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

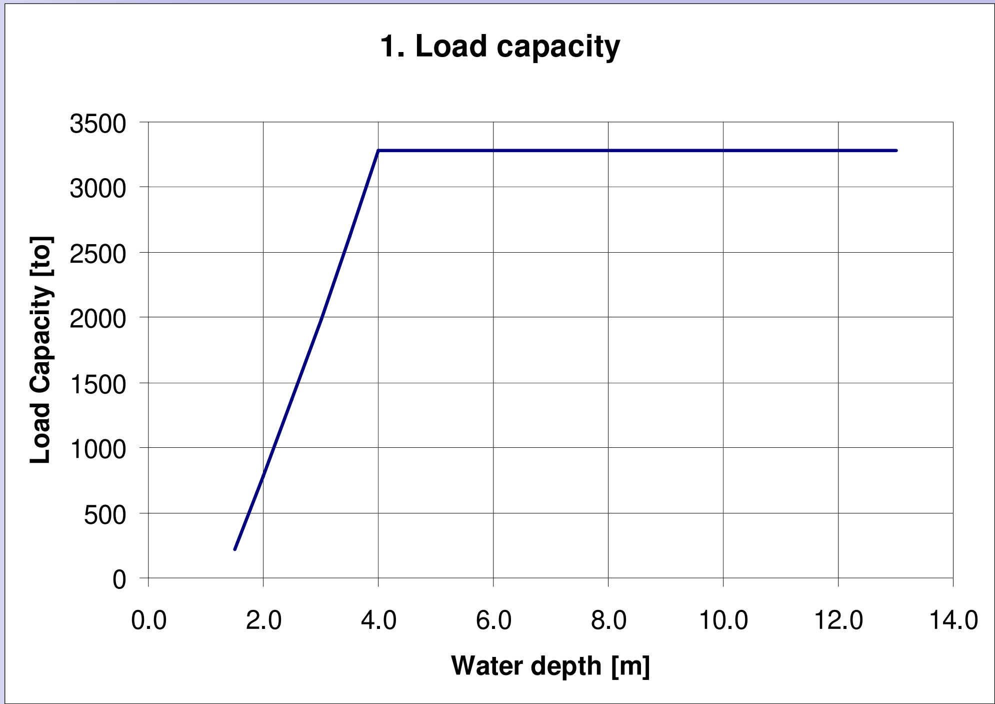
The water depth will have an influence two main aspects of transport efficiency :

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

Influence of the water depth on transport efficiency

The load capacity

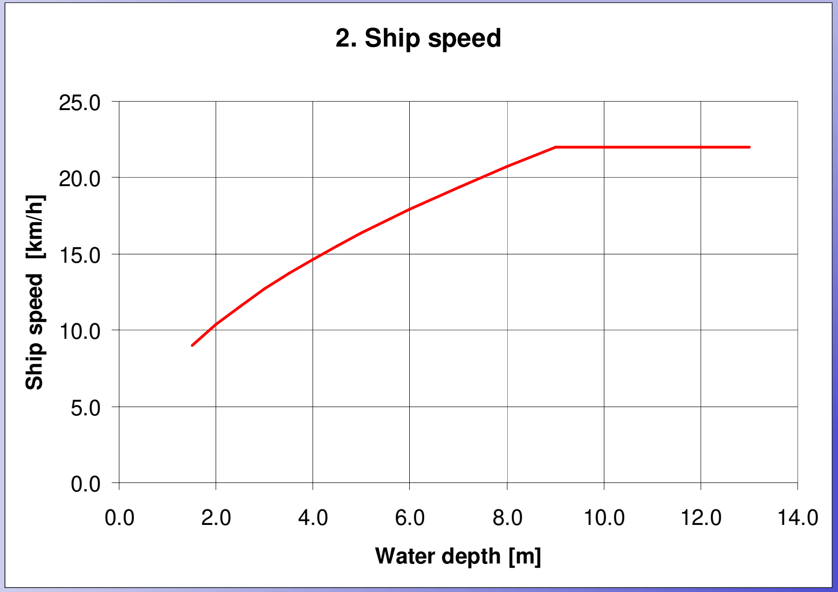
For any ship, keel clearance is necessary to advance and to manoeuvre. The keel clearance should be greater then 0,3 m. As function of the water depth, the load capacity starts at zero and increases until the design draught of the ship is reached.



