# Workshop Inland Navigation CO2 emissions

## Energy efficiency of inland water ships
## - and how to improve it

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# Energy efficiency of inland water ships

We propose to use the energy efficiency index EEFI as benchmarking index. The index EEOI will have the same relevance, as is obtained by data of ship operation.

$$EEDI = \frac{C_F \times SFC \times P}{Capacity \times V_{ref}}$$

In fact, this simple expression shows

**$CO_2$ Emission / transport performance**

Slow and large ocean vessels will obtain a value of about 5 gr $CO_2$/tkm and RoRo ships or ferries will reach 50 gr. $CO_2$/tkm

# Influence of the water depth on transport efficiency

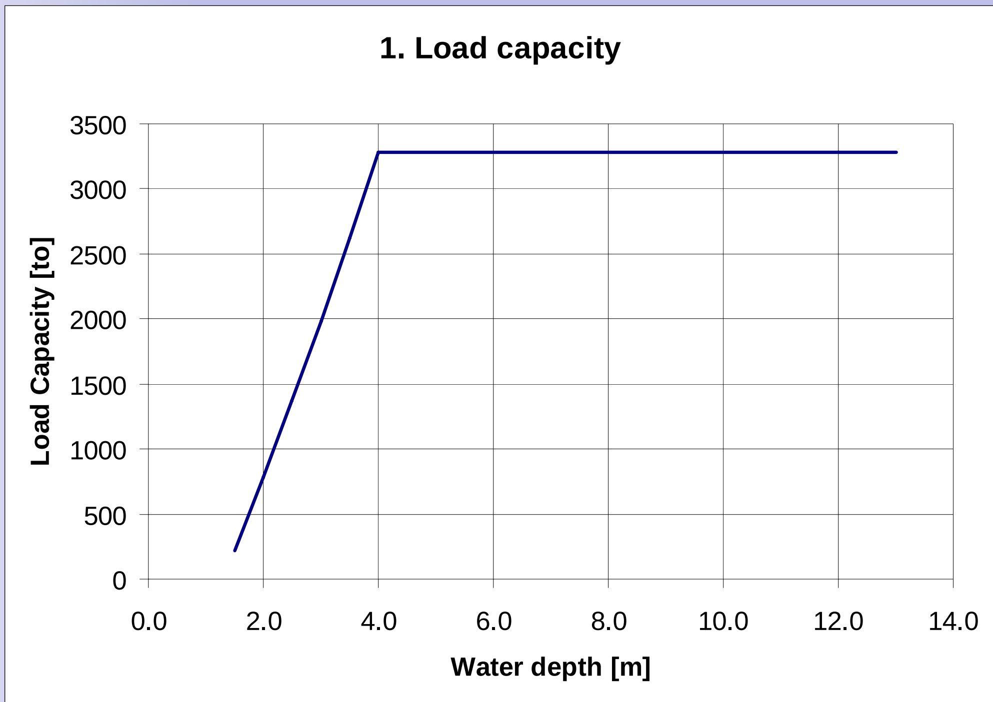
The water depth will have an influence two main aspects of transport efficiency :

- The load capacity of the ship
- The speed of the ship

# Influence of the water depth on transport efficiency

## The load capacity

For any ship, keel clearance is necessary to advance and to manoeuvre. The keel clearance should be greater then 0,3 m. As function of the water depth, the load capacity starts at zero and increases until the design draught of the ship is reached.



