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

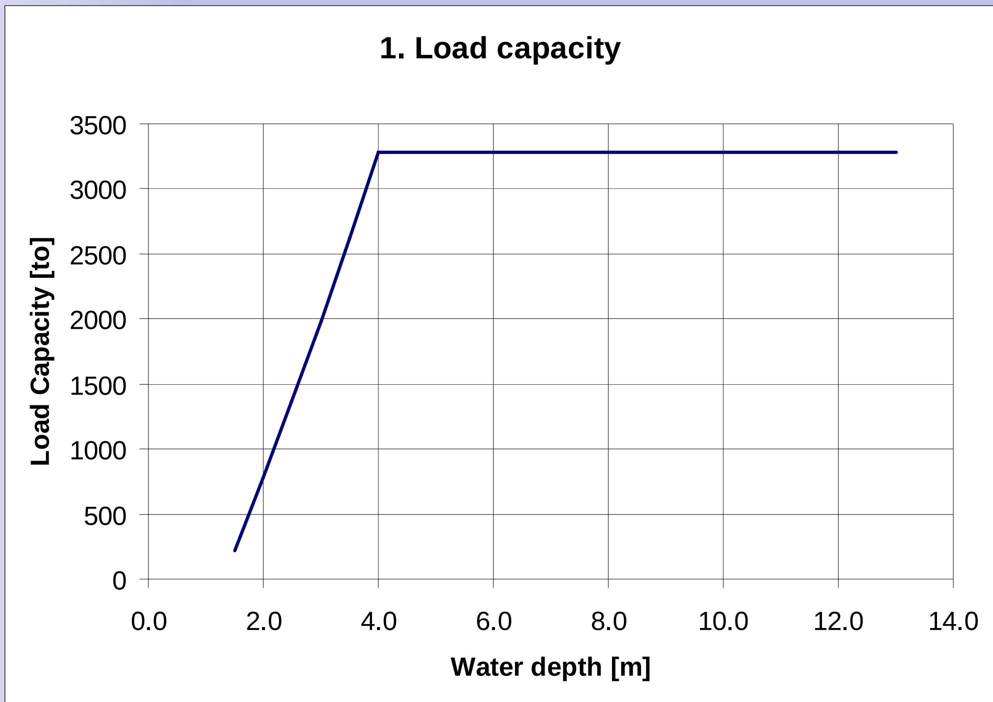
The water depth will have an influence two main aspects of transport efficiency :