Influence of the water depth on transport efficiency

Ship speed

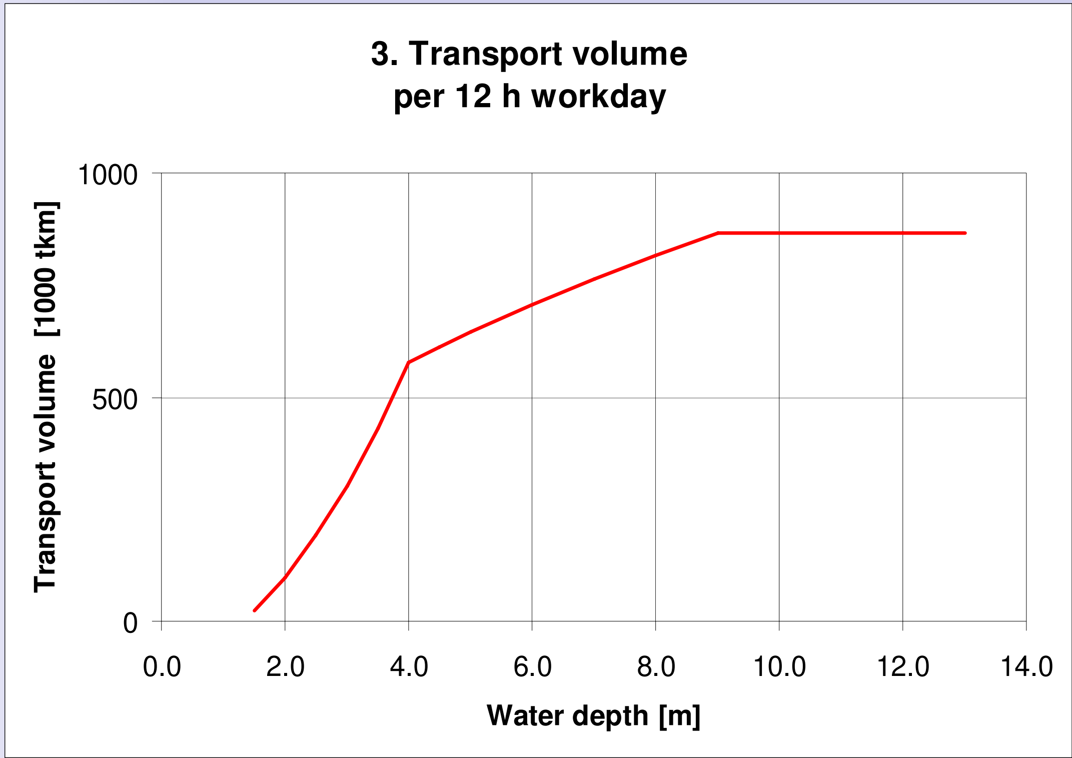
The practicable ship speed will increase, more or less proportionally to the root of the water depth. Typical IWS can reach a speed of 22 km/h, depending on the engine power and the hull form. For this speed level, a water depth of abt. 9 m will be necessary.



