Danube Transnational Programme
GRENDEL

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.

FACT SHEET N° 8

ENERGY EFFICIENT NAVIGATION

Photo by DST

In cooperation with

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GENERAL INFORMATIONS

Besides staff costs, the fuel burned is one of the most important parts of the operational expenditures. **E**nergy **E**fficient **N**avigation (EEN) lowers costs through reduced energy consumption and lesser engine wear. At the same time, it improves the environmental performance and is, therefore, considered as a no-regret greening option. Energy efficient navigation means optimal navigation adapted to environmental boundary conditions. In principle, the boatmaster has a considerable influence on how much energy is consumed. There are many reasons why EEN is important for inland navigation.

Emissions and ecological impact: The emissions are directly dependent on fuel consumption. Burning 1 kg of gasoil produces 3.15 kg of CO_2 and a specific consumption of 230 g(Diesel)/kWh that corresponds to approximately 720 g(CO_2)/kWh. The average CO_2 emission related to the transport performance for an inland vessel is highly dependent on ship characteristics, waterway conditions, operational profile and utilization. As a rough estimation 20 g(CO_2)/tkm can be assumed. Due to the more or less constant ratio of fuel consumption and emissions of air pollutants, EEN increases the environmental performance of the inland vessel and, at the same time, reduces operational costs.

Fuel costs: Fuel costs account for at least 20 % of the ship operating costs. Even small reductions in fuel costs can result in enormous savings. The following two tables show an exemplary calculation of fuel costs and their reduction for a typical cargo vessel.

Cargo vessel (110 m x 11.4 m)	
Consumption	400,000 l/year
Spec. Fuel Costs	e.g. 0.68 €/l
Fuel Costs	272,000 €/year

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

Competitive environment: Ship operators in inland navigation have to cope with a tense intra- and intermodal competitive situation. While there is no real alternative to maritime transport, inland waterway transport (IWT) competes with road and rail transport. Shipping has the best energy efficiency. However, the long life-cycles of ships and engines lead to delayed implementation of green drivetrain solutions and, therefore, disproportionate emissions of air pollutants. To keep the position of the eco-friendliest transport mode, IWT shall make every viable effort. Most other greening measures require investments and/or increase the operational costs. Energy efficient navigation improves the environmental performance and lowers the operating costs at no or very low costs.

PHYSICAL BACKGROUND

Energy efficient navigation requires on-board assistance tools, which are not readily available today, or a thorough understanding of the influencing factors and some physics. Besides operation, fuel consumption is mainly influenced by:

- Ship characteristics
  - length
  - draught
  - width
  - hull form (vessel typ)
  - engine (propulsion typ)
- Waterway characteristics
  - depth
  - width
  - current
  - bends and manoeuvring
  - traffic

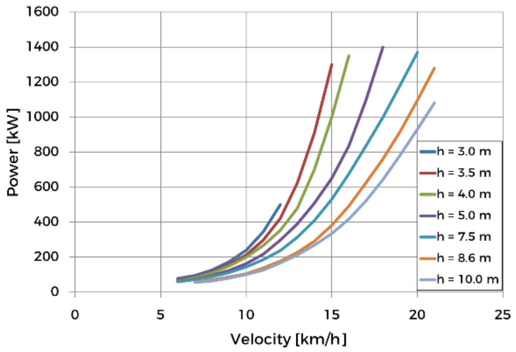
Other factors include sailing time, weather and cargo loading. In inland waterway transport it is important to take into account ship-induced flows and waves as they are not negligible. These include the bow and stern waves, the return current and the dynamic sinkage. Further factors are the shallow water and canal effects, in the event of the water being limited in depth or laterally.

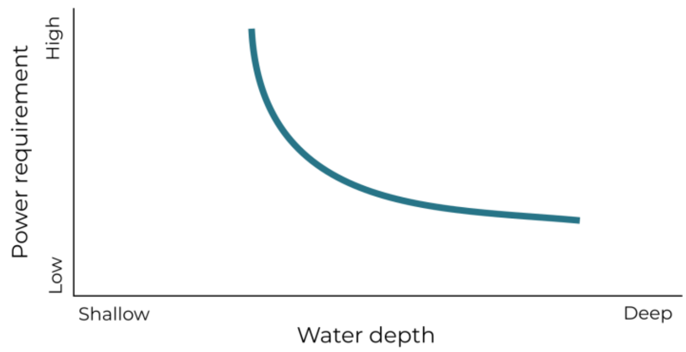
INFLUENCING FACTORS FOR ENERGY EFFICIENT NAVIGATION

The ship's power demand is dependent on the speed, different resistance components and influencing factors. The following effects have an immediate effect on energy consumption.

