



Danube Transnational Programme

GRENDEL

Towards green, efficient and competitive river Danube transport

Greening technologies

Things you might have heard before...

GRENDEL Final Event

Benjamin FRIEDHOFF (DST)

Project co-funded by European Union Funds (ERDF, IPA)

29 October 2020 • Virtual



Background



Source: ausstellungsschiff.de



Source: marsys.tu-berlin.de/menue/forschung/elektra/



Source: www.vethpropulsion.com



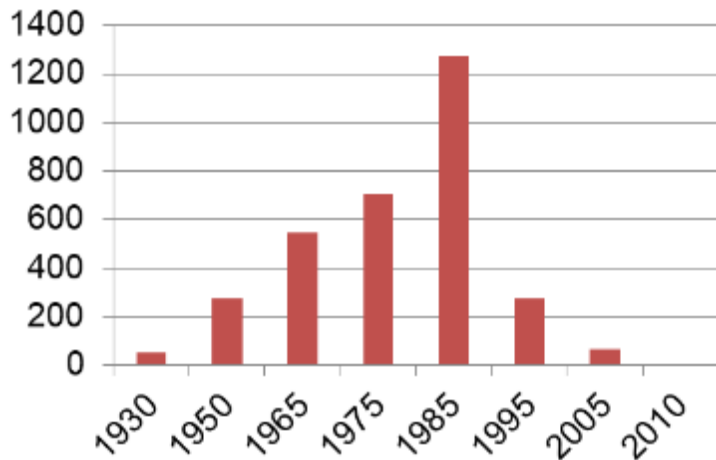
Source: shipspotting.com

Background

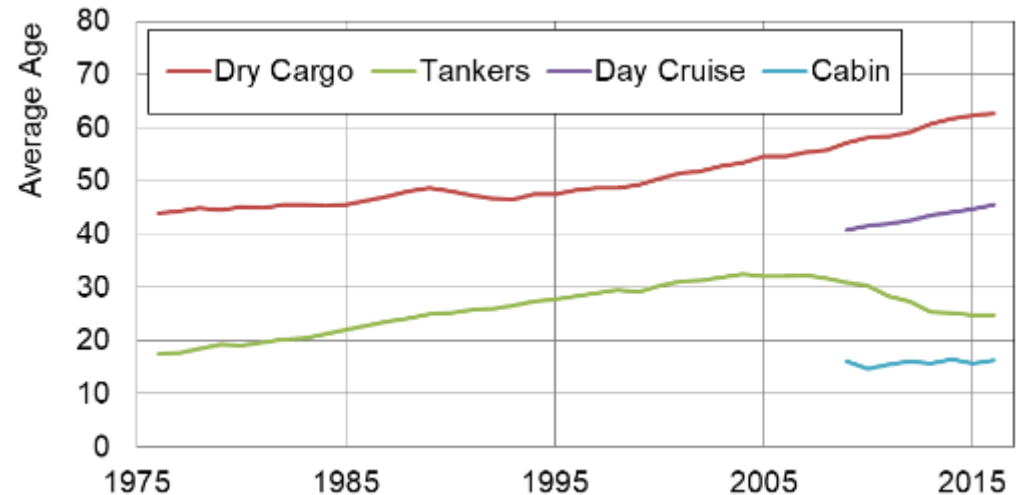


- Congested roads + capacity on waterways + low energy demand → Modal shift desired
- Long lifecycles + low renewal of engines → Too high emissions of air pollutants
- Fleet modernisation and greening required →! Limited investment capacity

Danube Fleet:



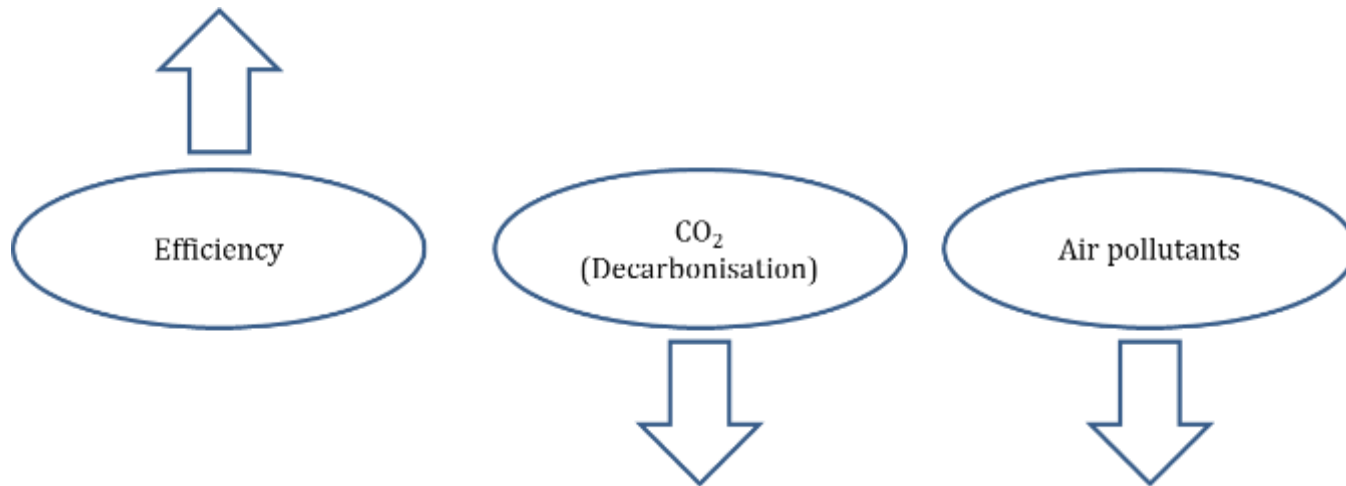
German Fleet



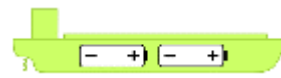
Background



- IWT sector has to invest for greening and new markets.
- Coordinated efforts required → GRENDEL
- Ultimate goal zero(-impact) emission
- Which technologies? Which transition pathways?
Any business case? Who pays?



Know-how transfer



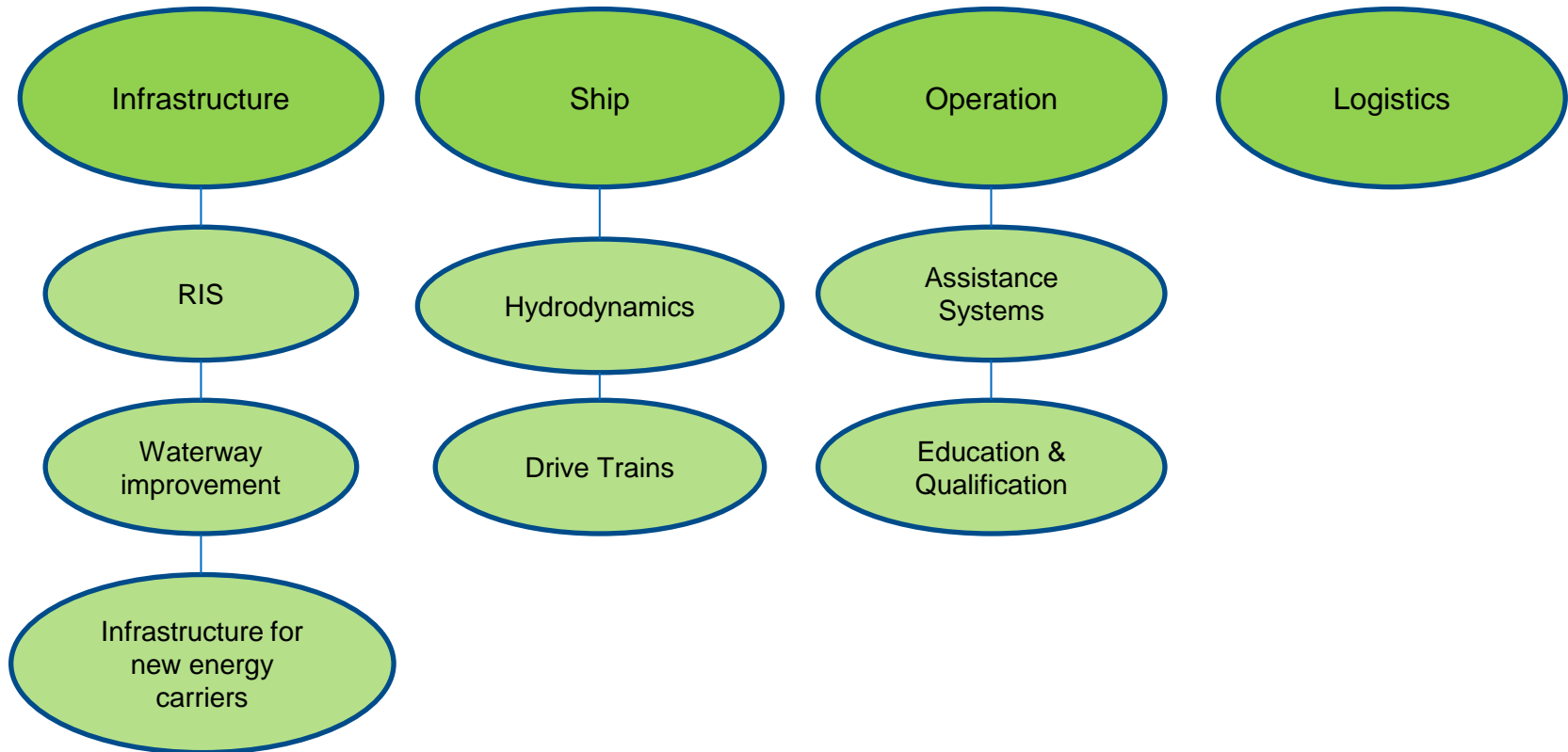
INNOVATIVE DANUBE VESSEL

- Know-how transfer events.
- Dedicated selection of measures for the Danube region.