Influence of the water depth on transport efficiency

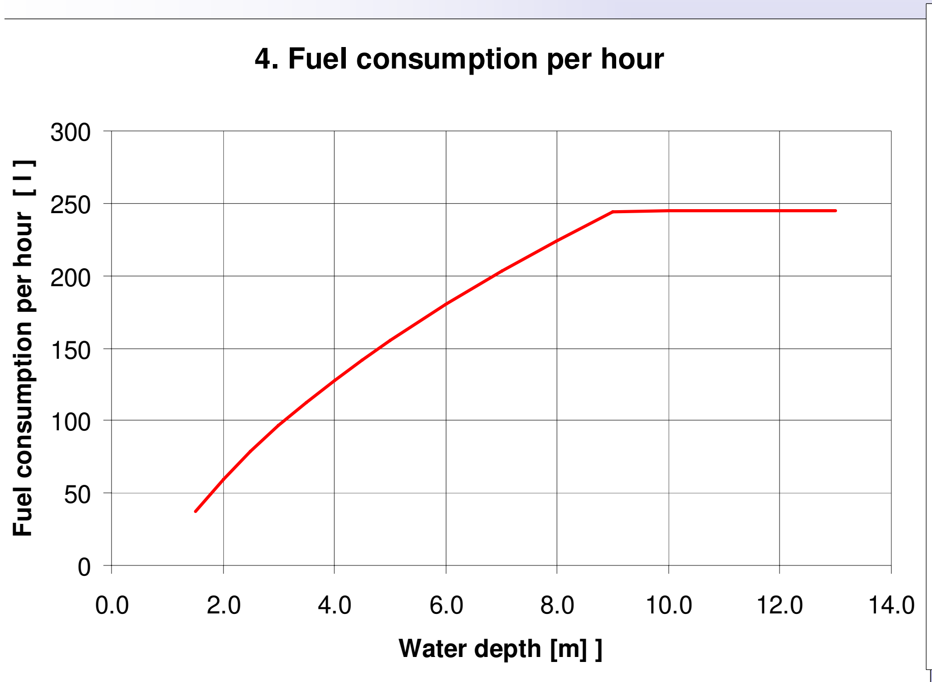
Example: Specific energy consumption

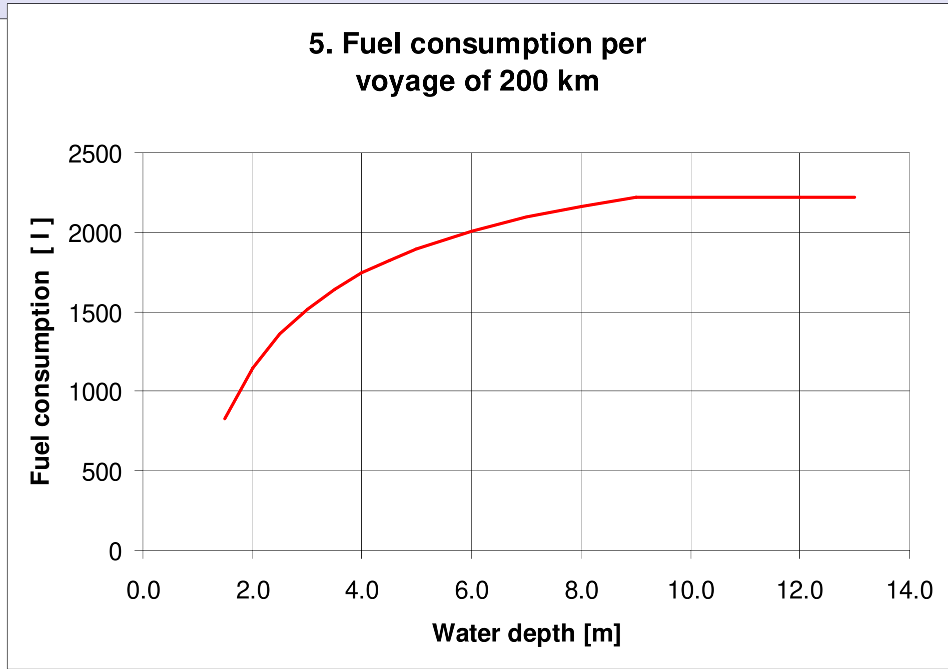
A IW cargo vessel works 12h per day, the transport distance being 200 km. The transport volume per day depends on load capacity and speed and is therefore a function of water depth:



Influence of the water depth on transport efficiency

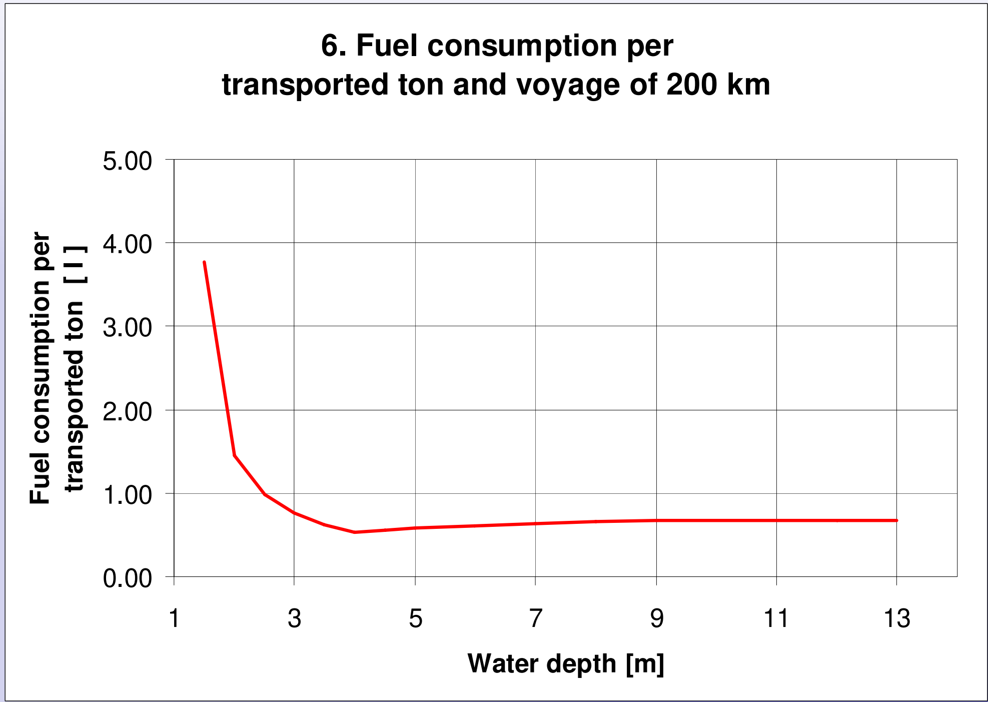
'he fuel consumption depends also on the water depth. As at low /ater depth, the travel will take longer, there will be strong ıfluence on fuel consumption.