POWER REQUIREMENT DEPENDING ON WATER DEPTH

In confined water, the required power is stronger depending on the velocity than in unrestricted water. The relationship between power and velocity can be described by an exponential curve. Due to interference of the wave system and the flow around the ship, a reduced water depth requires an increase in propulsive power needed to reach a given speed. The following diagram shows the required power against the velocity plotted for seven different water depths. Based on the diagram the conclusion can be made that the velocity is reduced with decreasing water depth and constant power. The relation between required power and water depth at constant speed is shown in the diagram on the right. The steep rise on the left side of the curve shows that the maximum speed is usually limited by the water depth.





The relationships between required power, velocity of the ship and water depth are the main basis for EEN. This principle can be used to reduce energy consumption. The three most important facts are:

- Power demand rises disproportionate with speed
- Power demand is increased by shallow water effects
- Maximum speed is limited at small water depth

OPTIMUM TRACK AND SPEED

The experienced skipper adjusts the engine power according to the boundary conditions: depending on ship's draught, water level, current, fairway conditions and surrounding traffic. Another constraint is that the cargo is delivered at a defined unloading time. A tight time schedule for the entire voyage leads ceteris paribus to higher average speeds and thus to higher power requirements and fuel consumption than a sufficient time window, which creates a variety of possibilities to adjust speed and power requirements and thus save fuel. Especially the adherence to the given travel duration while driving smoothly and energy-efficiently requires a lot of experience.

Every boatmaster can learn how to drive economically, which is dependent on currents, bends and different water depths to which the driving technique constantly has to be adapted. Smooth steering with minimized rudder activity also helps to reduce fuel consumption.

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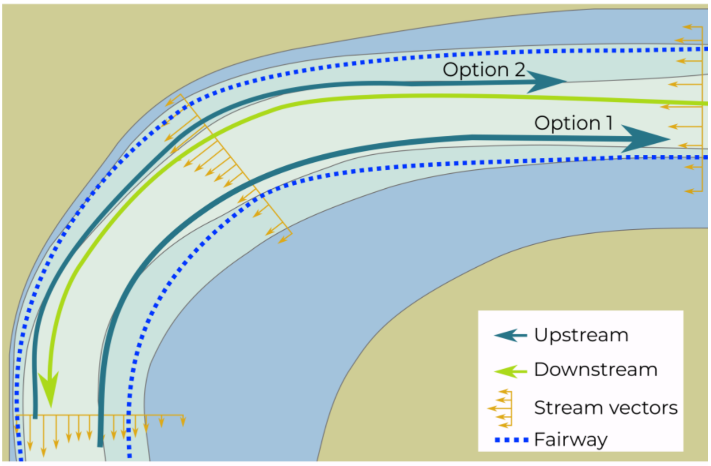
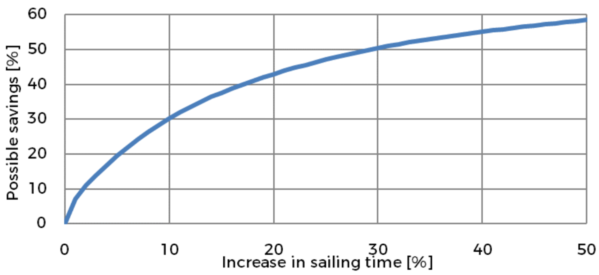
Energy efficient navigation in general can be split into optimized choice of the track and speed. Here the track choice is explained based on a typical river bend with higher water depth and velocity of the current on the outer bend and more shallow water with lesser current velocity on the inner side. The figure to the right shows three different routes (two options upstream, one downstream) to take the bend. Especially for the upstream case a lot of experience and/or data is required to determine the optimum between the two options, since the advantageous conditions of high water depth and low oncoming current velocity are separated. Downstream both effects vote for the outer track with the focus being placed on energy efficiency.



A journey covering stretches with different characteristics like water depth and current can be sailed in many different ways. With a defined duration of the trip, e.g. to stick to a fixed schedule, sailing with constant speed over ground is the easiest option to control the timeline. Constant speed through water or constant power are other sailing policies. However, due to the physical effects mentioned above it is more energy efficient to reduce the speed in sections with shallow water and compensate the corresponding loss in time in deeper sections. Complexity is further increased by different currents and the lateral choice of the track. Onboard tools to compute the optimum choice of speed and to assist trip planning are under development but require detailed information of the ship and waterway conditions. Simulations showed that depending on ship and stretch between 3 and 7 % of fuel can be saved with optimized sailing policies without extending the sailing time.

