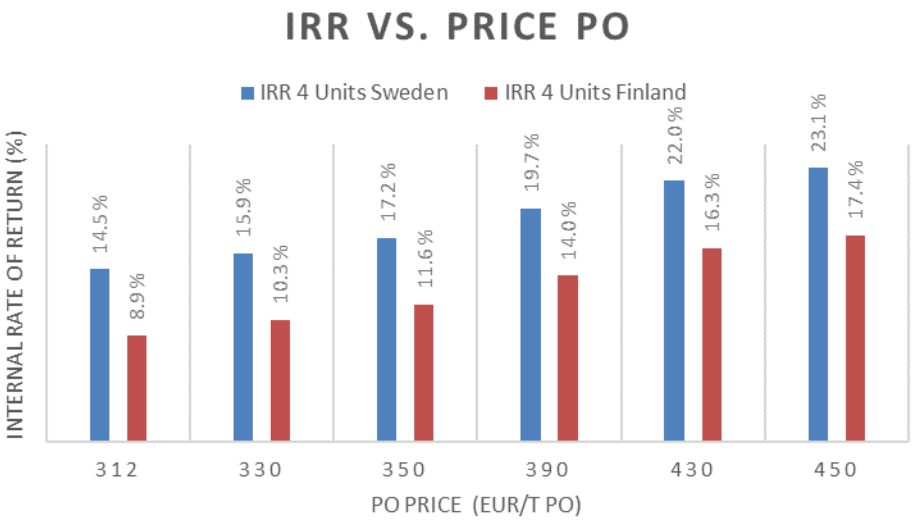
- Feedstock search: sawdust selected as prime feedstock

- Location search based on:
  - Availability of residues - costs vs quantity of feedstock graphs made
  - Proximity to harbours

- Pyrolysis plants located in pairs to share facilities

- Financial feasibility determined for Sweden and Finland cases based on market data.