Influence of the water depth on transport efficiency

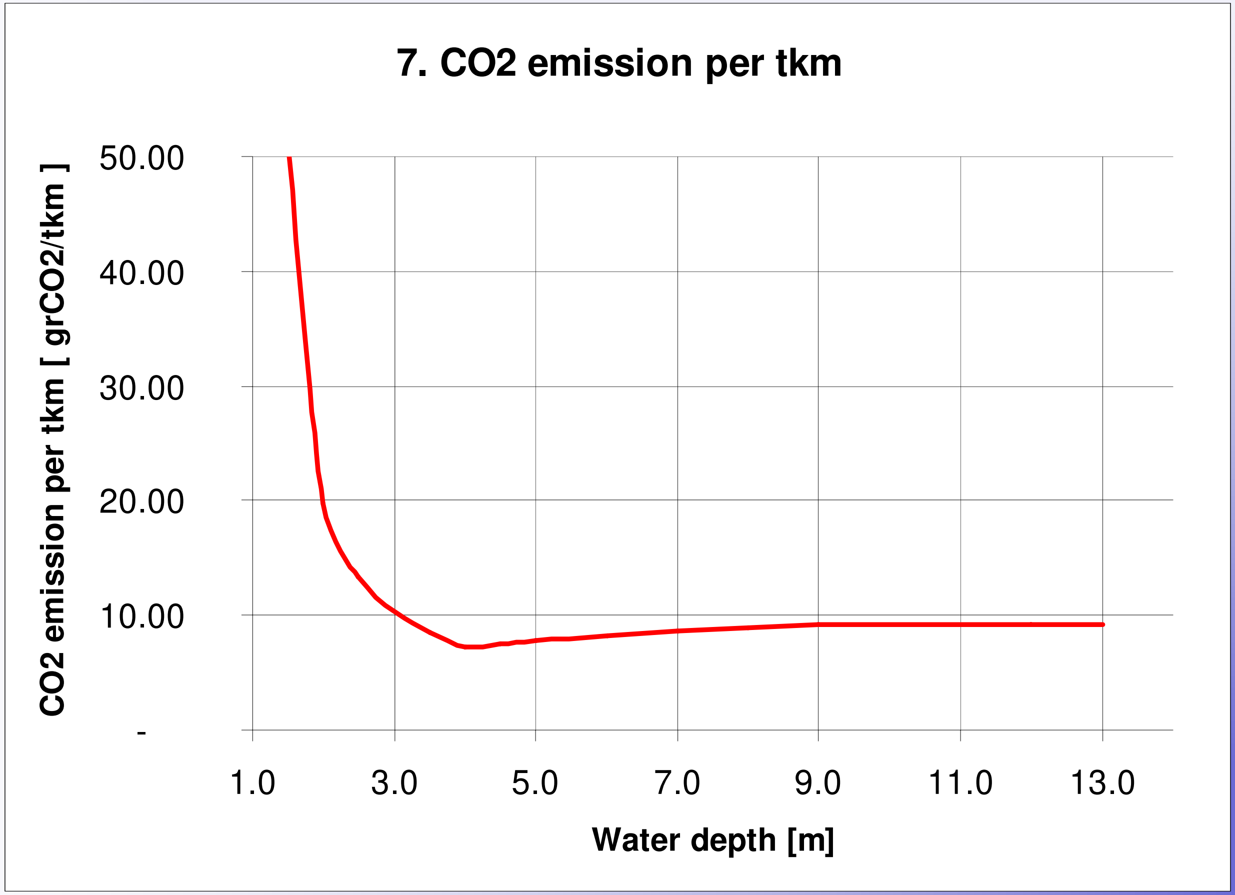
The fuel consumption has to seen in relation with the transport volume.



