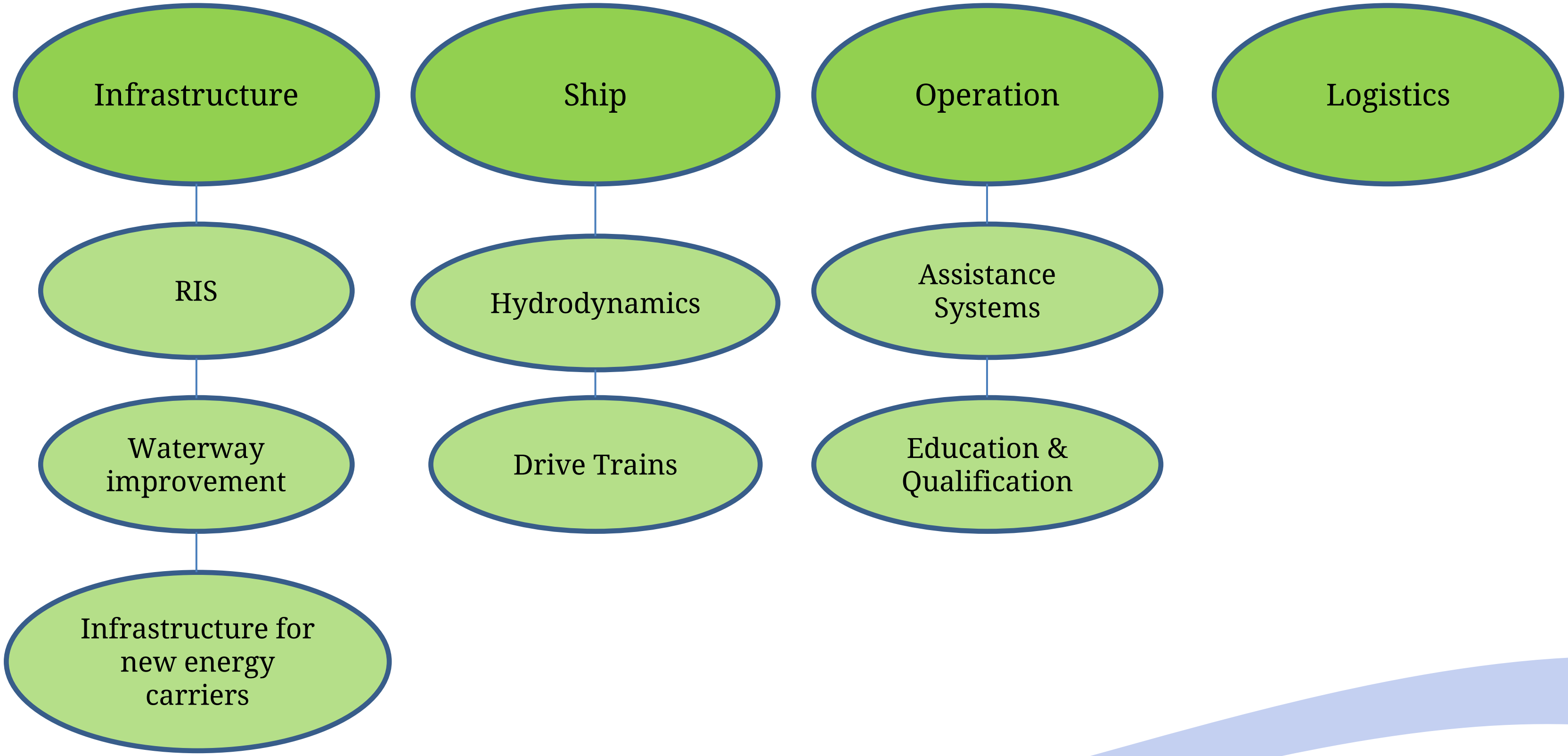
(Hydrodynamic) solutions to increase resilience & energy efficiency

Know-How Transfer Event for Modernisation of Danube inland vessels
29 September 2020