Background



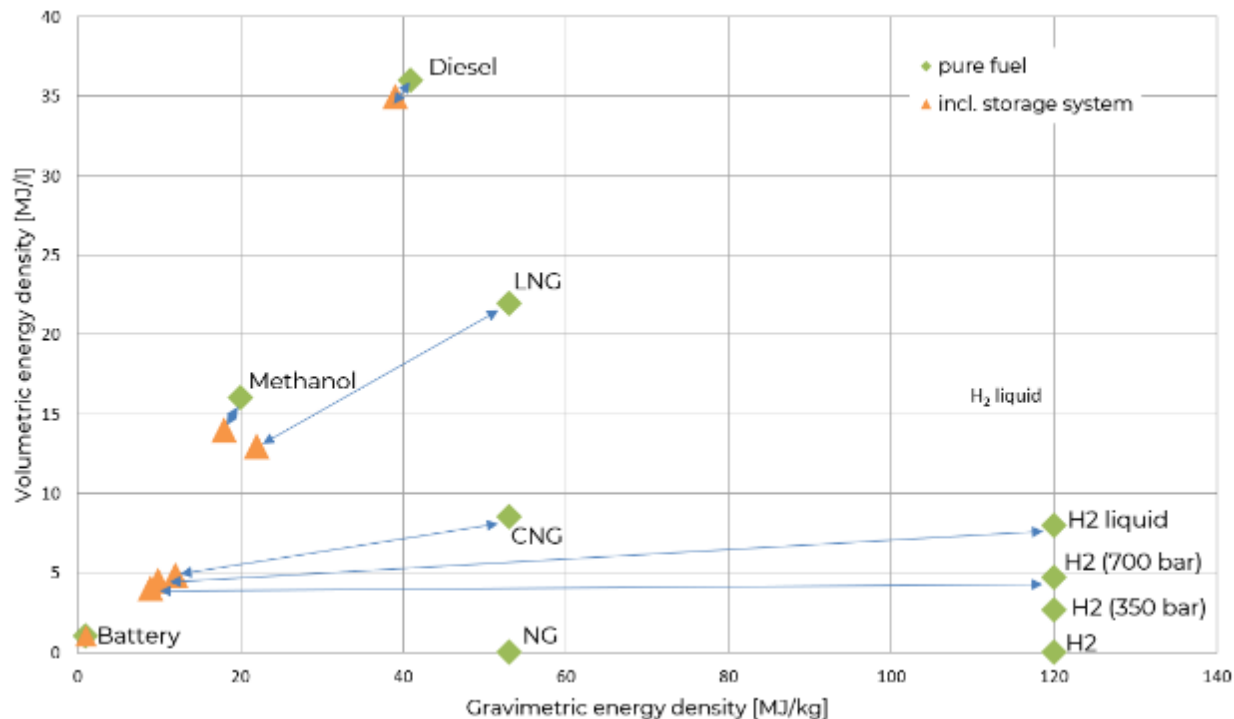
Greening Options



Energy Transition



- **Tomorrow is now**, especially in IWT
- Mannheim Declaration:
“[...] to develop a roadmap in order to reduce greenhouse gas emissions by 35% compared with 2015 by 2035, reduce pollutant emissions by at least 35% compared with 2015 by 2035, **largely** eliminate greenhouse gases and other pollutants by 2050. [...]”



Technological innovation factsheets



- **Info on Fleet Modernization**
- **No. 1** Gas and Gas-electric propulsion
- **No. 2** Diesel-electric propulsion
- **No. 3** After-treatment
- **No. 4** Fuel Cells
- **No. 5** Battery Electric Propulsion
- **No. 6** Drop-In (bio)Fuels
- **No. 7** Euro VI Truck and NRE Engines
- **No. 8** Energy Efficient Navigation