- 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

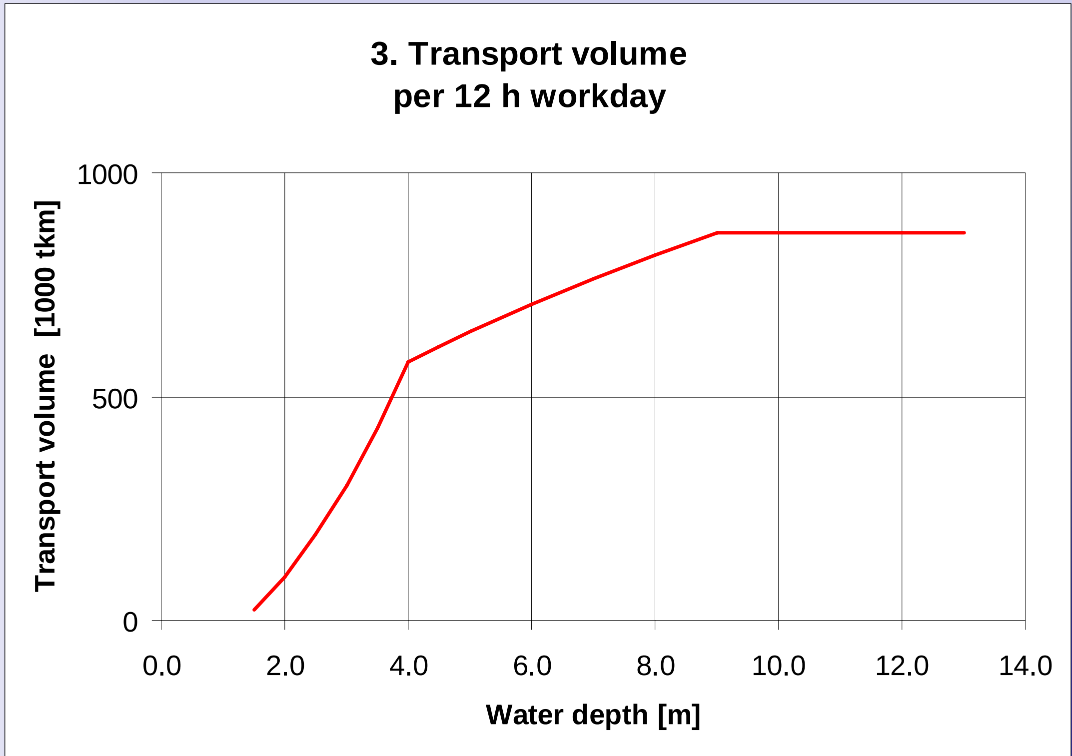
Ship speed

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

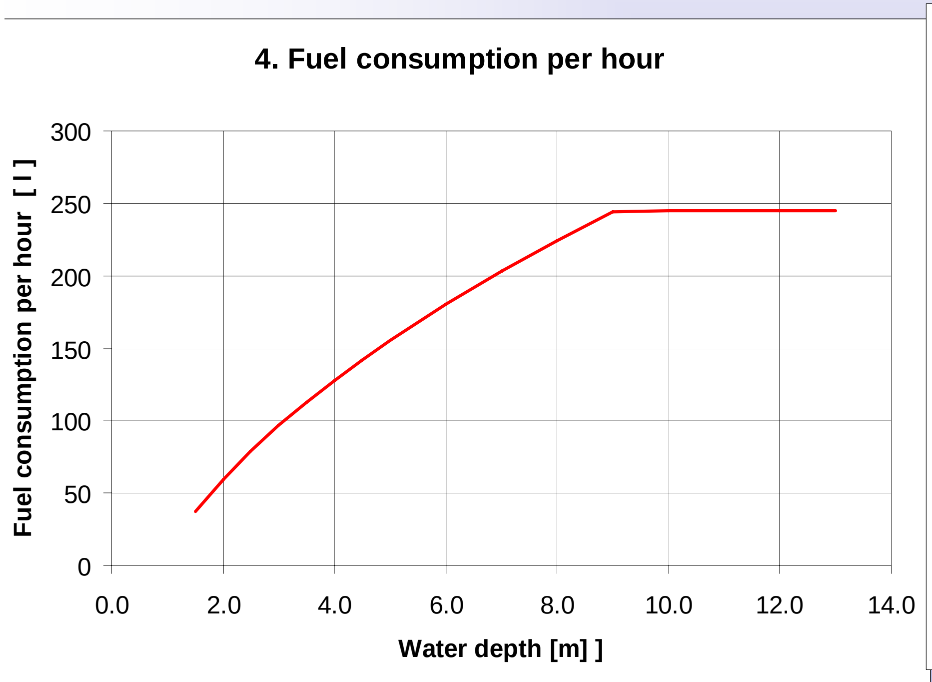
Example: Specific energy consumption

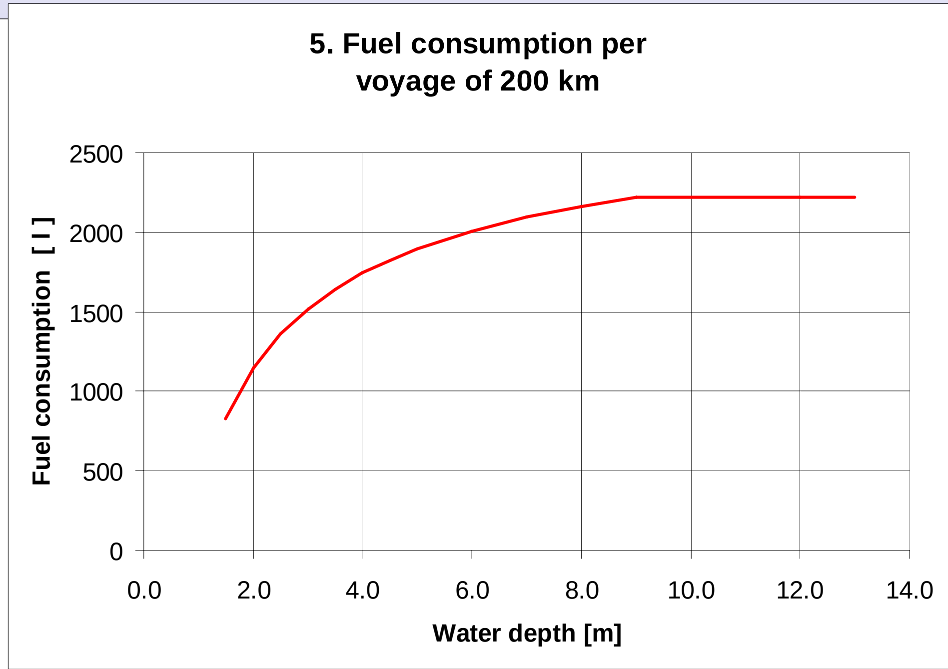
A IW cargo vessel works 12h per day, the transport distance being 200 km. The