Benjamin Friedhoff - DST

Motivation

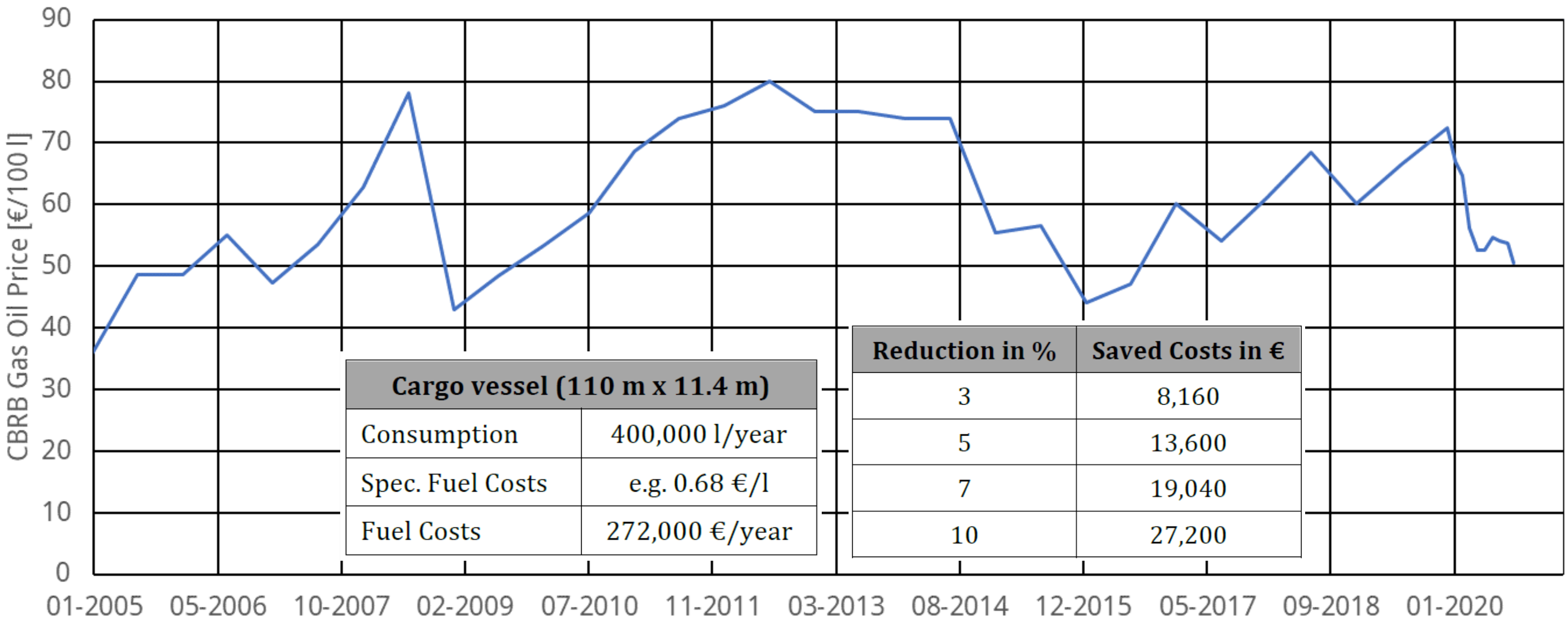
Many levers to improve economic and environmental performance of IWT:



- Infrastructure
  - RIS
  - Waterway improvement
  - Infrastructure for new energy carriers
- Ship
  - Hydrodynamics
  - Drive Trains
- Operation
  - Assistance Systems
  - Education & Qualification
- Logistics

Motivation

- Fuel is usually even more money than time.
- Energy costs will increase.
- Less energy demand means less costs <u>and</u> less emissions.