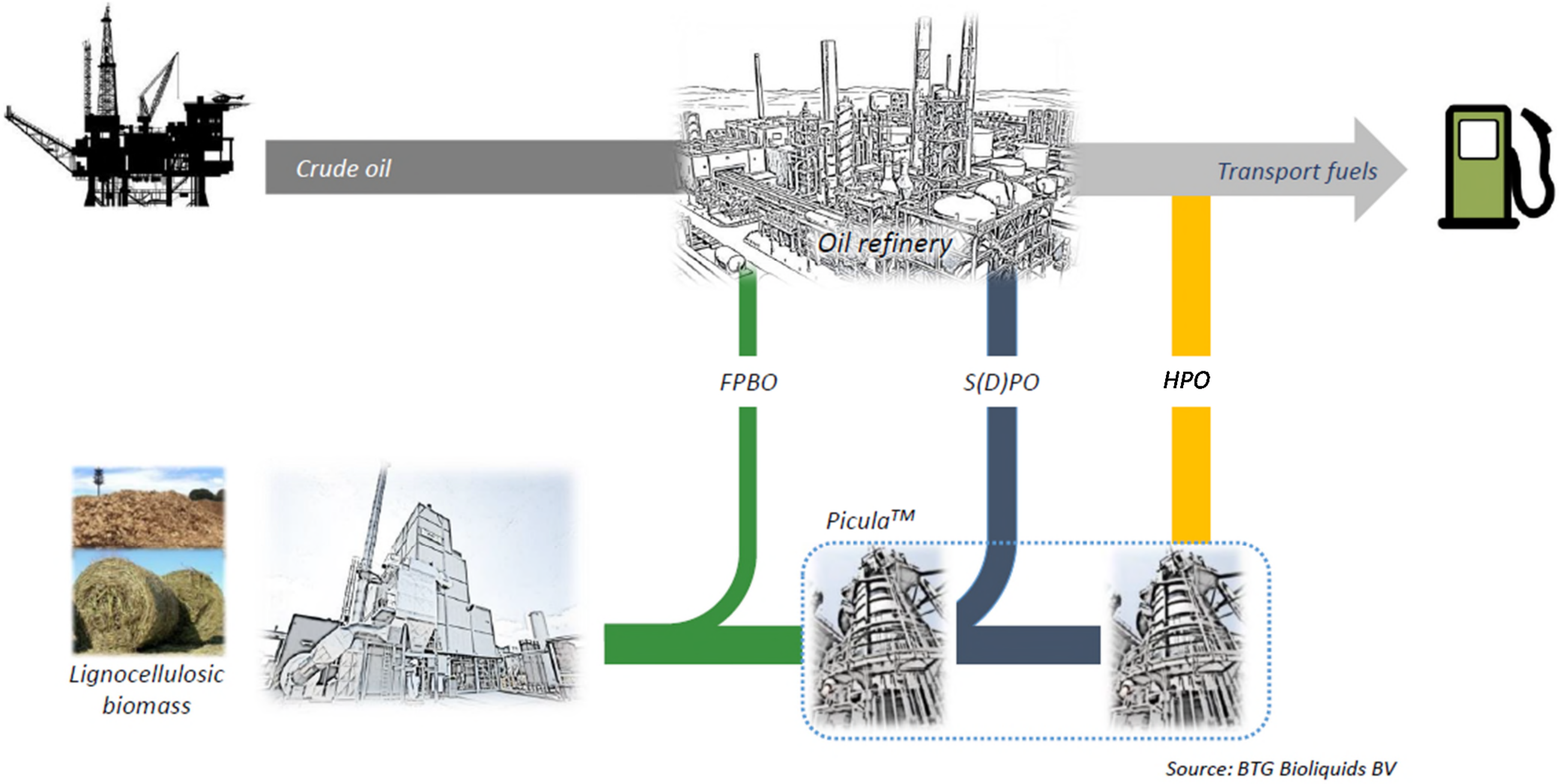




INTERNATIONAL TRANSPORT AND STORAGE

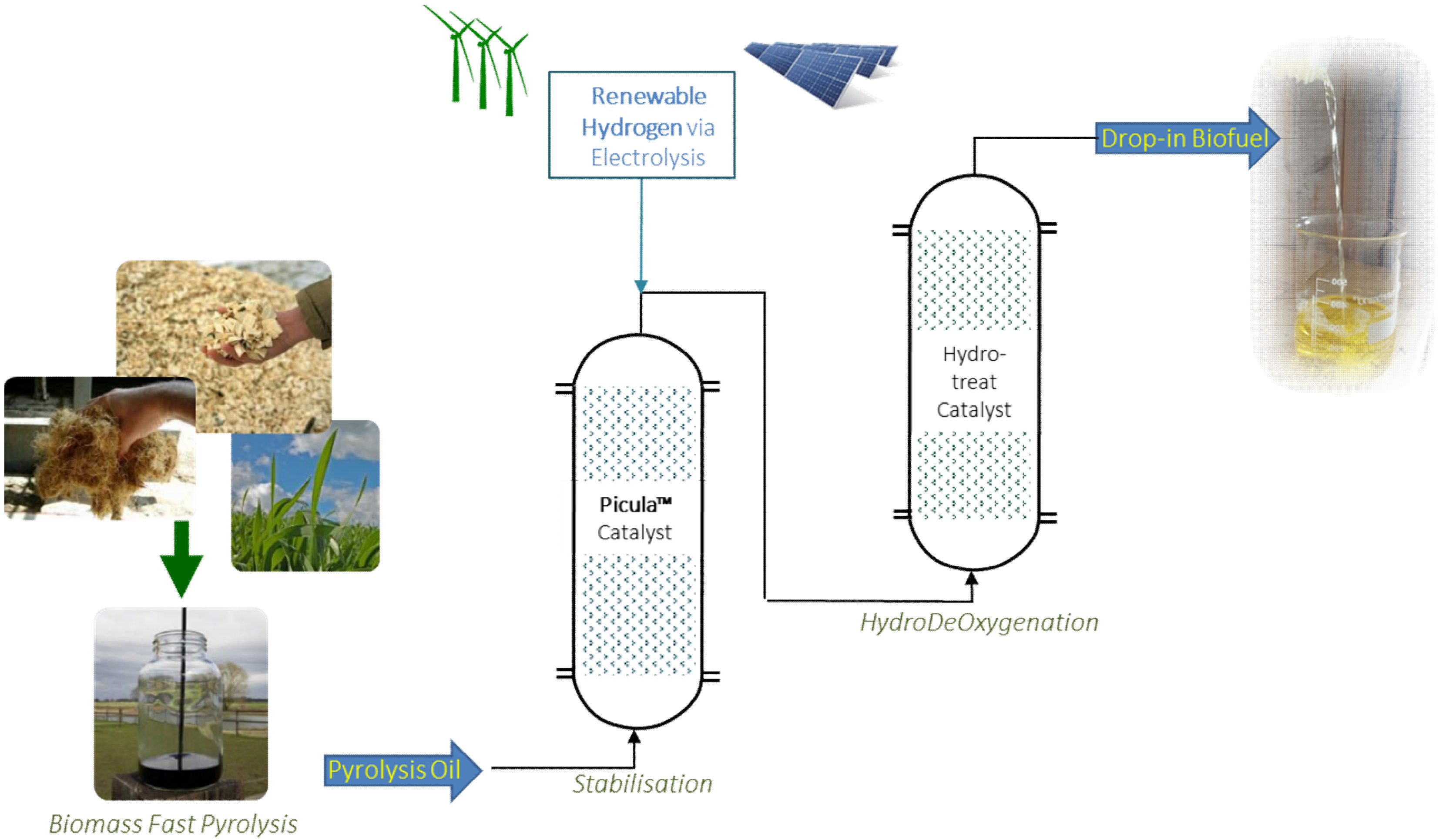
- Three ports were selected:
  - Skellefteå and Skutskär in Sweden
  - Kokkola in Finland
- Two alternatives for transport
  - Port-to-port
  - ‘Sweden hub’ – a ‘hub’ in the South of Sweden followed by transport to Rotterdam
- Other issues investigated
  - River transport, rail transport
  - Ship size
- No show-stoppers were identified; Port-to-port is financially more attractive, costs are ca 60 Euro/tonne for a 24-day interval.