transport volume per day depends on load capacity and speed and is therefore a function of water depth:



Influence of the water depth on transport efficiency

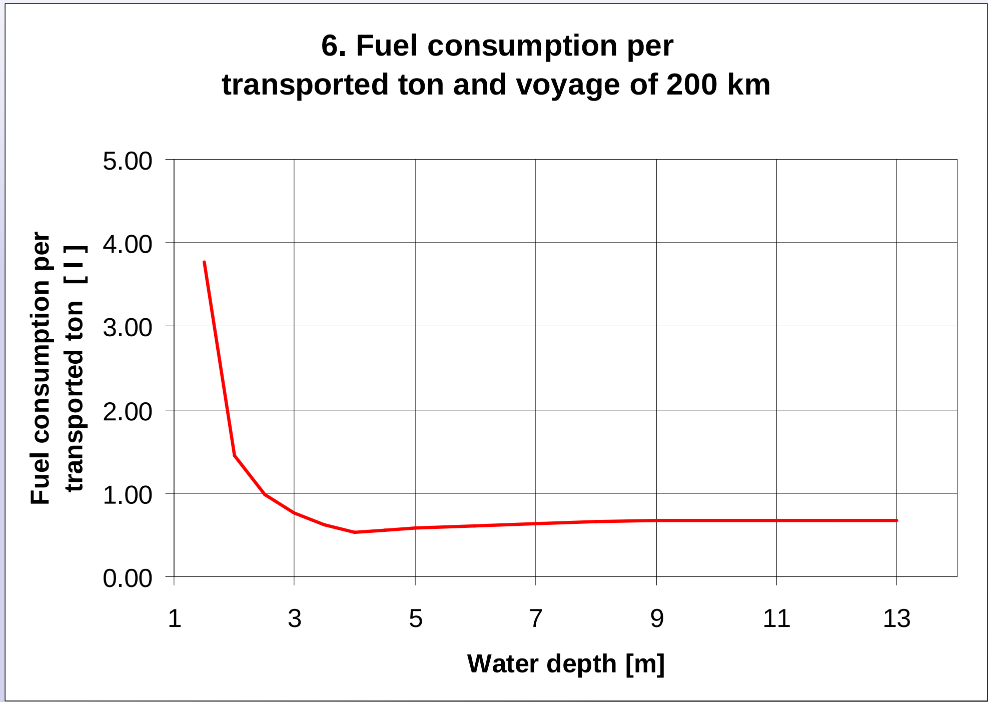
ʼhe fuel consumption depends also on the water depth. As at low /ater depth, the travel will take longer, there will be strong ıfluence on fuel consumption.