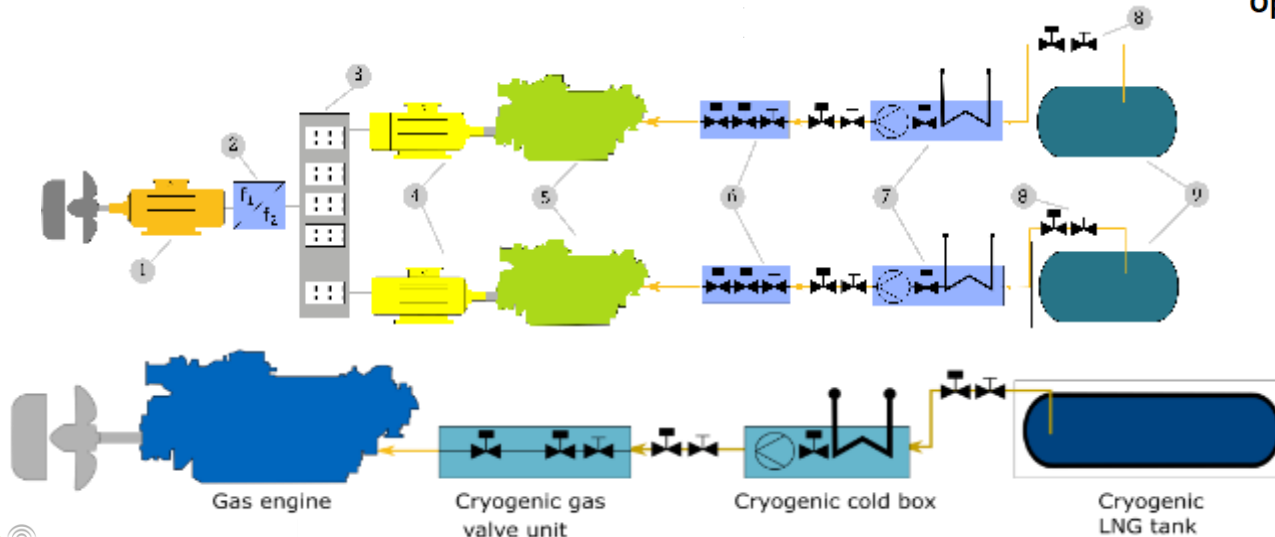
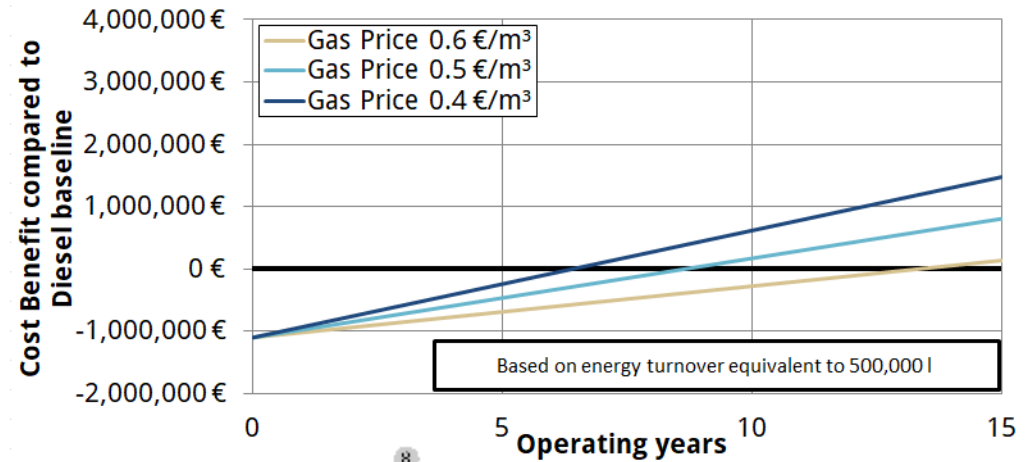
<http://www.interreg-danube.eu/approved-projects/grendel/section/technological-factsheets>

<https://www.dst-org.de/en/grendel/>

LNG / LBM



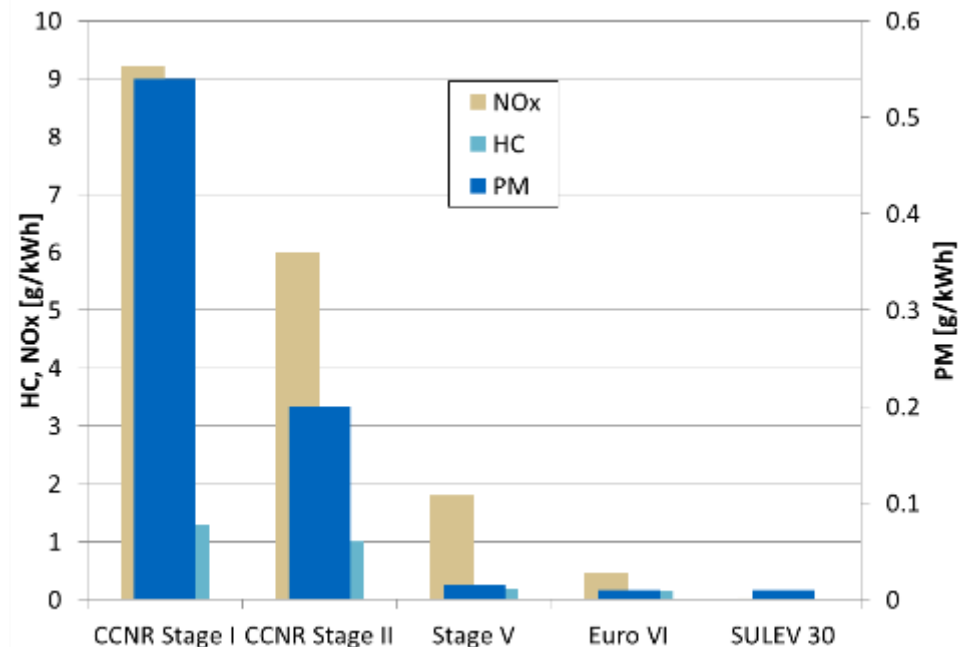
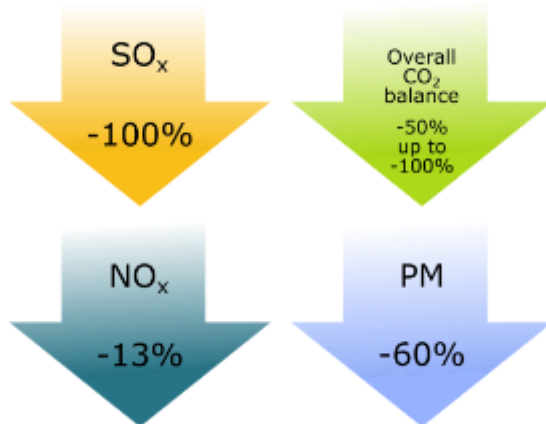
- From fossil sources or from biomass or from renewable energy (Power-to-Gas)
- Cryogenic pressure tanks
- CNG as option for moderate energy demand