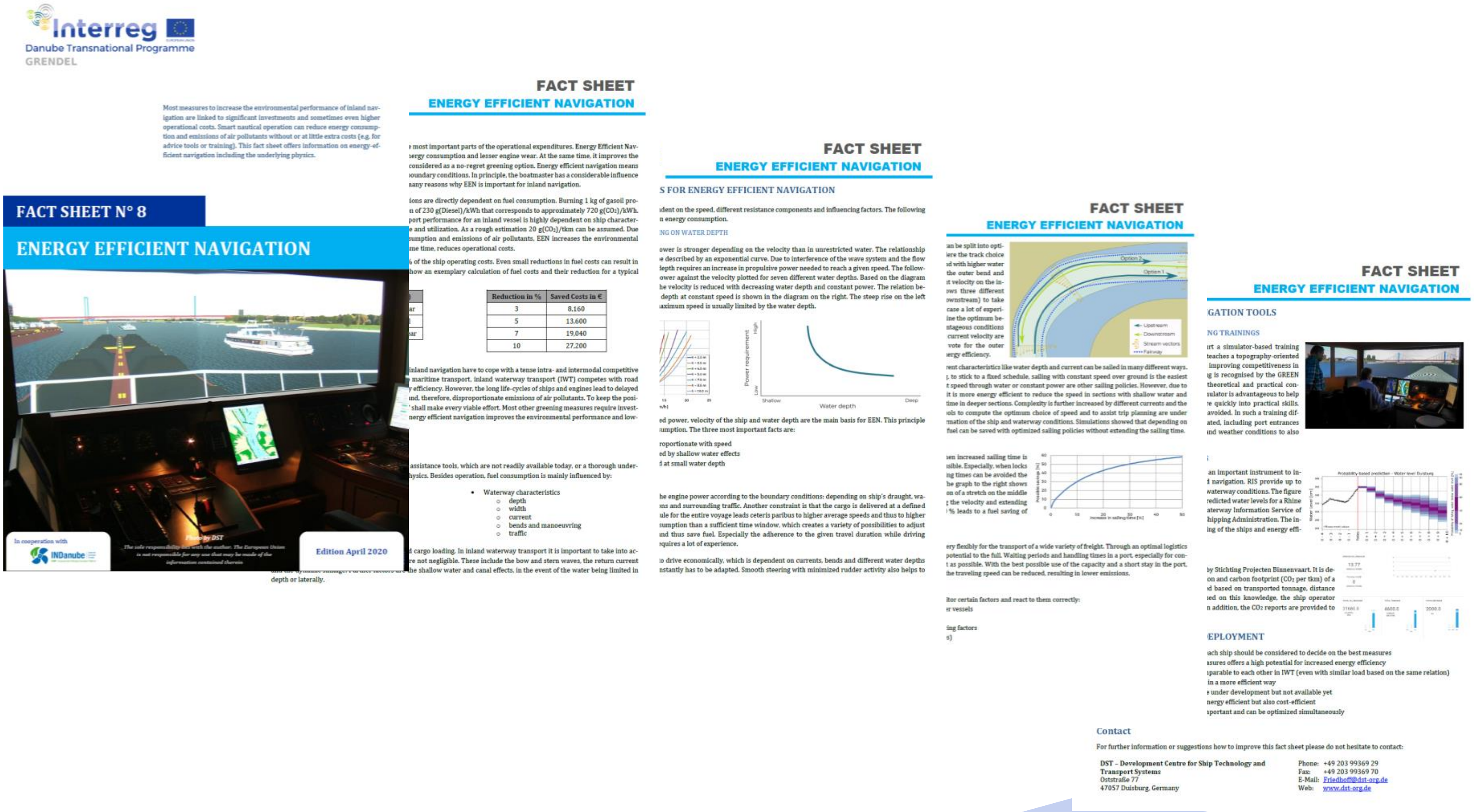


Cargo vessel (110 m x 11.4 m)	
Consumption	400,000 l/year
Spec. Fuel Costs	e.g. 0.68 €/l
Fuel Costs	272,000 €/year

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

Source (data): interrijn.com

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.

FACT SHEET N° 8

ENERGY EFFICIENT NAVIGATION

Photo by DST

In cooperation with

Edition April 2020

FACT SHEET

ENERGY EFFICIENT NAVIGATION

e most important parts of the operational expenditures. Energy Efficient Nav-
nergy 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.

ions are directly dependent on fuel consumption. Burning 1 kg of gasoil pro-
n of 230 g(Diesel)/kWh that corresponds to approximately 720 g(CO_2)/kWh.
port performance for an inland vessel is highly dependent on ship character-
e and utilization. As a rough estimation 20 g(CO_2)/tkm can be assumed. Due
sumption and emissions of air pollutants, EEN increases the environmental
me time, reduces operational costs.

% of the ship operating costs. Even small reductions in fuel costs can result in
how 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
y efficiency. However, the long life-cycles of ships and engines lead to delayed
nd, therefore, disproportionate emissions of air pollutants. To keep the posi-
' shall make every viable effort. Most other greening measures require invest-
nergy efficient navigation improves the environmental performance and low-

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

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

d cargo loading. In inland waterway transport it is important to take into ac-
re not negligible. These include the bow and stern waves, the return current
he shallow water and canal effects, in the event of the water being limited in
depth or laterally.

FACT SHEET

ENERGY EFFICIENT NAVIGATION

S FOR ENERGY EFFICIENT NAVIGATION

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

NG ON WATER DEPTH

ower is stronger depending on the velocity than in unrestricted water. The relationship
e 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 follow-
ower against the velocity plotted for seven different water depths. Based on the diagram
he velocity is reduced with decreasing water depth and constant power. The relation be-
depth at constant speed is shown in the diagram on the right. The steep rise on the left
aximum speed is usually limited by the water depth.

ed power, velocity of the ship and water depth are the main basis for EEN. This principle
umption. The three most important facts are:

roportionate with speed
ed by shallow water effects
d at small water depth

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

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

---

FACT SHEET

ENERGY EFFICIENT NAVIGATION

an be split into opti-
ere the track choice
d with higher water
the outer bend and
t velocity on the in-
ows three different
ownstream) to take
case a lot of experi-
ine the optimum be-
ntageous conditions
current velocity are
vote for the outer
ergy efficiency.

rent 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
t 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
ols to compute the optimum choice of speed and to assist trip planning are under
mation of the ship and waterway conditions. Simulations showed that depending on
fuel can be saved with optimized sailing policies without extending the sailing time.

en increased sailing time is
sible. Especially, when locks
ng times can be avoided the
he graph to the right shows
on of a stretch on the middle
the velocity and extending
% leads to a fuel saving of

ery 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 con-
t as possible. With the best possible use of the capacity and a short stay in the port,
he traveling speed can be reduced, resulting in lower emissions.

itor certain factors and react to them correctly:
r vessels

ing factors
s)

FACT SHEET

ENERGY EFFICIENT NAVIGATION

GATION TOOLS

NG TRAININGS

rt a simulator-based training
teaches a topography-oriented
improving competitiveness in
g is recognised by the GREEN
theoretical and practical con-
ulator is advantageous to help
e quickly into practical skills.
avoided. In such a training dif-
ated, including port entrances
nd weather conditions to also

an important instrument to in-
d navigation. RIS provide up to
waterway conditions. The figure
redicted water levels for a Rhine
aterway Information Service of
hipping Administration. The in-
ing of the ships and energy effi-

by Stichting Projecten Binnenvaart. It is de-
on and carbon footprint (CO_2 per tkm) of a
d based on transported tonnage, distance
ed on this knowledge, the ship operator
n addition, the CO_2 reports are provided to