Influence of the water depth on transport efficiency

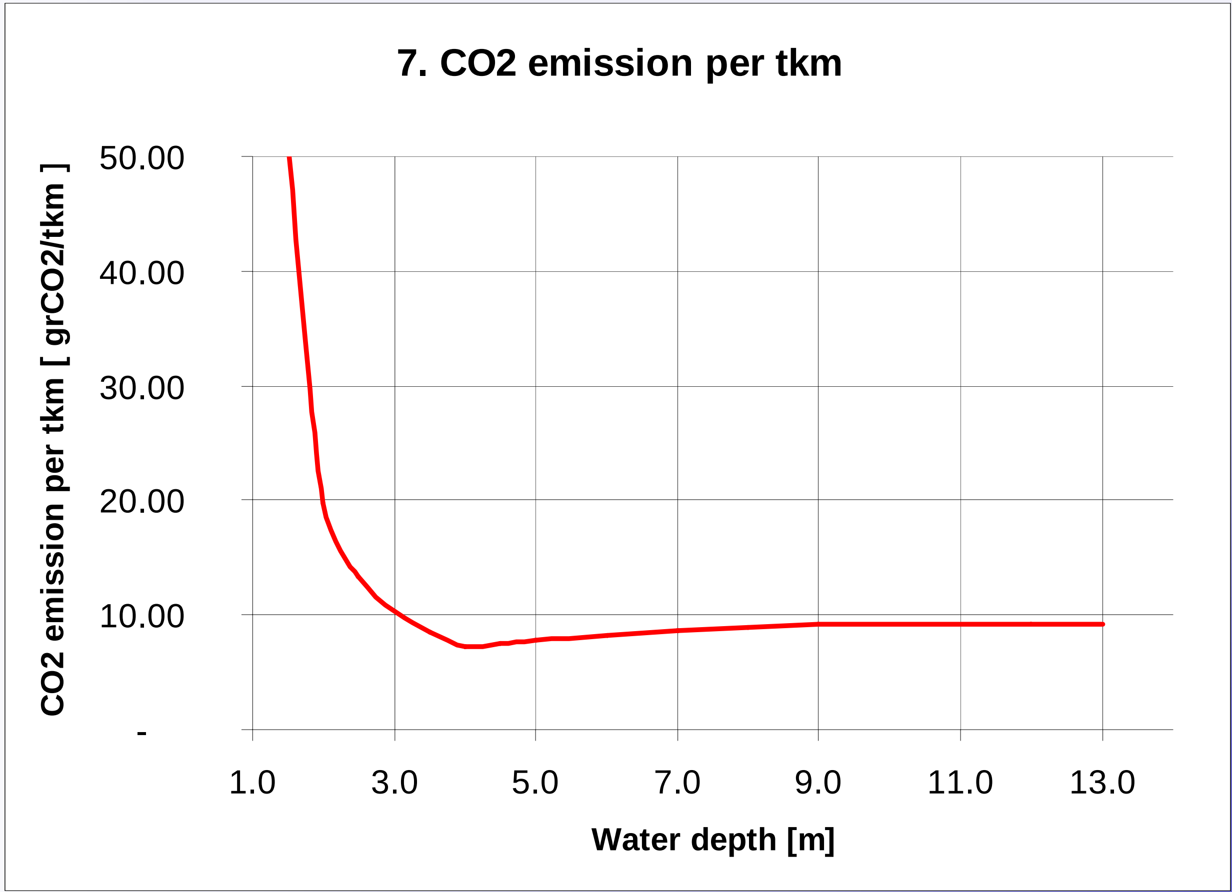
The fuel consumption has to seen in relation with the transport volume.