Drop-In (Bio) Fuels (in St. V engines)

- Gas-to-Liquid (GTL), Biomass-to-Liquid (BTL), Power-to-Liquid (PTL)
- 2nd and 3rd generation bio-fuels e.g. Hydrotreated-Vegetable-Oil (HVO)
- Synthetic fuels covered by EN15940
- Blends up to 100% (unlike FAME)
- Marinised Euro VI and NRE engines
- Direct and diesel electric drive
- 90% target in reach
- Future availability for the sector?



Exhaust Gas After-Treatment



Exhaust Gas Recirculation: NO_x ↓ PM ↑

Diesel Oxidation Catalyst (DOC): HC, CO ↓

Diesel Particulate Filter (DPF): PM ↓

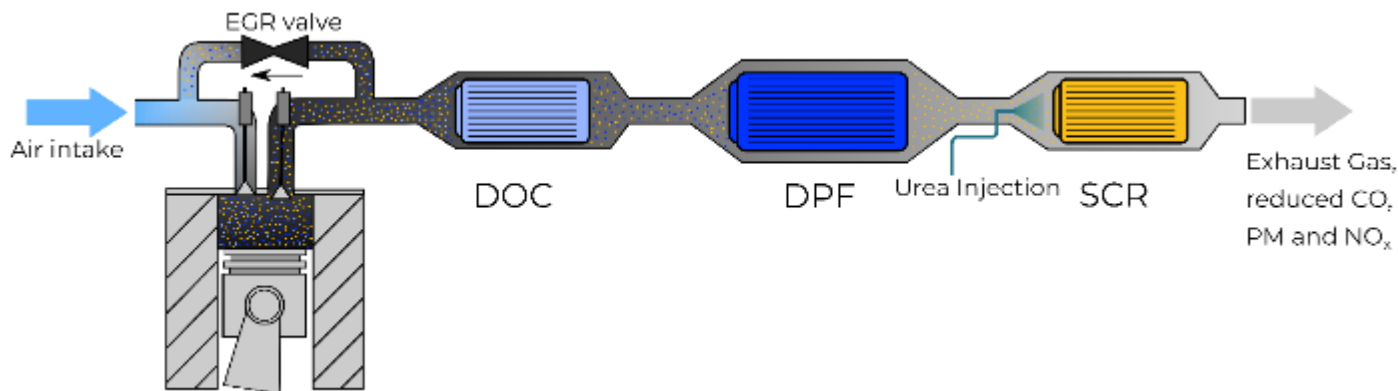
Selective Catalyst Reduction (SCR) No_x ↓

Efficiency ↑

AFTER-TREATMENT DESIGN

The design of after-treatment systems depends on prerequisites like:

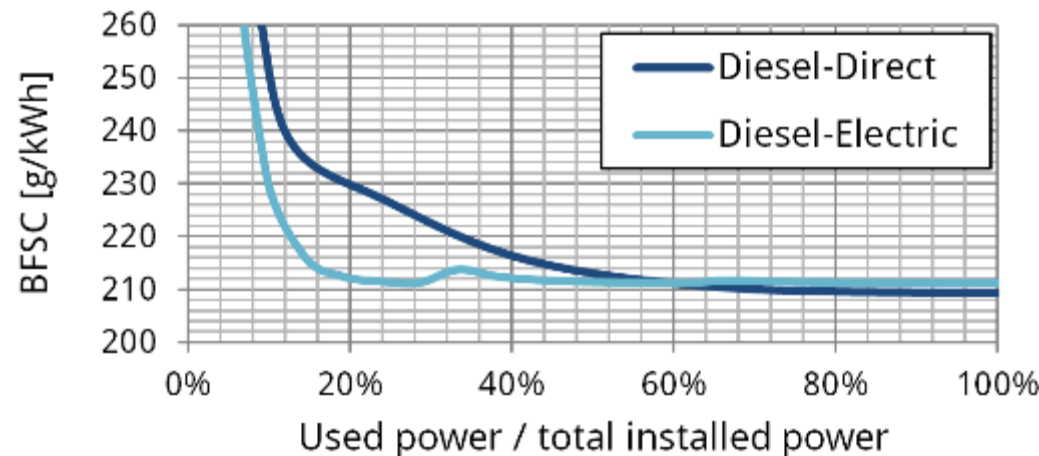
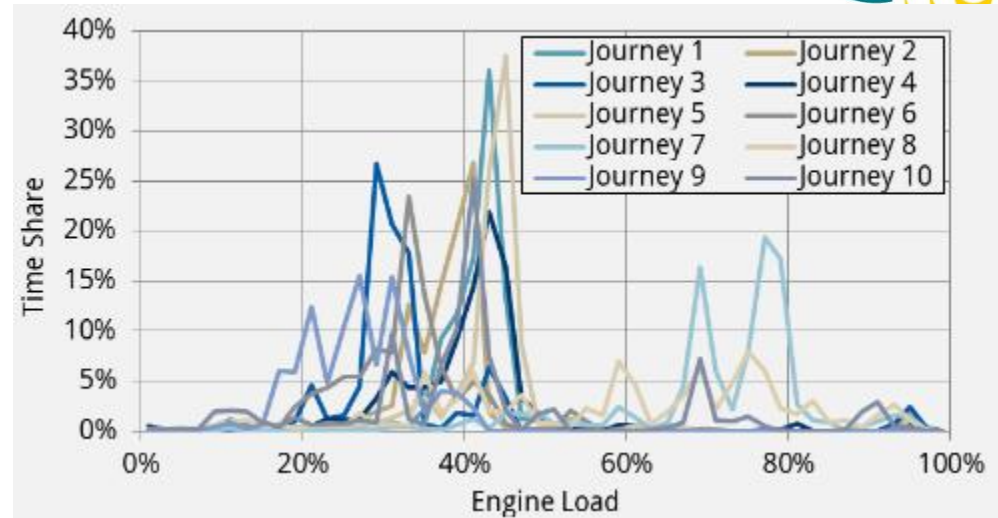
- Exhaust gas temperature
- Allowable back pressure of the engine
- Operational profile
- Available space in engine room or on deck
- Mass flow rate of exhaust gas
- Engine condition