EPLOYMENT

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

Contact

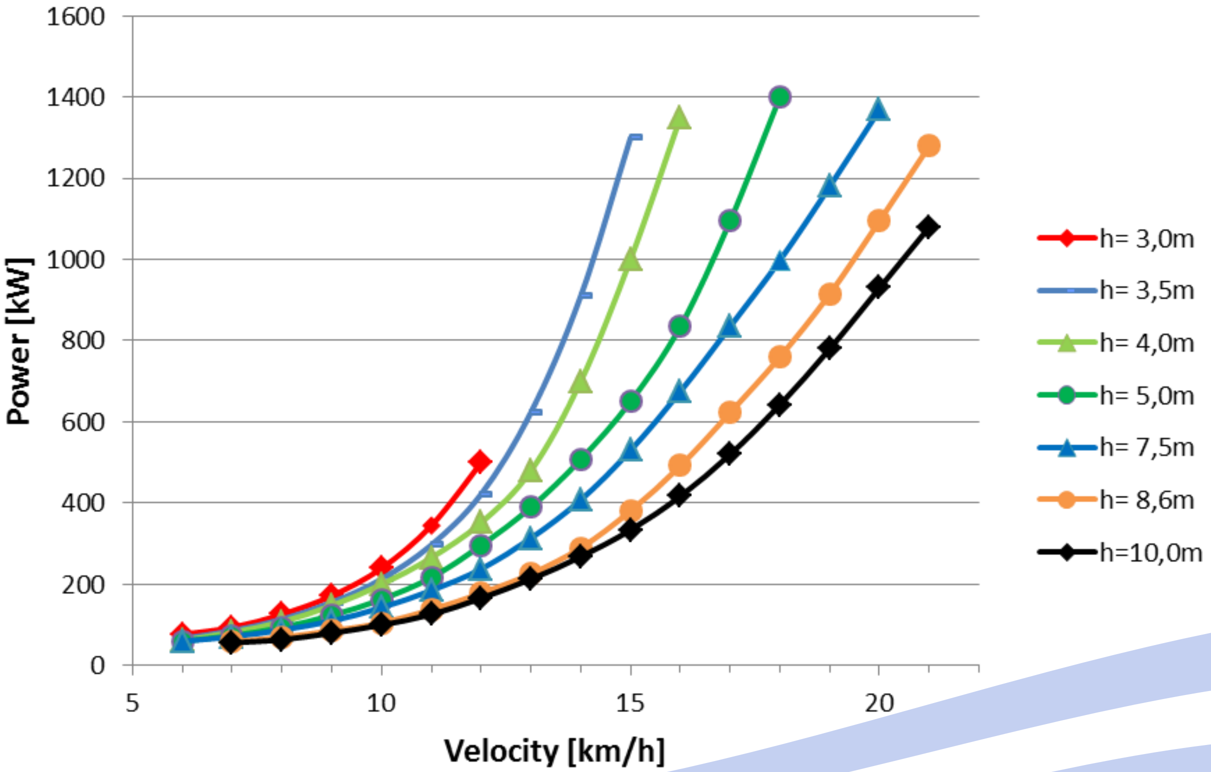
For further information or suggestions how to improve this fact sheet please do not hesitate to contact:

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: Friedhoff@dst-org.de
Web: www.dst-org.de

Energy Efficient Navigation

- Power demand rises disproportionate with speed.
- Power demand is increased by shallow water effects.
- Speed is reduced at small water depth.

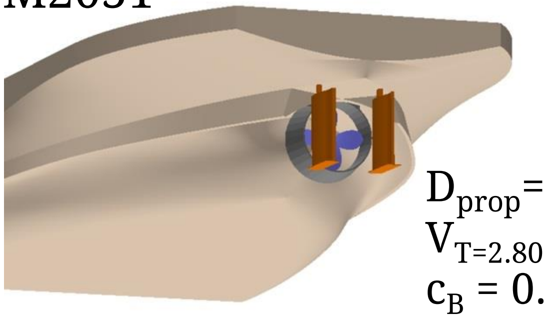


Energy Efficient Navigation

- Awareness
  - VoortVarend Besparen, Topofahrt Training, PROMINENT
  - Annex II of Directive (EU) 2017/2973:
    … a boatmaster shall be able to plan a journey and conduct navigation on inland waterways, including being able to choose the most logical, economic and ecological sailing route…
  - CESNI/QP Professional Qualification
- Optimized choice of speed and track
  - Smart Steaming
  - Advice tools under development
- Voyage planning with minimized waiting times (Slow Steaming)
- Increased utilization by better logistics

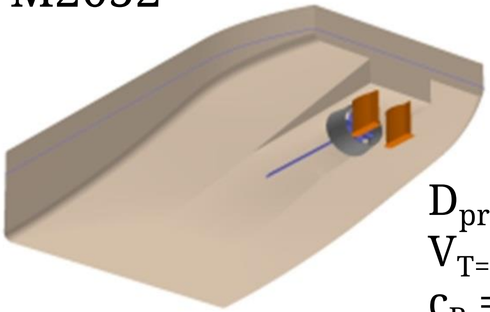
Design for operation (1)

M2051



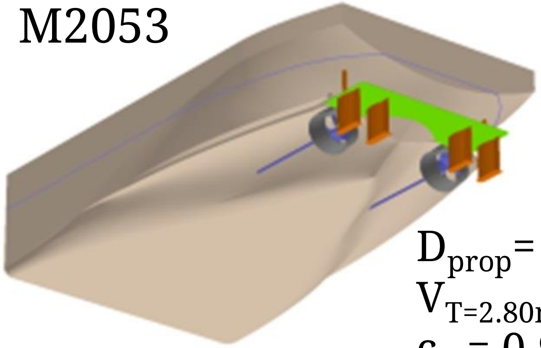
D_{prop}= 1.76 m
$V_{T=2.80m}$=3088 m³
c_B = 0.88