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

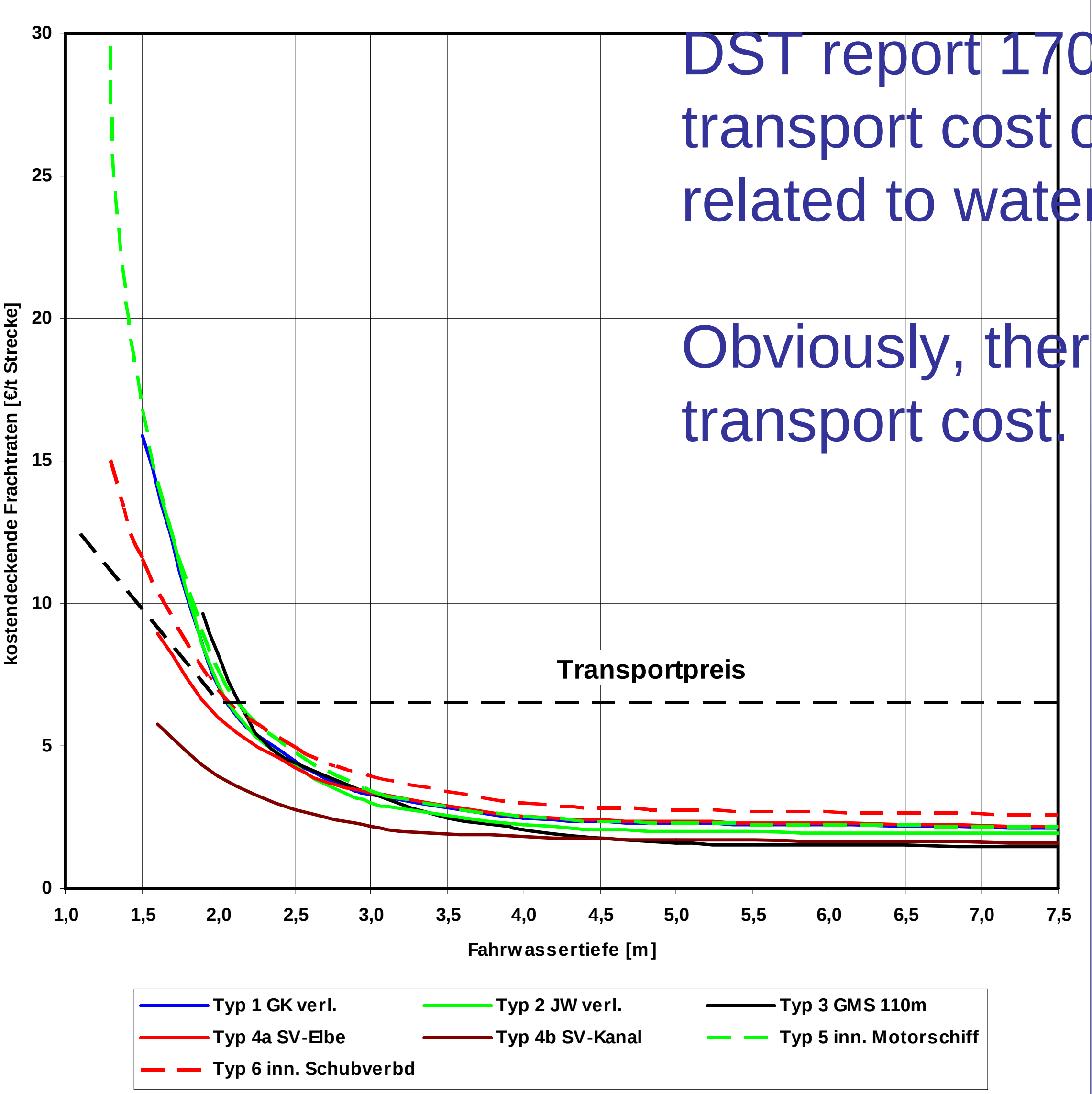
Scale effect

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

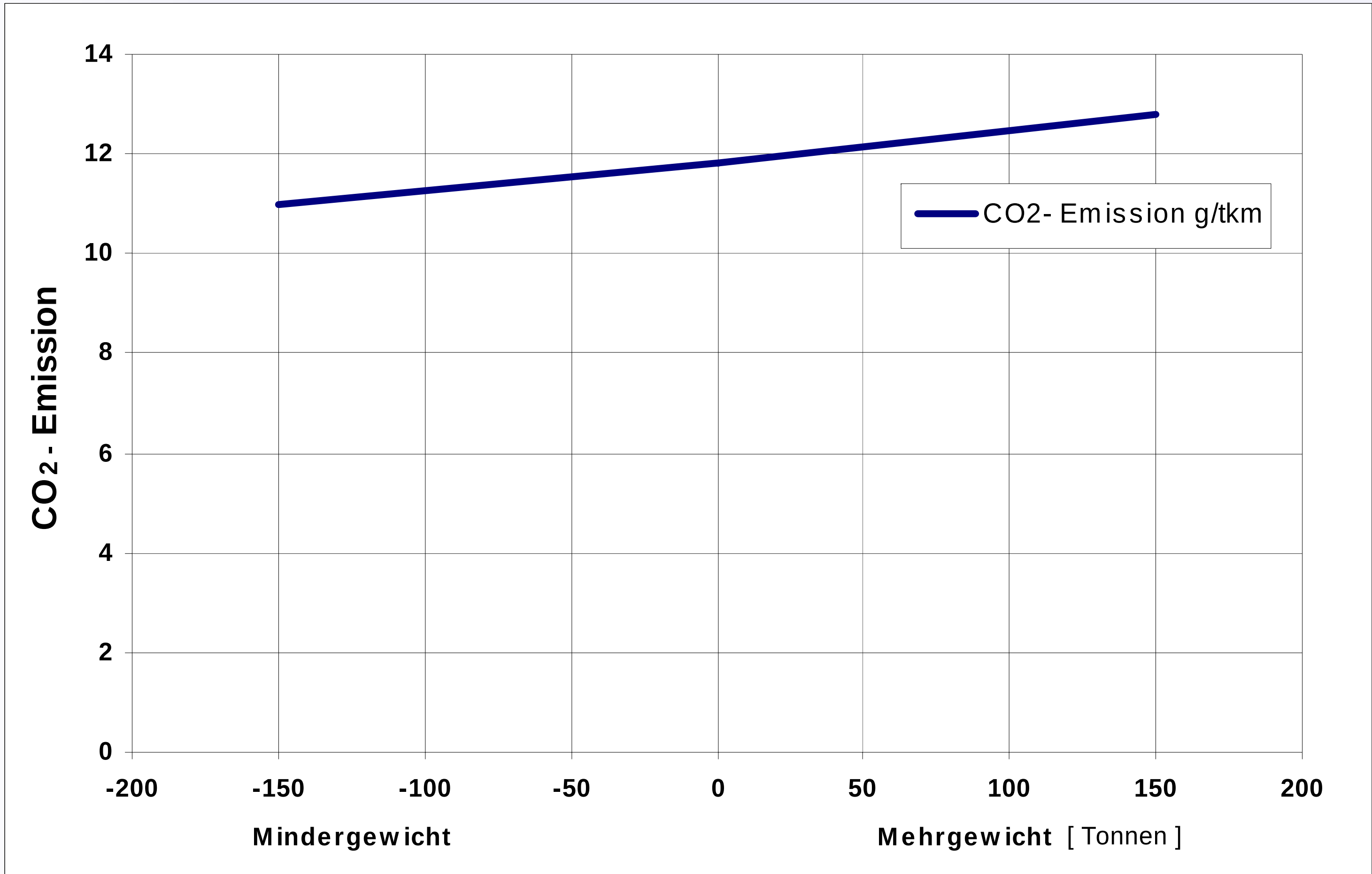
Improving transport efficiency

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 Pushing train 2+2	4,0	2340	11200	4,79
Schubverband 2spurig-3gliedrig 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