# Influence of the water depth on transport efficiency

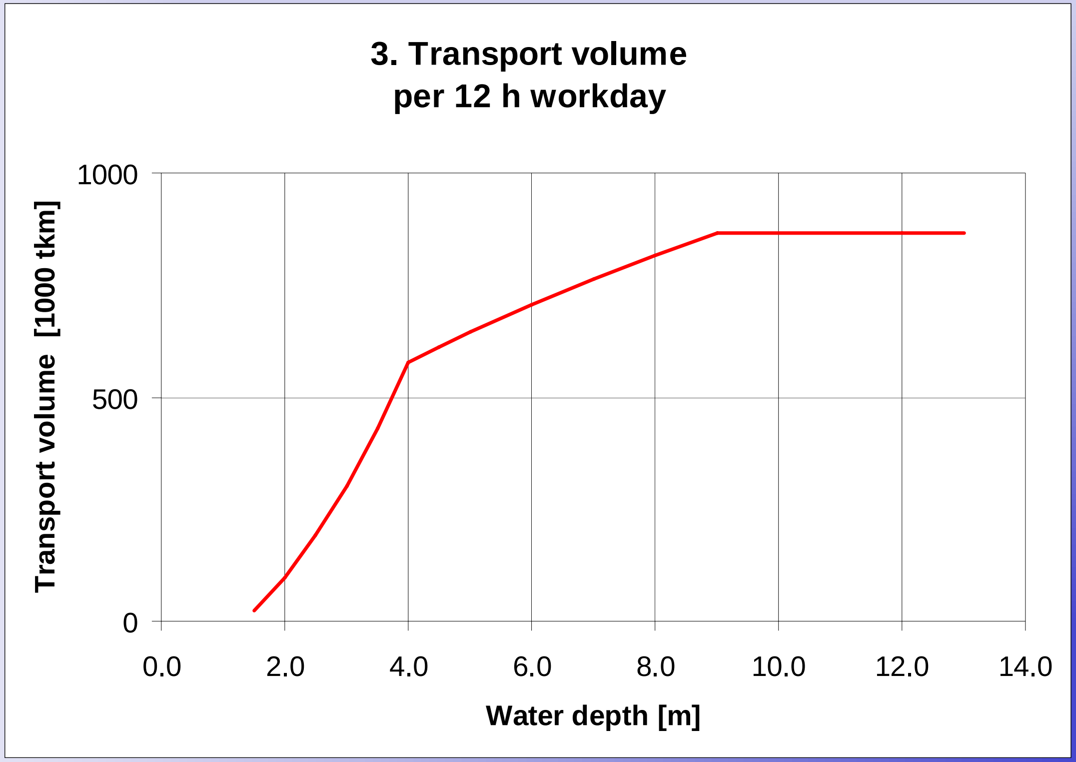
## Ship speed

The practicable ship speed will increase, more or less proportionally to the root of the water depth.  Typical IWS can reach a speed of 22 km/h, depending on the engine power and the hull form. For this speed level, a water depth of abt. 9 m will be necessary.