INCREASE IN SAILING TIME

Without critical time of arrival and when increased sailing time is acceptable much higher savings are possible. Especially, when locks or terminals are approached and waiting times can be avoided the fuel is saved without disadvantages. The graph to the right shows data out of simulations for the navigation of a stretch on the middle Rhine in upstream direction. Reducing the velocity and extending the fastest possible sailing time by 10 % leads to a fuel saving of 30 %.



LOGISTIC CHAIN

Inland waterway vessels can be used very flexibly for the transport of a wide variety of freight. Through an optimal logistics chain, the inland vessels can use their potential to the full. Waiting periods and handling times in a port, especially for container transport, must be kept as short as possible. With the best possible use of the capacity and a short stay in the port, with the same transport performance the traveling speed can be reduced, resulting in lower emissions.

BOATMASTER SKILLS

The boatmasters must constantly monitor certain factors and react to them correctly:

- Minimum safe distance to other vessels
- Effect of groyne fields
- Cross flow of external influencing factors
- Curve travel (centrifugal forces)
- Up- and Downstream trips

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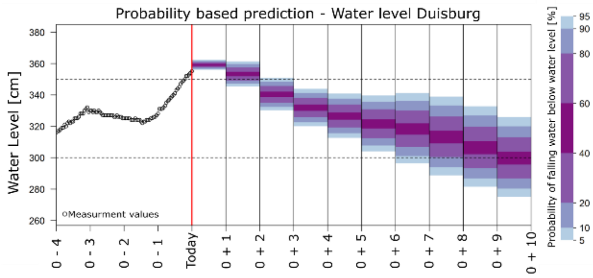
ENERGY EFFICIENT NAVIGATION TOOLS

TOPOGRAPHY-ORIENTED SAILING TRAININGS

Within the German project Topofahrt a simulator-based training was developed. The two-day course teaches a topography-oriented driving style and thus contributes to improving competitiveness in inland navigation. The TOPO-Training is recognised by the GREEN AWARD foundation and comprises theoretical and practical contents. Training on a ship-handling simulator is advantageous to help theoretical knowledge translate more quickly into practical skills. Furthermore, the risk of accidents is avoided. In such a training different types of vessels can be simulated, including port entrances and exits as well as different water and weather conditions to also train emergency manoeuvres.

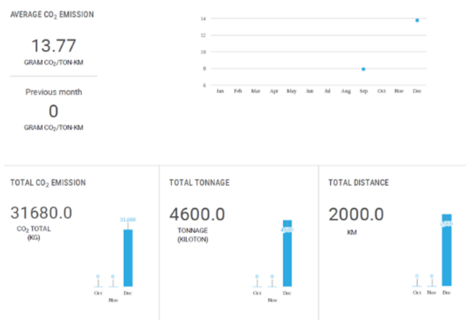
RIVER INFORMATION SERVICES

River Information Services (RIS) are an important instrument to increase safety and efficiency in inland navigation. RIS provide up to date information on water levels and waterway conditions. The figure shows an example of measured and predicted water levels for a Rhine gauge provided via the Electronic Waterway Information Service of the German Federal Waterways and Shipping Administration. The information is used for optimized loading of the ships and energy efficient navigation.



ECONAUT

Econaut is an app that was launched by Stichting Projecten Binnenvaart. It is designed to monitor the fuel consumption and carbon footprint (CO_2 per tkm) of a vessel. The CO_2 emission is calculated based on transported tonnage, distance travelled and fuel consumption. Based on this knowledge, the ship operator should adapt his driving behaviour. In addition, the CO_2 reports are provided to ship owners as well as contractors.



CONSIDERATIONS FOR DEPLOYMENT

- Individual cost structure of each ship should be considered to decide on the best measures
- Combination of different measures offers a high potential for increased energy efficiency
- No two trips are directly comparable to each other in IWT (even with similar load based on the same relation)
- Awareness helps a lot to sail in a more efficient way
- Advice tools based on RIS are under development but not available yet
- Smart Steaming is not only energy efficient but also cost-efficient
- Precise scheduling is most important and can be optimized simultaneously

Contact

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