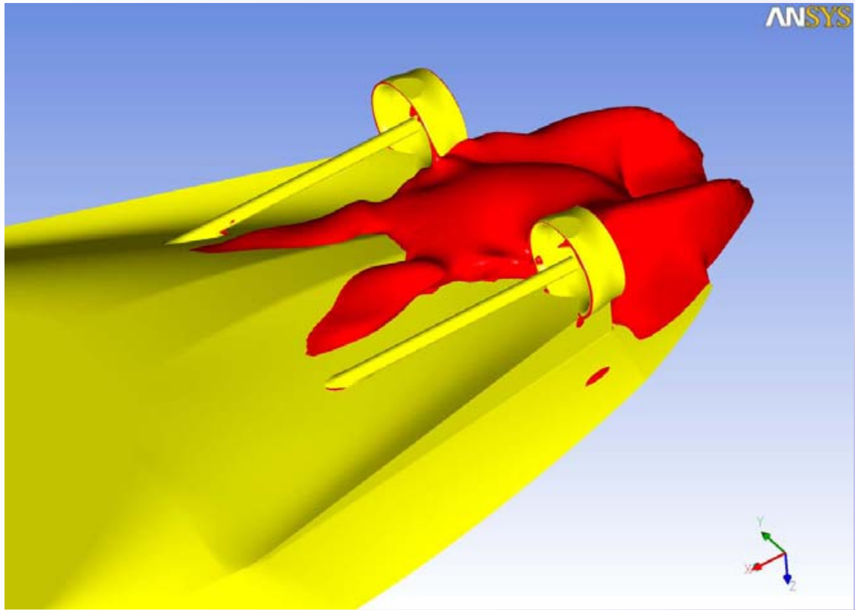
Improving transport efficiency

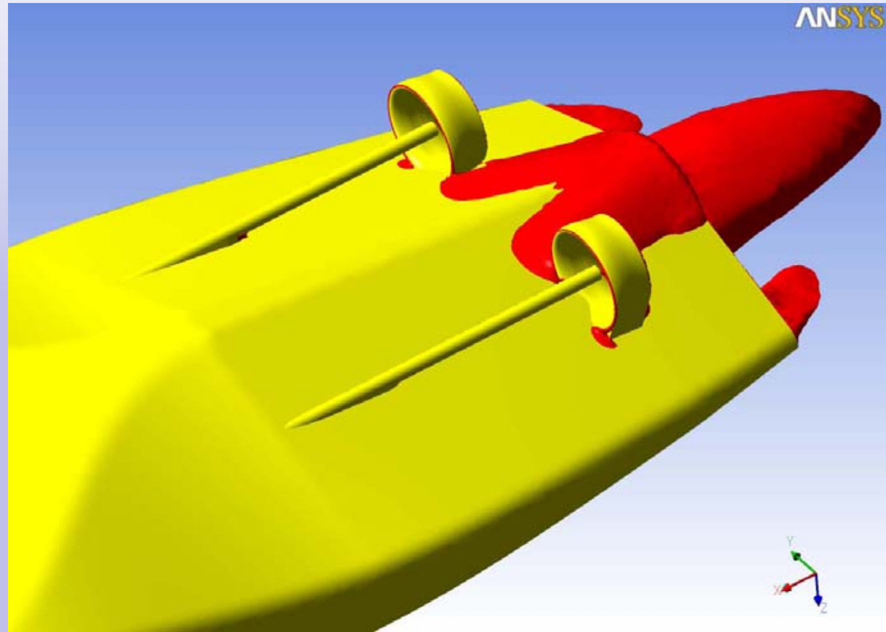
Hull form

Small changes in the hull form may produce a big difference

Improving transport efficiency