# Influence of the water depth on transport efficiency

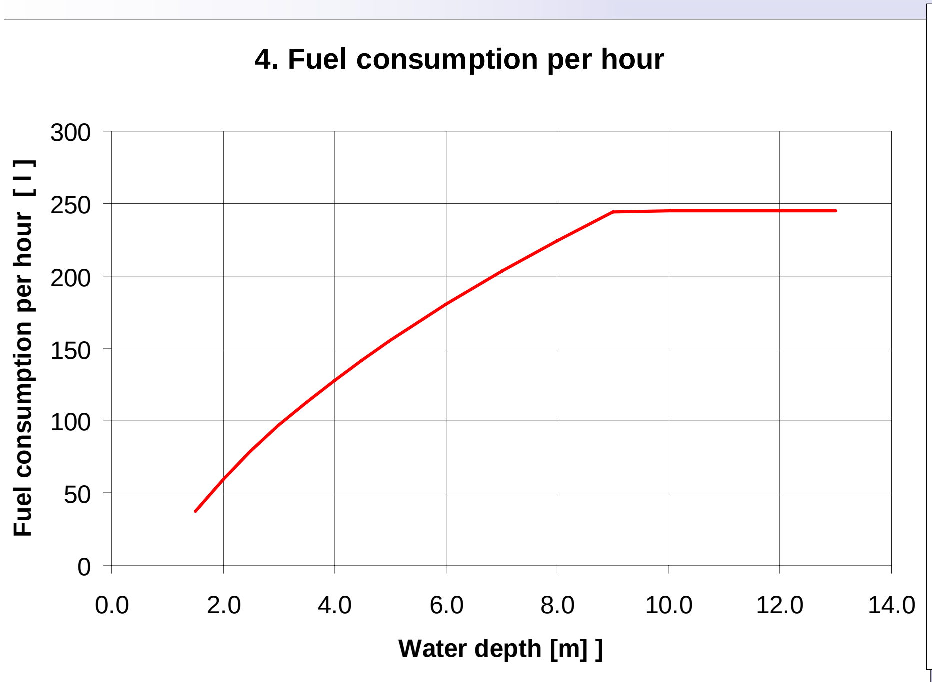
## Example: Specific energy consumption

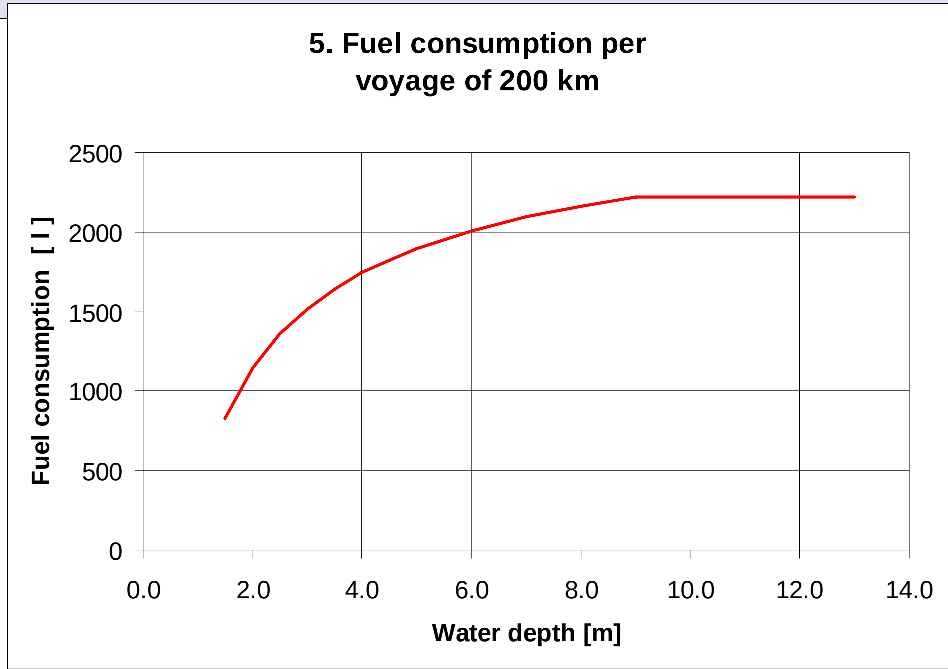
A IW cargo vessel works 12h per day, the transport distance being 200 km. The transport volume per day depends on load capacity and speed and is therefore a function of water depth:



# Influence of the water depth on transport efficiency

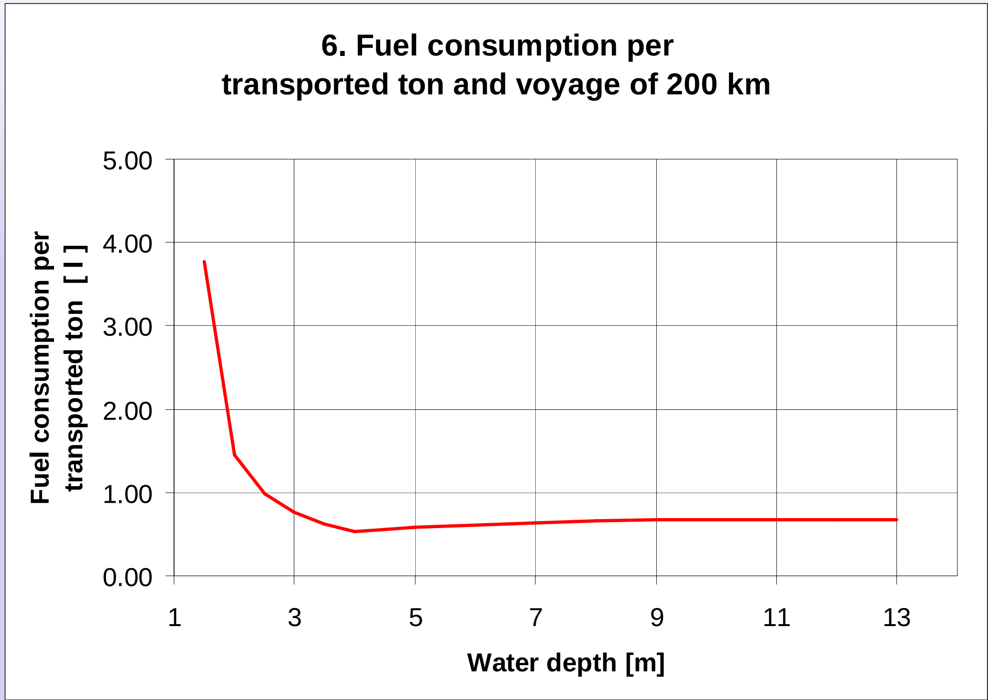
'he fuel consumption depends also on the water depth. As at low /ater depth, the travel will take longer, there will be strong ıfluence on fuel consumption.