M2052



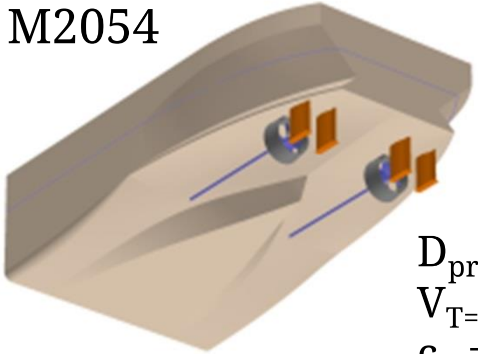
D_{prop}= 1.76 m
$V_{T=2.80m}$=3150 m³
c_B = 0.89

M2053



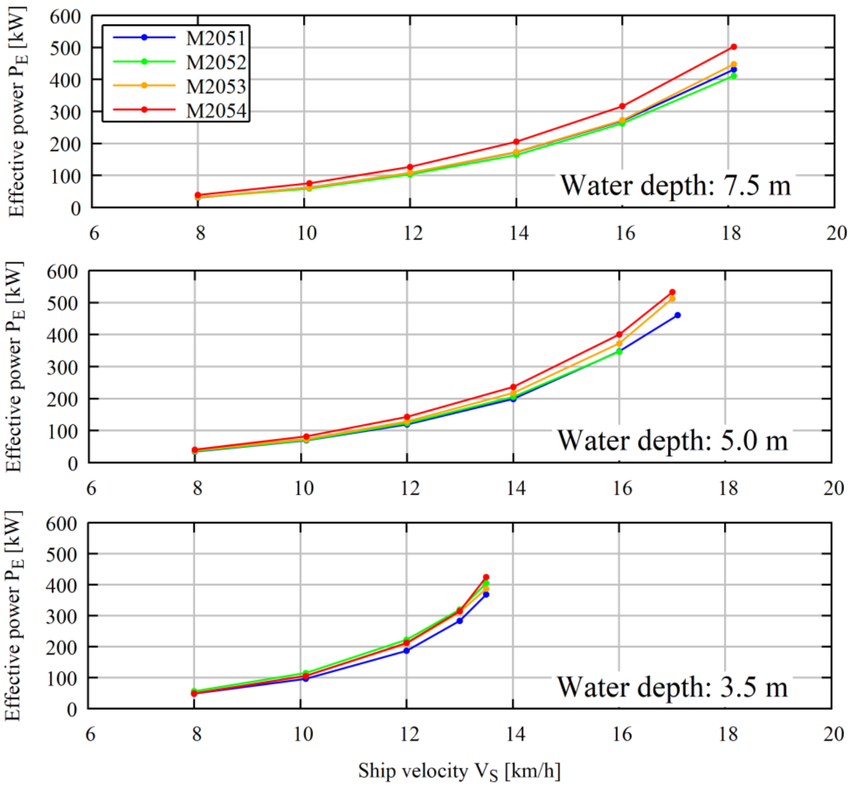
D_{prop}= 1.60 m
$V_{T=2.80m}$=3162 m³
c_B = 0.90

M2054

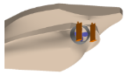


D_{prop}= 1.60 m
$V_{T=2.80m}$=3129 m³
c_B = 0.89

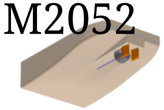
Design for operation (2)