X-Electric Systems

- Ready for any power source
- Easier implementation of batteries and fuel cells

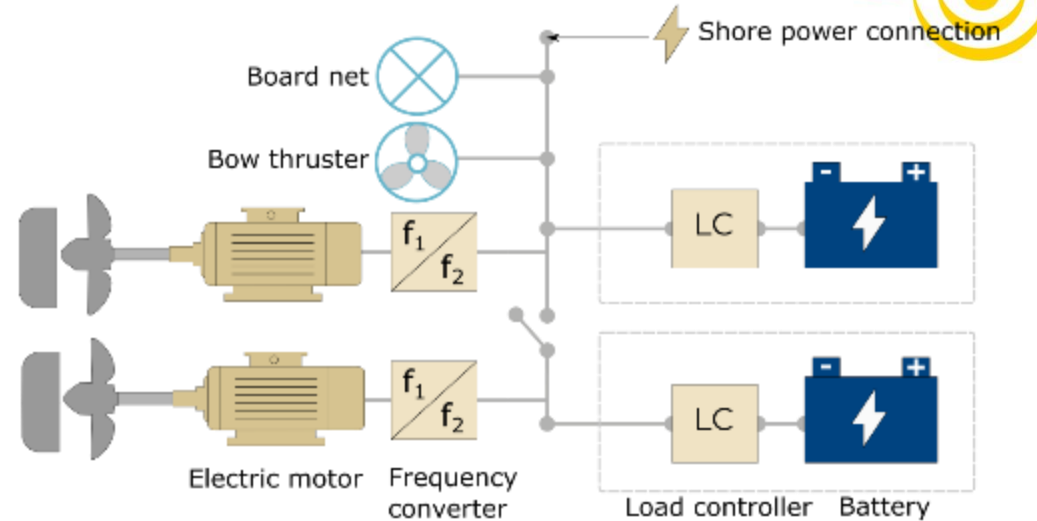
Advantages	Shortcomings
Engines run in their optimum	Investment costs
Increased overall efficiency	Additional losses
Silent	Weight
Lower emissions of air pollutants	Space
More flexibility to generate auxiliary energy	



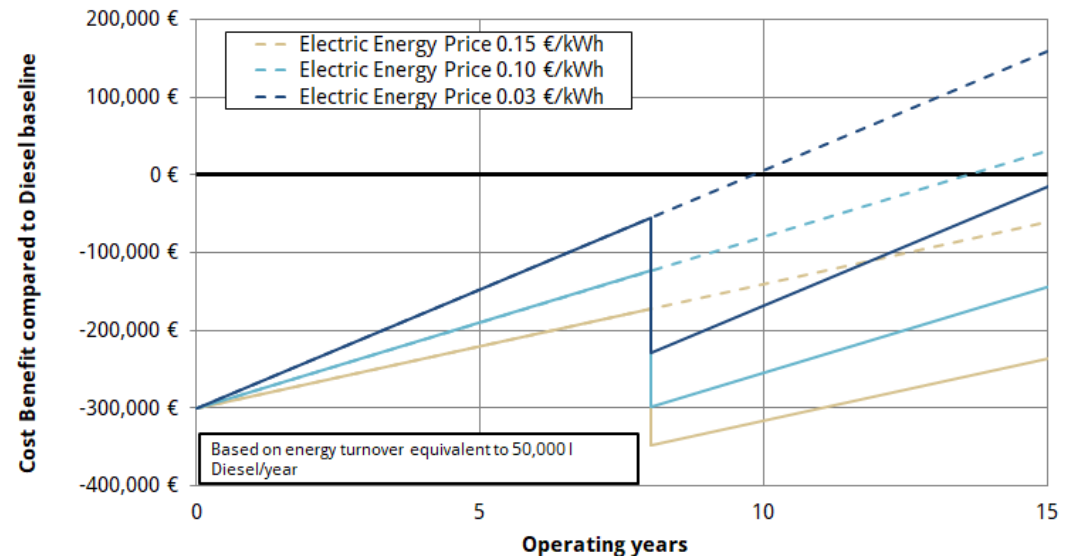
Battery Electric Sailing



- Charging on board or ashore
- Infrastructure for charging or exchange of battery containers
- Own battery or “energy-as-a-service”
- Good for peak shaving and local emission reduction