# Influence of the water depth on transport efficiency

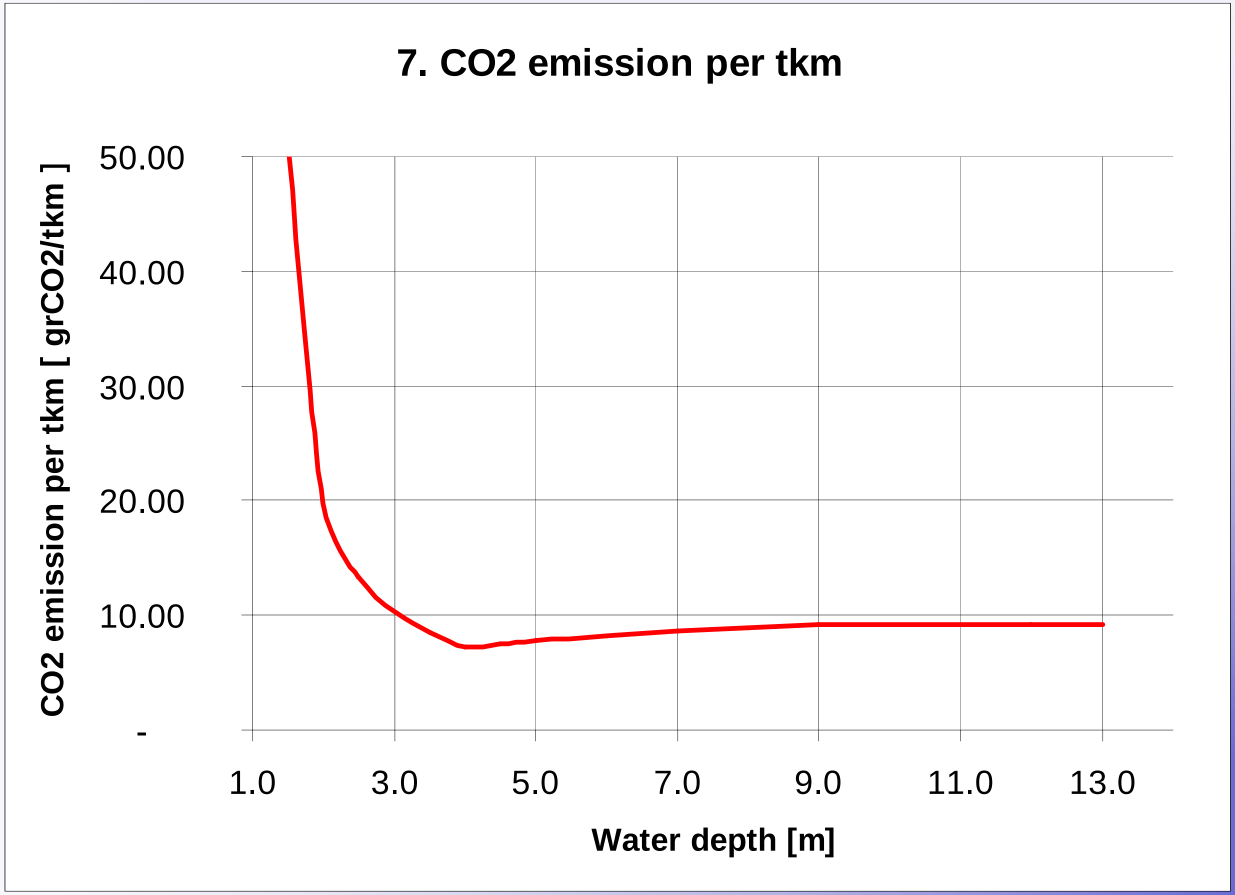
The fuel consumption has to seen in relation with the transport volume.




In our example it is obvious that the specific energy consumption will reach a low level at water depth larger then 2,5 m.

# Influence of the water depth on transport efficiency

The same applies to the specific $CO_2$- Emission.




Interesting to see that at water depth larger then 4 m, the IWS transport reaches its best transport efficiency.