UPGRADING TO MARINE BIOFUELS



- Upgrading of pyrolysis oil to transport fuels requires hydrogenation. This can be done in a refinery (co-feeding), or stand-alone

UPGRADING TO MARINE BIOFUELS



- Stand-alone upgrading involves a two-step process, with two different catalysts
- The process is working on pilot scale; demo plant is planned

UPGRADING TO MARINE BIOFUELS

Water content	25	wt%
Density	1,170	kg/m^3
LHV	16	MJ/kg
Acid Number	70	mg$_{KOH}$/g
Sulfur	< 0.5	wt%
FlashPoint	?	°C
Cetane Number	< 20	-

Crude Pyrolysis Oil

Water content	< 0.1	wt%
Density	870	kg/m^3
LHV	> 40	MJ/kg
Acid Number	< 0.15	mg$_{KOH}$/g
Sulfur	< 0.05	wt%
FlashPoint	25	°C
Cetane Number	?	-

Hydrotreated Pyrolysis Oil (HPO)

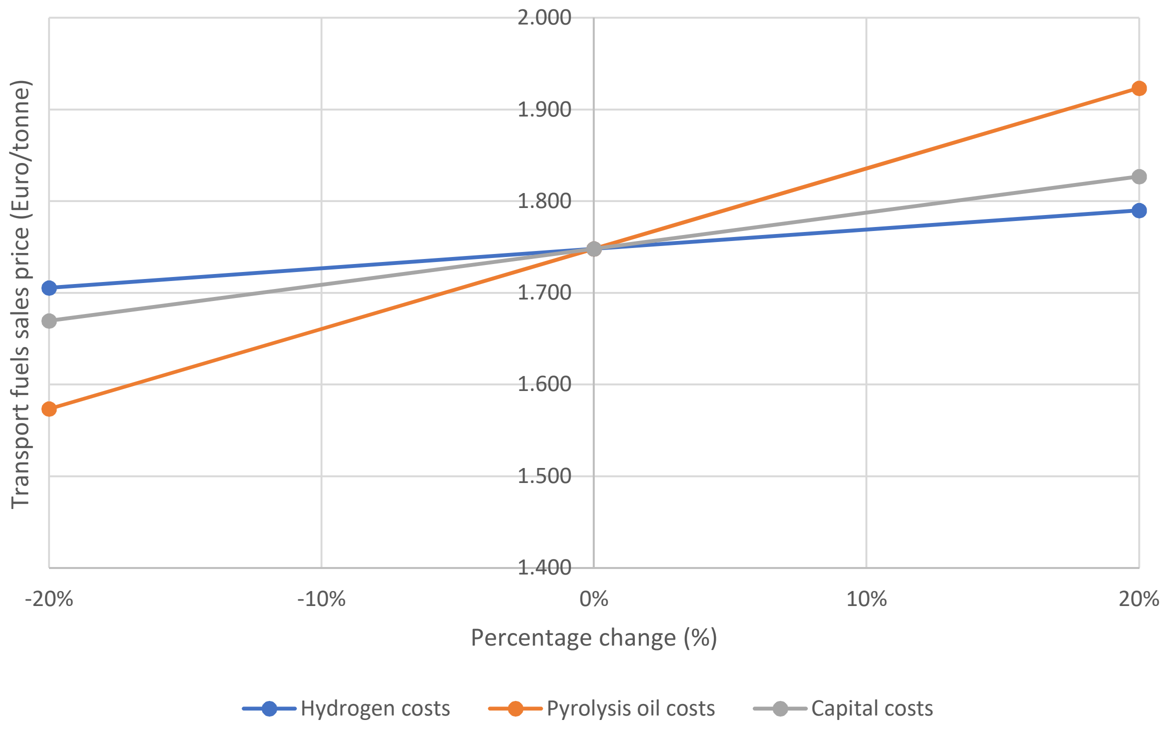
Water content	-	wt%
Density	< 890	kg/m^3
LHV	42	MJ/kg
Acid Number	< 0.5	mg$_{KOH}$/g
Sulfur	< 0.1	wt%
FlashPoint	> 60	°C
Cetane Number	> 40	-

Marine Distillate Fuel (DMA)

Comparison between pyrolysis oil, HPO and fossil Marine Distillate Fuel

UPGRADING TO MARINE BIOFUELS

- Techno-economic evaluation carried out
  - Transport fuel output: ca 72,000 tonne/year
  - Costs for transport fuels are roughly twice that of current fuels
  - Important cost items: pyrolysis oil, capital costs, hydrogen
  - Because the process has not been proven on a full scale, there are significant uncertainties in the TE evaluation.
  - Hydrogen is an essential feedstock for the plant. Nearly 40% of the energy in the product comes from hydrogen. This means that the sustainability of hydrogen is key to the sustainability of the process.



MUSIC
Market Uptake Support for Intermediate Bioenergy Carriers

UPGRADING TO MARINE BIOFUELS

Costs of using sustainable hydrogen - Does it make sense to use sustainable hydrogen

Definition of three hydrogen mixes; and emission savings per mix (Fossil fuel comparator 94 gCO2-eq/MJ fuel):

Parameter	Fully 'green'	Mix of 'green' and 'grey'	Fully 'grey'
Percentage production H2			
- PEM Electrolysis	100%	50%	0%
- NG reforming (RES electricity)	0%	40%	100%
- NG+CO2 capture (RES electrcity	0%	10%	0%
CO2 emissions transport fuel (gCO2 eq/MJ fuel)	7,8	18,2	32,9
Emission savings compared to comparator (gCO2 eq/MJ fuel)	86,2	75,8	61,1
Emission savings percentage	92%	81%	65%
Emission savings (tCO2-eq/tonne of fuel)	3,77	3,31	2,67

Costs per tonne of CO2 emission reduction – costs are lower for sustainable hydrogen

Parameter	Fully 'green'	Mix of 'green' and 'grey'	Fully 'grey'
Averaged costs of hydrogen (Euro/tonne H2)	3.300	2.494	1.560
Price difference with regular fuel (Euro/tonne	1.152	1.044	917
Costs per tonne of CO2-eq saved (Euro/tonne CO2-eq)	306	315	344

FINAL OBSERVATIONS

- The value chain from biomass to marine transport fuel using pyrolysis oil is technically viable – apart from the (TRL6) upgrading; no show-stoppers have been identified
- Costs for transport are substantial, but within acceptable limits.
- The higher design capacity does not lead to significantly lower transport fuel costs, mostly due to price increases
- Upgrading of pyrolysis oil to transport fuels will require additional demo/scale up activities; the sourcing/production of hydrogen is pivotal for economic and sustainability reasons

THANK YOU FOR YOUR ATTENTION!

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857806.