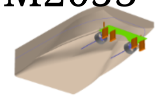
M2051



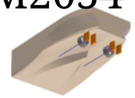
M2052



M2053

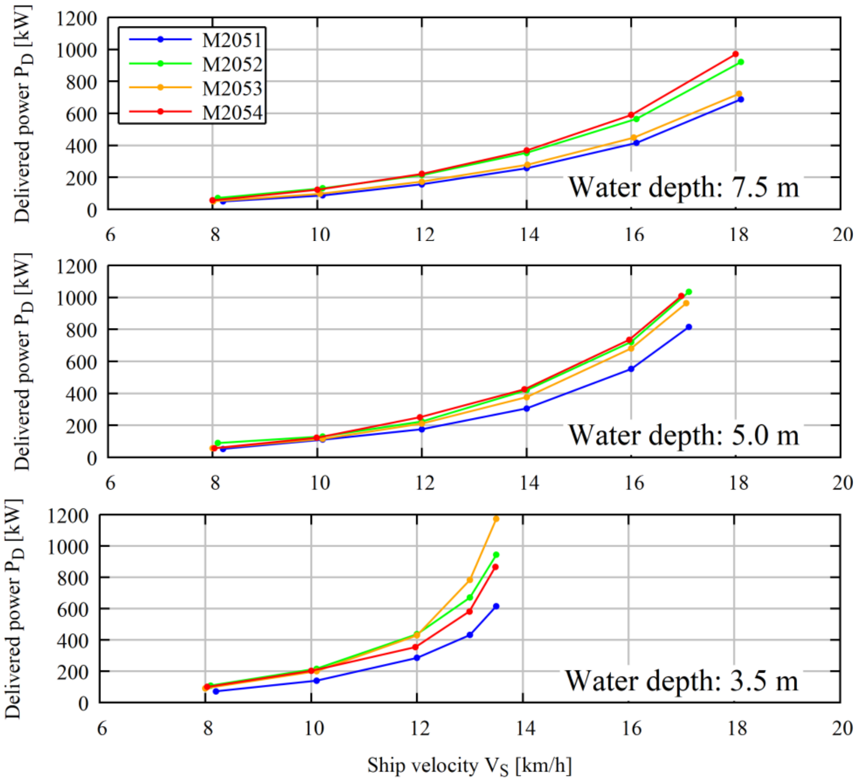


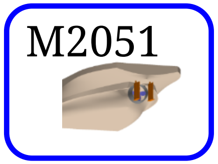
M2054



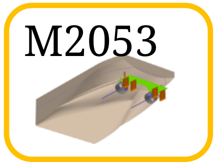
- Differences < 20%
- Similar behavior of all stern shapes in shallow water
- Optimization is not simply related to ship resistance

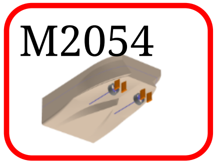
Design for operation (3)




M2051


M2052

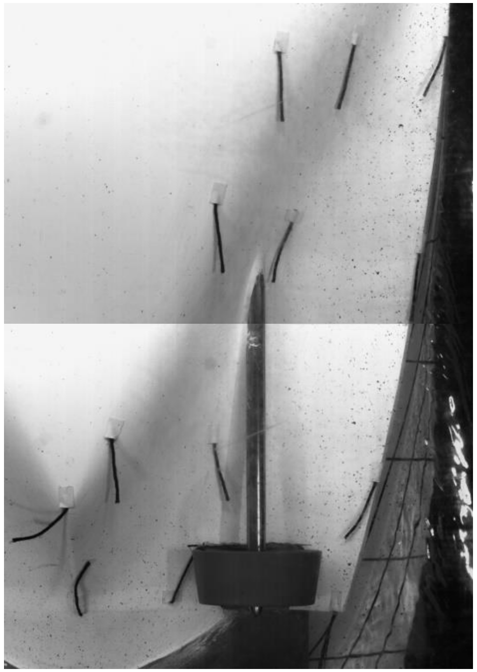

M2053

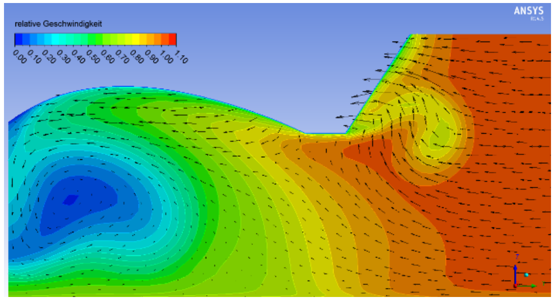

M2054

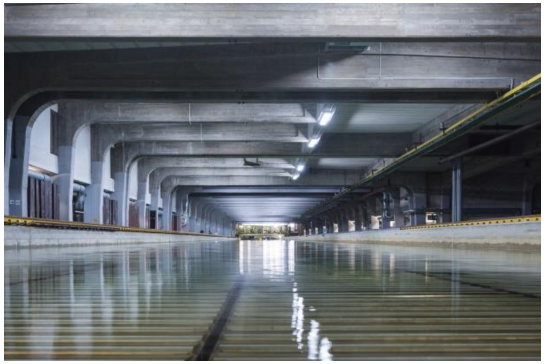
- ➢ M2053 works well in deep water but is worst in shallow water
- ➢ Factor 2 between best and worst ship design in shallow water
- ➢ Complex hull-propulsor interaction needs to be considered

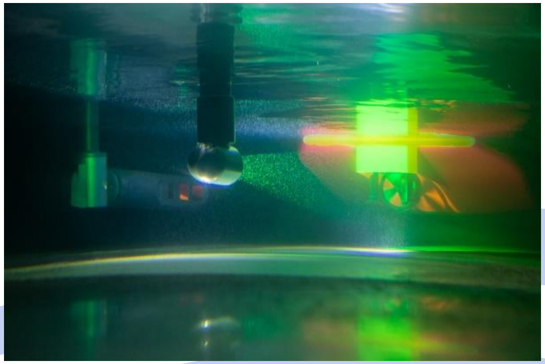
Hydrodynamic Optimisation

- Widely used for newbuilds:
  - Basic design
  - CFD simulations
  - Local modifications
  - CFD confirmation
  - Scale model tests
    - Resistance
    - Open Water
    - Self-Propulsion
- What can be done for the existing fleet?