# Improving transport efficiency

Ship type

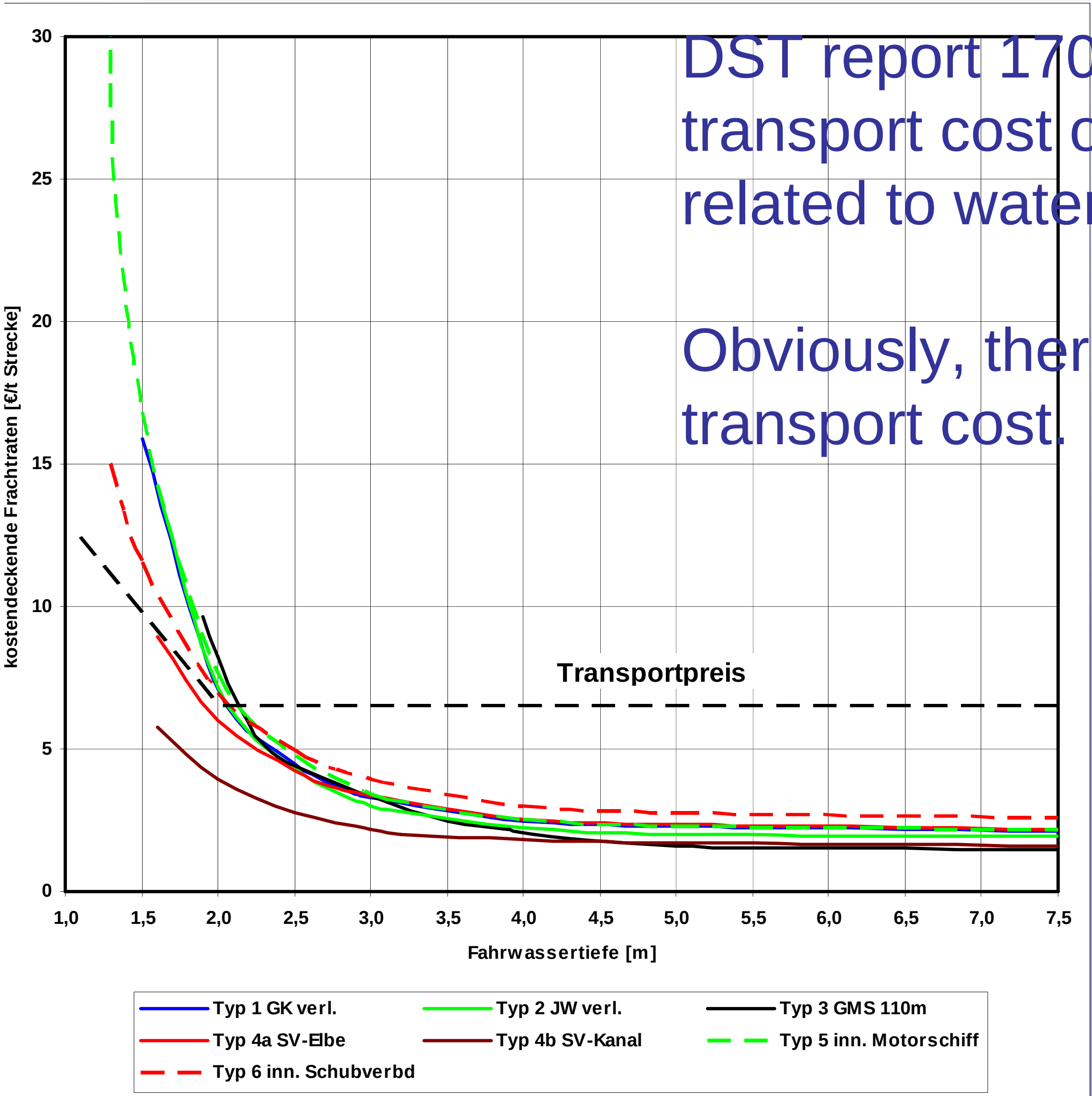
Scale effect

Propulsion

Ship weight

Hull form

# mproving transport efficiency




DST report 1701 investigated how the transport cost of different ship types is related to water depth.

Obviously, there are big differences in transport cost.

# Improving transport efficiency

## There is also a scale effect in transport efficiency...

h = 5,0 m, T = 2,5 m, V = 13 km/h

| Typ | L x B [m] | V [m³] | dW [ t ] | ms [ t ] | $P_B$ [kW] | $D_P$ [m] | $CO_2$ [g/tkm] |
|---|---|---|---|---|---|---|---|
| Peniche | 39,0 x 5,1 | 450 | 366 | 84 | 309 | 1,10 | 47,1 |
| Gustav Koenigs | 67,0 x 8,2 | 1178 | 935 | 243 | 549 | 1,40 | 31,3 |
| Johann Welker | 80,0 x 9,5 | 1672 | 1272 | 400 | 421 | 1,50 | 17,6 |
| Gütermotorschiff | 110,0 x 11,4 | 2750 | 1900 | 850 | 230 | 1,85 | 6,4 |
| Jowi-Klasse | 135,0 x 17,0 | 4745 | 3335 | 1410 | 480 | 3 x 1,74 | 7,7 |
| Langschiff | 150,0 x 15,0 | 4904 | 3404 | 1500 | 390 | 2 x 1,76 | 6,1 |
| Schubverband 2spurig-2gliedrig | 193,0 x 22,8 | 8600 | 6260 | 2340 | 1365 | 3 x 2,05 | 11,6 |
| Schubverband 2spurig-3gliedrig | 269,5 x 22,8 | 12550 | 9390 | 3160 | 2100 | 3 x 2,05 | 11,9 |
| LKW $V_{mittel}$ = 72,5 km/h | - | - | 26 | 14 | 320 | - | 37,4 |
| PKW $V_{mittel}$ = 100 km/h | - | - | 0,5 | 1,4 | 75 | - | 240 |