Hull form

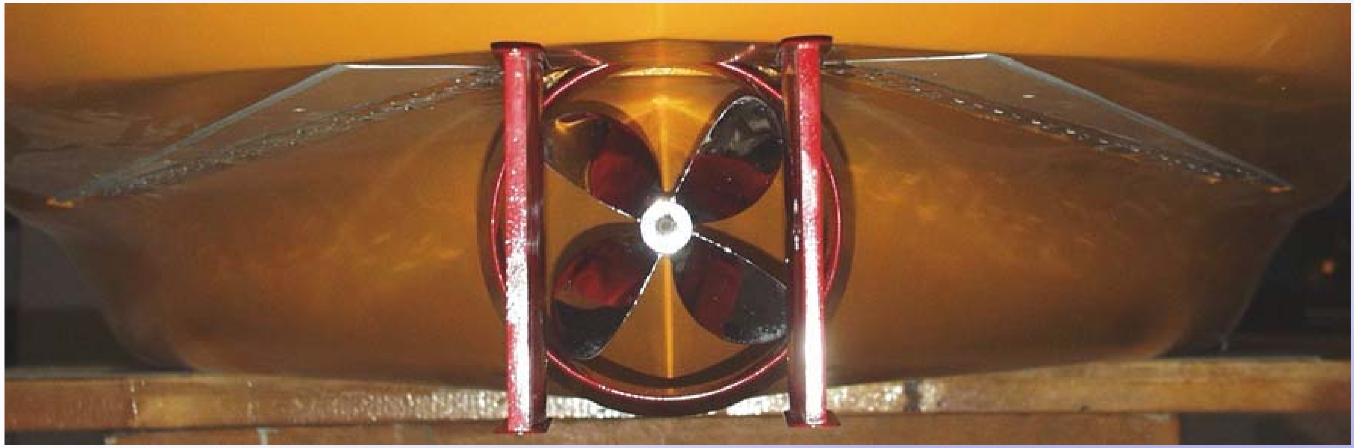


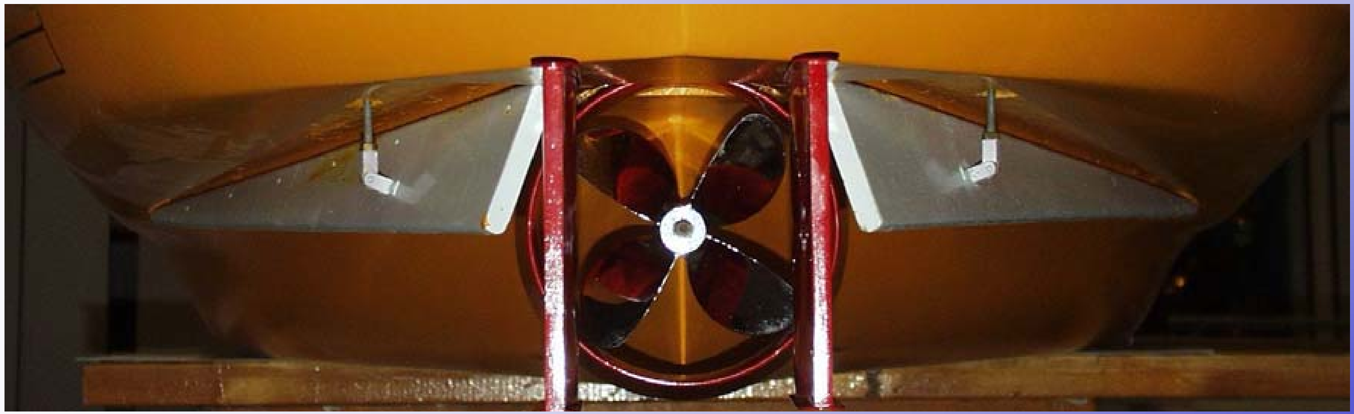


CFD calculations are detecting flow separation areas

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