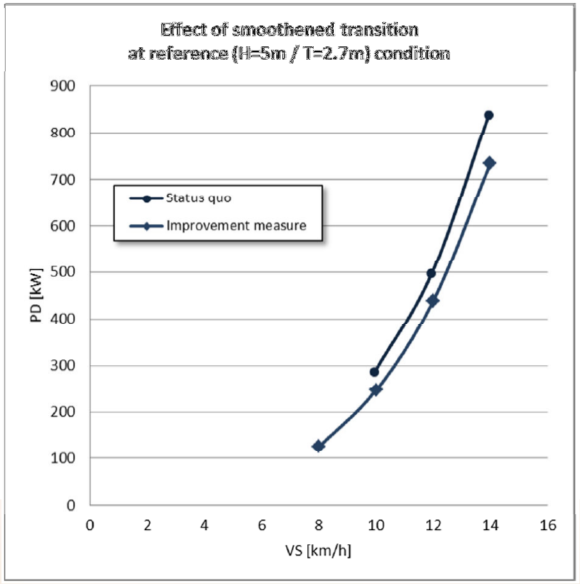




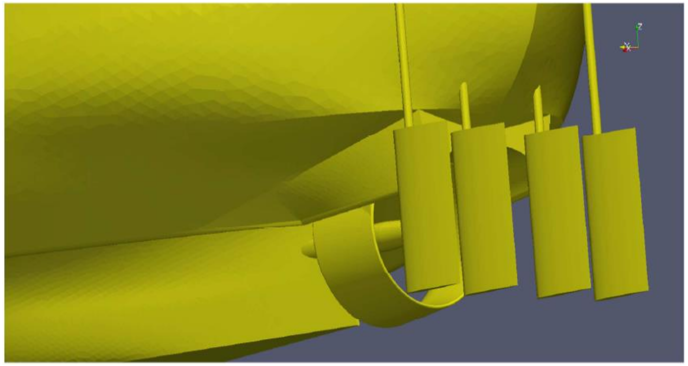


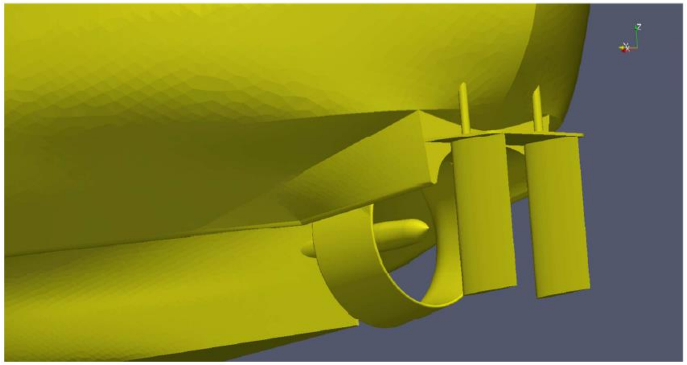


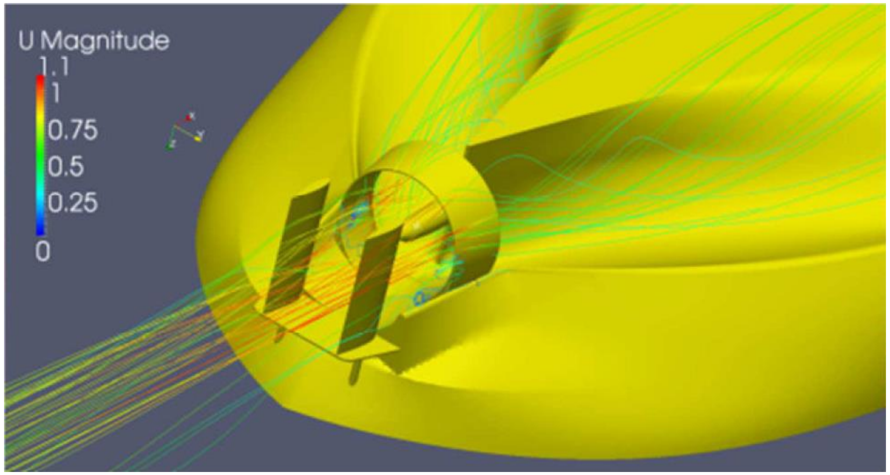
Coupled Convoys

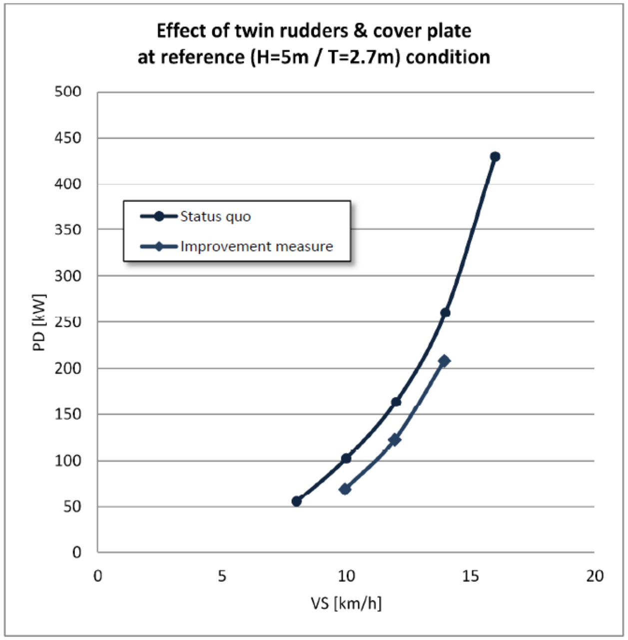


Retrofit Optimisation



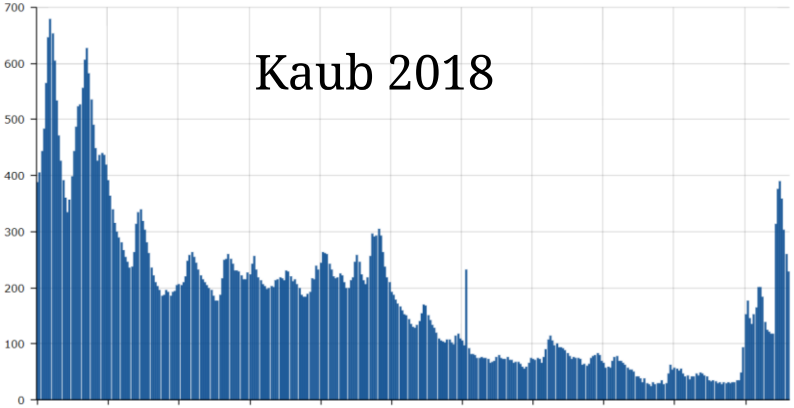




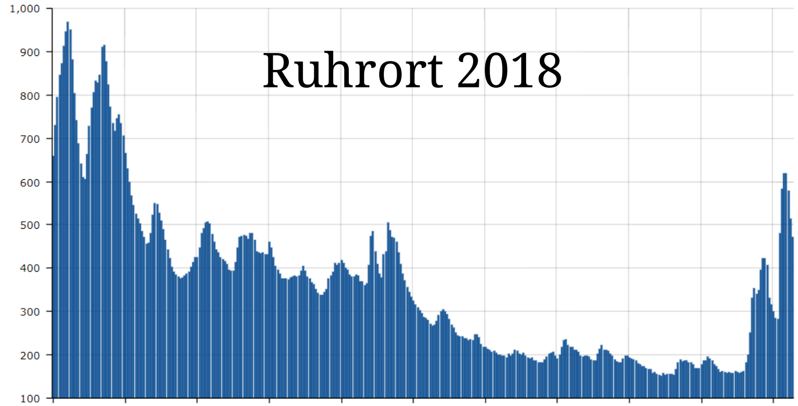


Resilience

When climate change is faster than waterway development…



Kaub 2018



Ruhrort 2018

Source: interrijn.com

Resilience

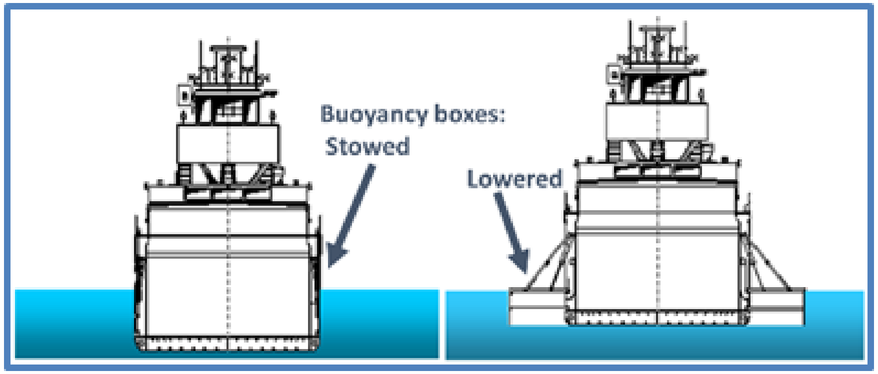
- Efficiency calls for maximizing propeller diameter.
- Ventilation needs to be prevented for low draughts.