# Improving transport efficiency

Propeller efficiency plays a key role

$CO_2$ -emission of a large cargo motor ship (L x B x T = 110,0 m x 11,4 m x 2,5 m)

| | $P_B$ [kW] | **spezifischer $CO_2$-Ausstoß** **specific $CO_2$-exhaust** [g/tkm] | | |
|---|---|---|---|---|
| | | **zu Berg** **upstream** | **ohne Strömung** **streamless** | **zu Tal** **downstream** |
| freier Propeller free propeller B-series | 715 | 25,3 | 16,8 | 11,5 |
| Kaplan-Propeller in Düse ducted propeller K-series | 572 | 20,2 | 12,6 | 9,2 |
| Skew-Propeller in Düse ducted skew-propeller | 536 | 18,9 | 11,8 | 8,6 |

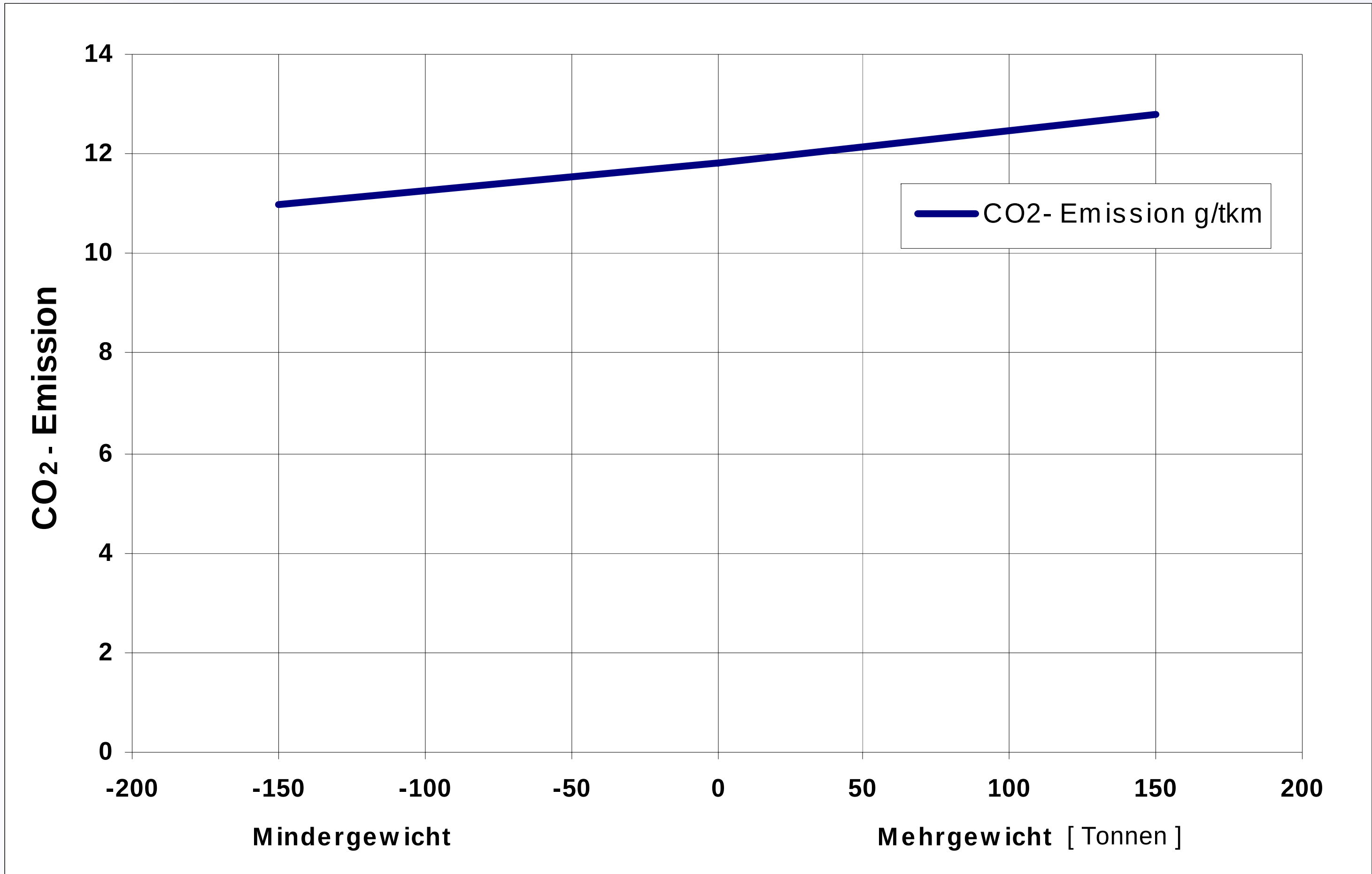
# Improving transport efficiency

## Ship light weight

| Typ | $T_{max}$ [m] | ms [ t ] | dW [ t ] | dW / ms [ - ] |
|---|---|---|---|---|
| Peniche | 2,5 | 84 | 366 | 4,36 |
| Gustav Koenigs | 2,7 | 243 | 1276 | 5,25 |
| Johann Welker | 2,9 | 400 | 1940 | 4,85 |
| Gütermotorschiff | 3,2 | 850 | 2681 | 3,15 |
| Jowi-Klasse | 3,2 | 1410 | 4761 | 3,38 |
| Langschiff | 3,5 | 1500 | 5406 | 3,60 |
| Schubverband 2spurig-2gliedrig<br>Pushing train 2+2 | 4,0 | 2340 | 11200 | 4,79 |
| Schubverband 2spurig-3gliedrig<br>Pushing train 2+2+2 | 4,0 | 3160 | 16800 | 5,32 |
| LKW | | 14 | 26 | 1,86 |