Source: Zero Emission Services B.V. (ZES)



Hydrogen FC and ICE

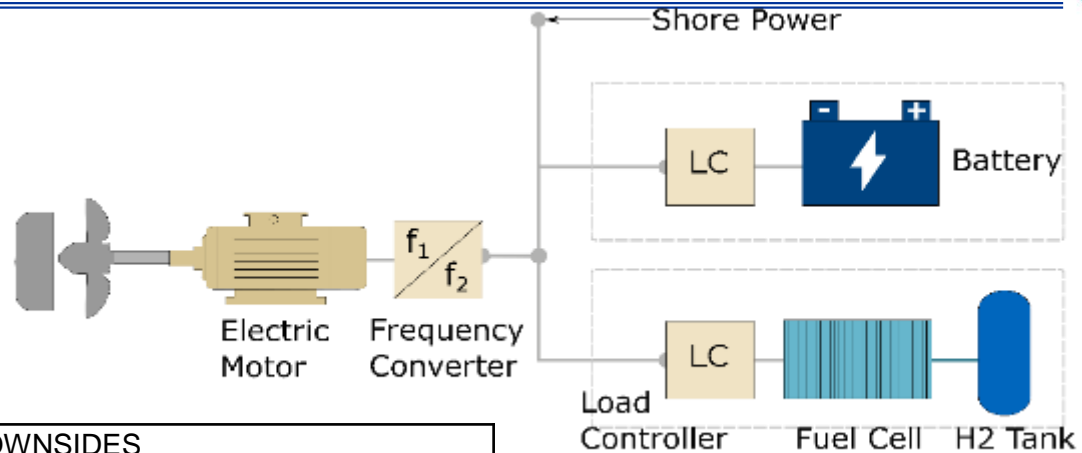


Hydrogen

- Liquid in cryogenic tanks
- Compressed

Other energy carriers

- Methanol
- LOHC
- Methane
- Ammonia



BENEFITS	DOWNSIDES
<ul style="list-style-type: none"> • High efficiency at full load and (depending on application) at partial load • Good controllability • Good performance extension due to modular design • High development potential 	<ul style="list-style-type: none"> • High investment costs • Operating experience in field test still low • Shorter useful life compared to market-dominating products (combustion engine) • Few suppliers



Energy Efficient Navigation



FACT SHEET N° 8

ENERGY EFFICIENT NAVIGATION



FACT SHEET ENERGY EFFICIENT NAVIGATION

Most measures to increase the environmental performance of inland navigation are linked to significant investments and sometimes even higher operational costs. Smart nautical operation can reduce energy consumption and emissions of air pollutants without or at little extra costs (e.g. for advice tools or training). This fact sheet offers information on energy-efficient navigation including the underlying physics.

Most important parts of the operational expenditure, Energy Efficient Navigation consumption and lesser engine wear. At the same time, it improves the considered as a no-regret greening option. Energy efficient navigation means boundary conditions. In principle, the boatmaster has a considerable influence many reasons why EEN is important for inland navigation.

Losses are directly dependent on fuel consumption. Burning 1 kg of fossil produces 230 g(Diesel)/kWh that corresponds to approximately 220 g(CO₂)/kWh. port performance for an inland vessel is highly dependent on ship characteristics and utilization. As a rough estimation 20 g(CO₂)/Nm can be assumed. Due to consumption and emissions of air pollutants, EEN increases the environmental time, reduces operational costs.

of the ship operating costs. Even small reductions in fuel costs can result in show an exemplary calculation of fuel costs and their reduction for a typical

Reduction in %	Saved Costs in €
3	8,160
5	13,600
7	19,040
10	27,200

Inland navigation have to cope with a tense intra- and intermodal competitive maritime transport, inland waterway transport (IWT) competes with road efficiency. However, the long life-cycles of ships and engines lead to delayed and, therefore, disproportionate emissions of air pollutants. To keep the position shall make every viable effort. Most other greening measures require investment. Energy efficient navigation improves the environmental performance and lower

assistance tools, which are not readily available today, or a thorough understanding. Besides operation, fuel consumption is mainly influenced by:

- Waterway characteristics
 - depth
 - width
 - current
 - bends and manoeuvring
 - traffic

of cargo loading. In inland waterway transport it is important to take into account not negligible. These include the bow and stern waves, the return current in shallow water and canal effects, in the event of the water being limited in

depth or laterally.

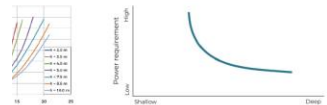
FACT SHEET ENERGY EFFICIENT NAVIGATION

5 FOR ENERGY EFFICIENT NAVIGATION

ident on the speed, different resistance components and influencing factors. The following energy consumption.