- Optimization allows draughts as low as 75% of prop. diameter.
- Stopping may require a powerful thruster.

Flextunnel

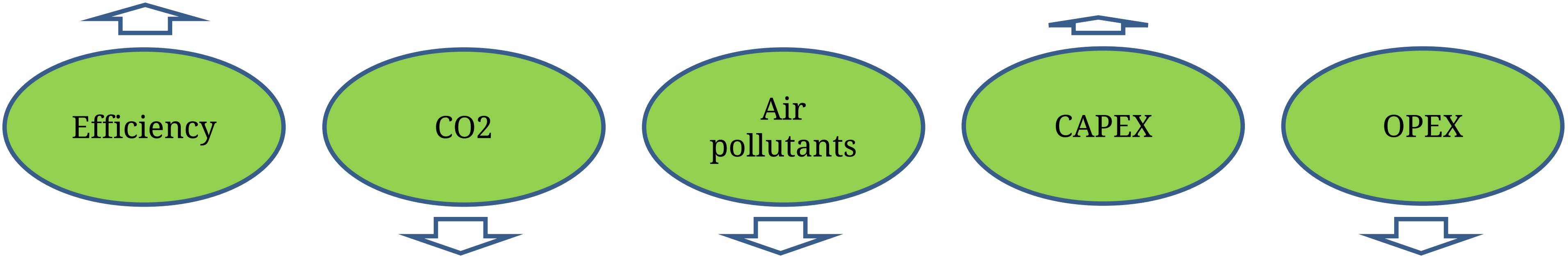
Source: Leo van Zon – Damen Marine Components

NOVIMOVE

- Innovative Vessel Concepts
- Increase the resilience of IWT
- Focus on low water scenarios → add buoyancy
- Concept → Techn. Verification → Operational Ver. → Economic Validation



Questions?



Efficiency

CO2

Air pollutants

CAPEX

OPEX

It's Possibly Easy

Becoming a bit Greener

Contact:
DST
Benjamin Friedhoff
friedhoff@dst-org.de
+49-203-9936929