# Improving transport efficiency

## Ship light weight




Marginal influence of ship weight reduction

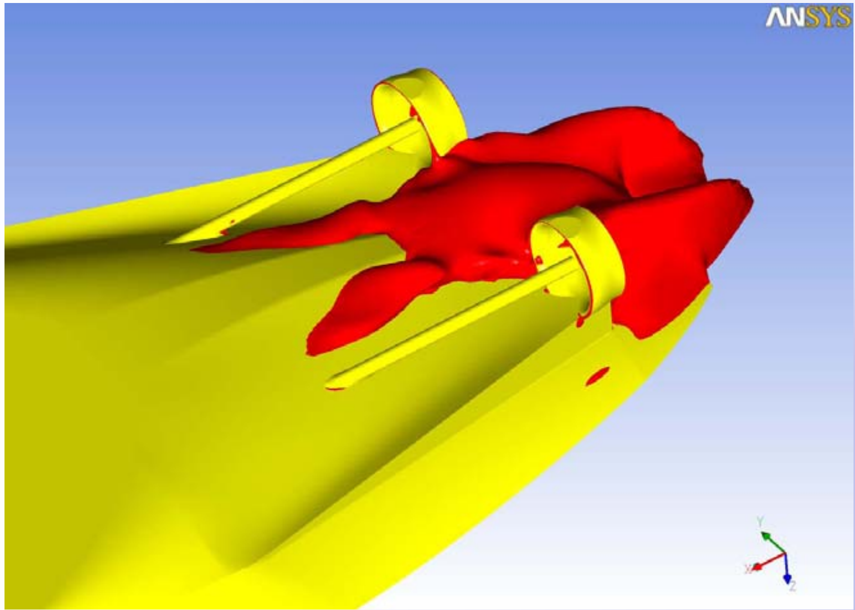
# Improving transport efficiency

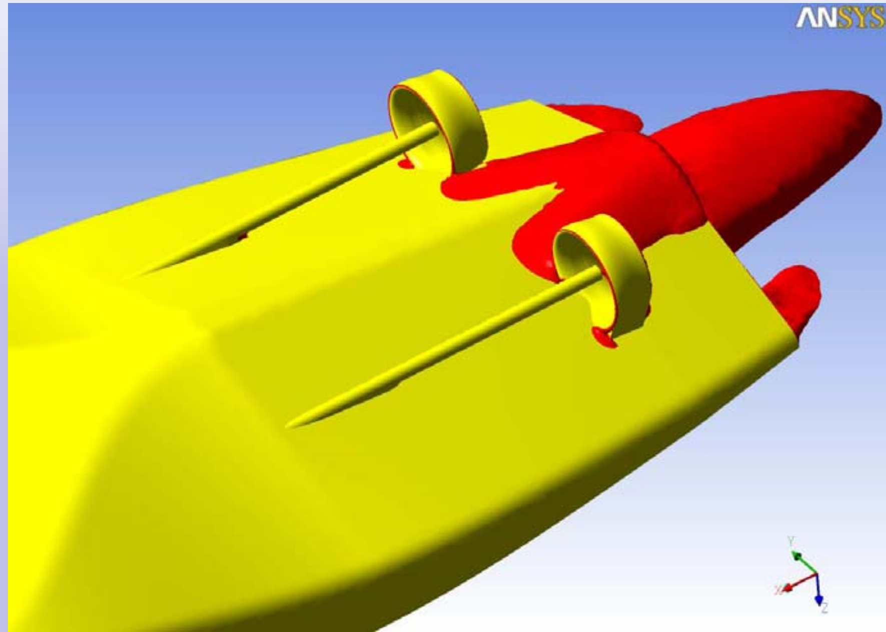
## Hull form

Small changes in the hull form may produce a big difference

# Improving transport efficiency

## Hull form

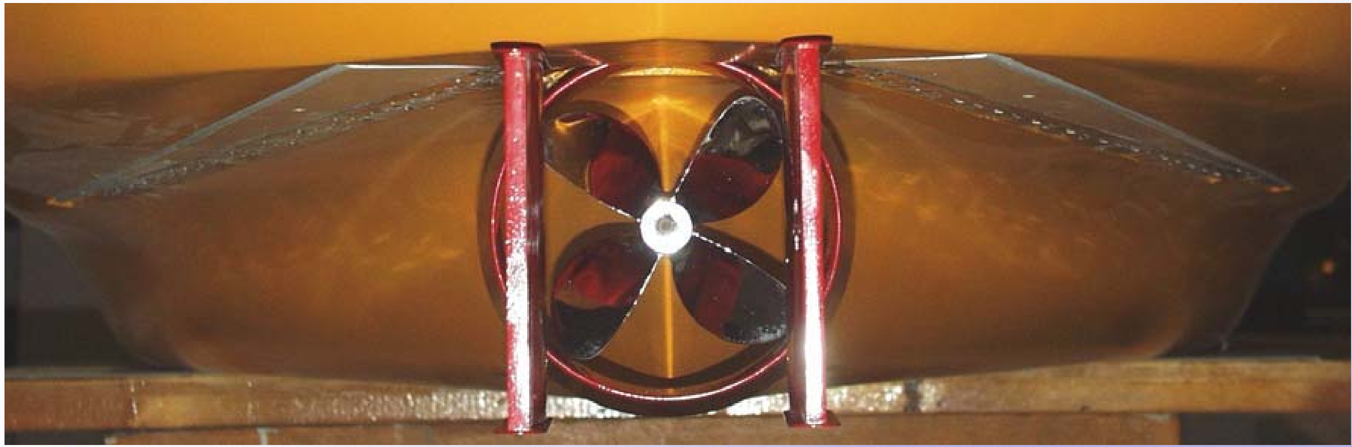