NG ON WATER DEPTH

power is stronger depending on the velocity than in unrestricted water. The relationship is described by an exponential curve. Due to interference of the wave system and the flow depth requires an increase in propulsive power needed to reach a given speed. The following graph against the velocity plotted for seven different water depths. Based on the diagram the velocity is reduced with decreasing water depth and constant power. The relationship at constant speed is shown in the diagram on the right. The steep rise on the left axis means speed is usually limited by the water depth.



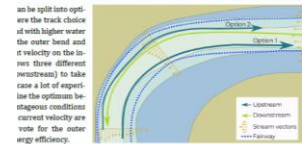
and power, velocity of the ship and water depth are the main basis for EEN. This principle is the same for all vessels. The three most important factors are:

- proportionate with speed
- of by shallow water effects
- at small water depth

the engine power according to the boundary conditions: depending on ship's draught, wave and surrounding traffic. Another constraint is that the cargo is delivered at a defined time for the entire voyage leads to higher average speeds and thus to higher consumption than a sufficient time window, which creates a variety of possibilities to adjust and thus save fuel. Especially the adherence to the given travel duration while driving requires a lot of experience.

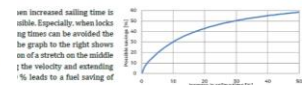
to drive economically, which is dependent on currents, bends and different water depths constantly has to be adapted. Smooth steering with minimized rudder activity also helps to

FACT SHEET ENERGY EFFICIENT NAVIGATION



can be split into optimal track choice at higher water the outer bend and its velocity on the inner (three different waterstream) to take care a lot of experience the optimum best conditions current velocity are vital for the outer energy efficiency.

water characteristics like water depth and current can be sailed in many different ways. To stick to a fixed schedule, sailing with constant speed over ground is the easiest speed through water or constant power are other sailing policies. However, due to it is more energy efficient to reduce the speed in sections with shallow water and time in deeper sections. Complexity is further increased by different currents and the ship to compute the optimum choice of speed and to assist trip planning are under the ship and waterway conditions. Simulations showed that depending on fuel can be saved with optimized sailing policies without extending the sailing time.



an increased sailing time is viable. Especially when locking times can be avoided the graph to the right shows on a stretch on the middle the velocity and extending % leads to a fuel saving of

flexibly for the transport of a wide variety of freight. Through an optimal logistics potential to the full. Waiting periods and handling times in a port, especially for container vessels. With the best possible use of the capacity and a short stay in the port, the travelling speed can be reduced, resulting in lower emissions.

But certain factors can react to them correctly:

- small vessels
- ing factors
- s)

FACT SHEET ENERGY EFFICIENT NAVIGATION

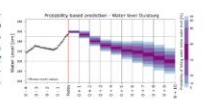
IGATION TOOLS

NG TRAININGS

of a simulator based training teaches a topography oriented improving competitiveness in g is recognized by the GREEN theoretical and practical simulator to advantageous to help quickly into practical skills. avoided. In such a training distance, including port entrances and weather conditions to also



an important instrument to inland navigation. RIS provide up to waterway conditions. The figure predicted water levels for a Rhine waterway Information Service of shipping Administration. This is the of the ships and energy efficiency.



by Stichting Projecten Binnenvaart. It is based on carbon footprint (CO₂ per km) of a based on transported tonnage, distance and on this knowledge, the ship operator in addition, the CO₂ reports are provided to

EMPLOYMENT

each ship should be considered to decide on the best measures offers a high potential for increased energy efficiency comparable to each other in IWT (even with similar load based on the same relation) in a more efficient way under development but not available yet energy efficient but also cost-efficient important and can be optimized simultaneously

Contact

For further information or suggestions how to improve this fact sheet please do not hesitate to contact:

DST - Development Centre for Ship Technology and Transport Systems
Oststraße 77
47057 Duisburg, Germany
Phone: +49 203 99369 29
Fax: +49 203 99369 70
E-Mail: ErstInfo@dst-arg.de
Web: www.dst-arg.de

Recommendations



Depending on budget, ambition and time-frame:

- Awareness and energy efficient navigation
- Maintenance
- Consulting an expert
- Exhaust gas after-treatment
- Right-sized Stage V (IWA/IWP or NRE), Euro VI engine
- Diesel-electric drivetrain
- (Blending of) bio-fuels
- LNG for the matching application
- Battery
- Fuel-Cell (Hydrogen, Methanol, Ammonia)
- Ammonia in ICE...





Danube Transnational Programme GRENDL

Benjamin FRIEDHOFF

Manager Experiments, Fleet Modernisation & Emissions

Development Centre for Ship Technology and Transport Systems

Oststr. 77, 47057 Duisburg/Germany

M +49 170 782 794 0 T +49 203 99 369 29

E friedhoff@dst-org.de W www.dst-org.de

Photo: © NAVROM

GRENDL “Green and efficient Danube fleet”

Towards modernisation & greening of Danube inland waterborne sector and strengthening its competitiveness

www.interreg-danube.eu/grendel