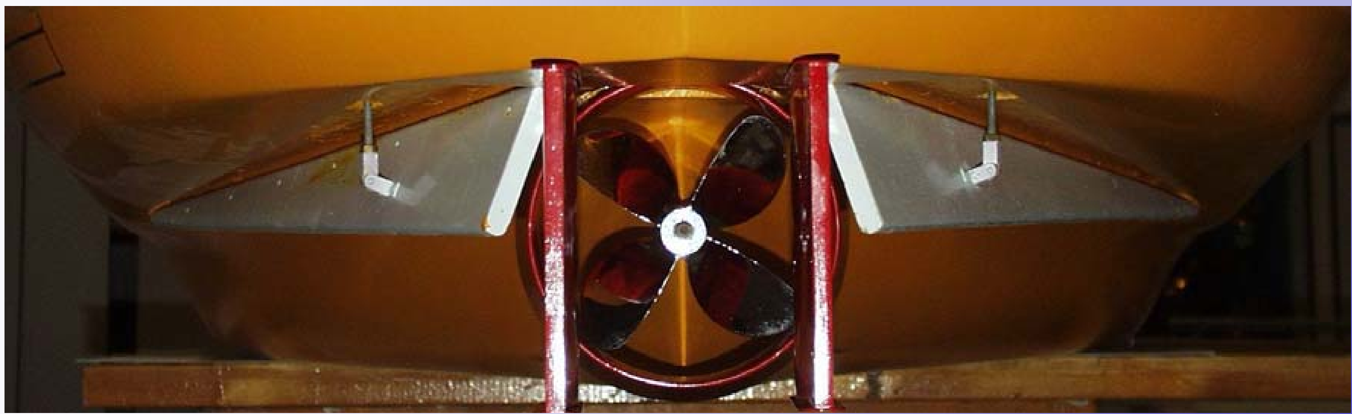




CFD calculations are detecting flow separation areas

# Improving transport efficiency

## Hull form





Hull with variable geometry

## Improving transport efficiency

Ship type

... As large as the waterway allows

Scale effect

Propulsion

...high performance propellers and nozzles

Ship weight

...don't expect too much

Hull form

...still decisive and pays off research