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

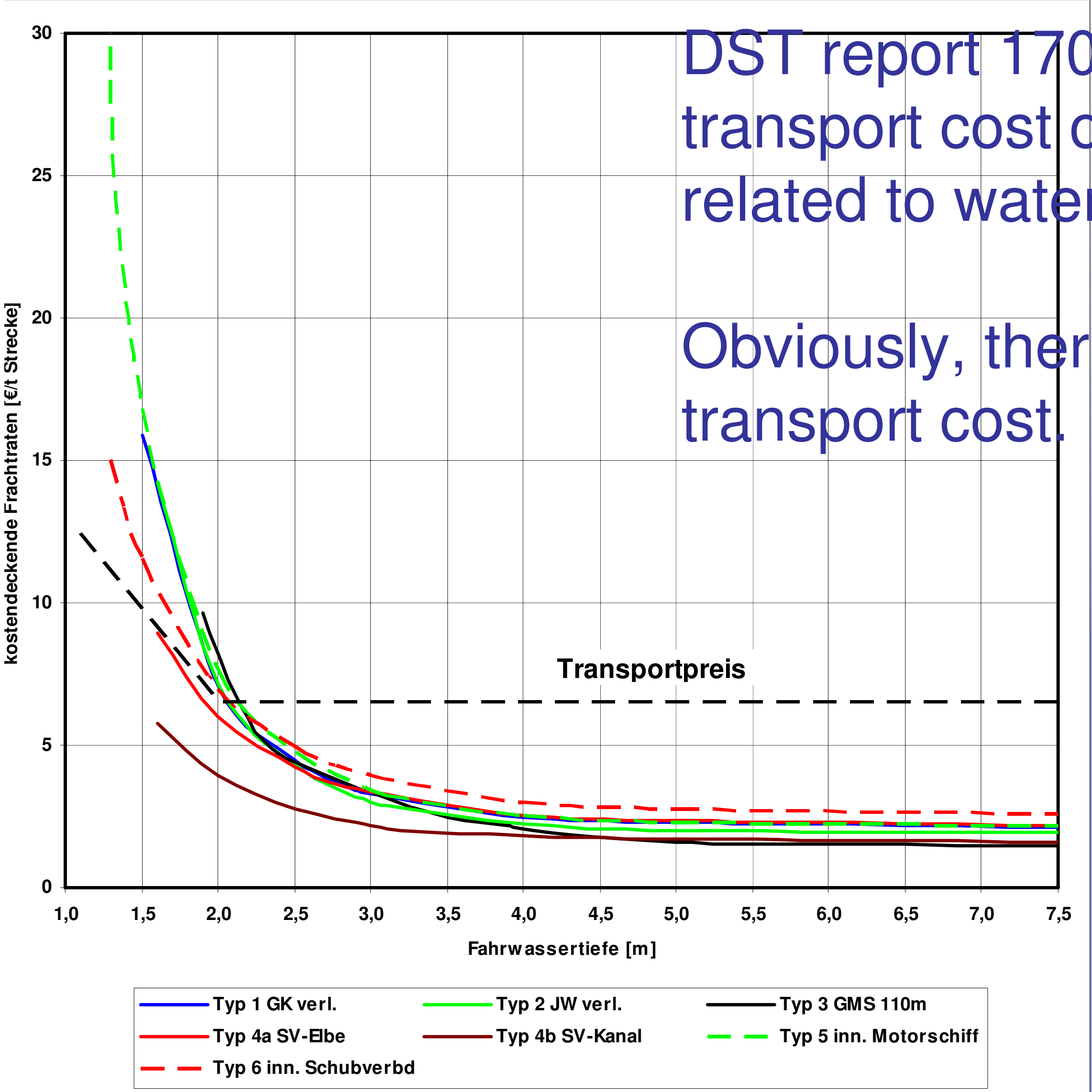
Scale effect

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

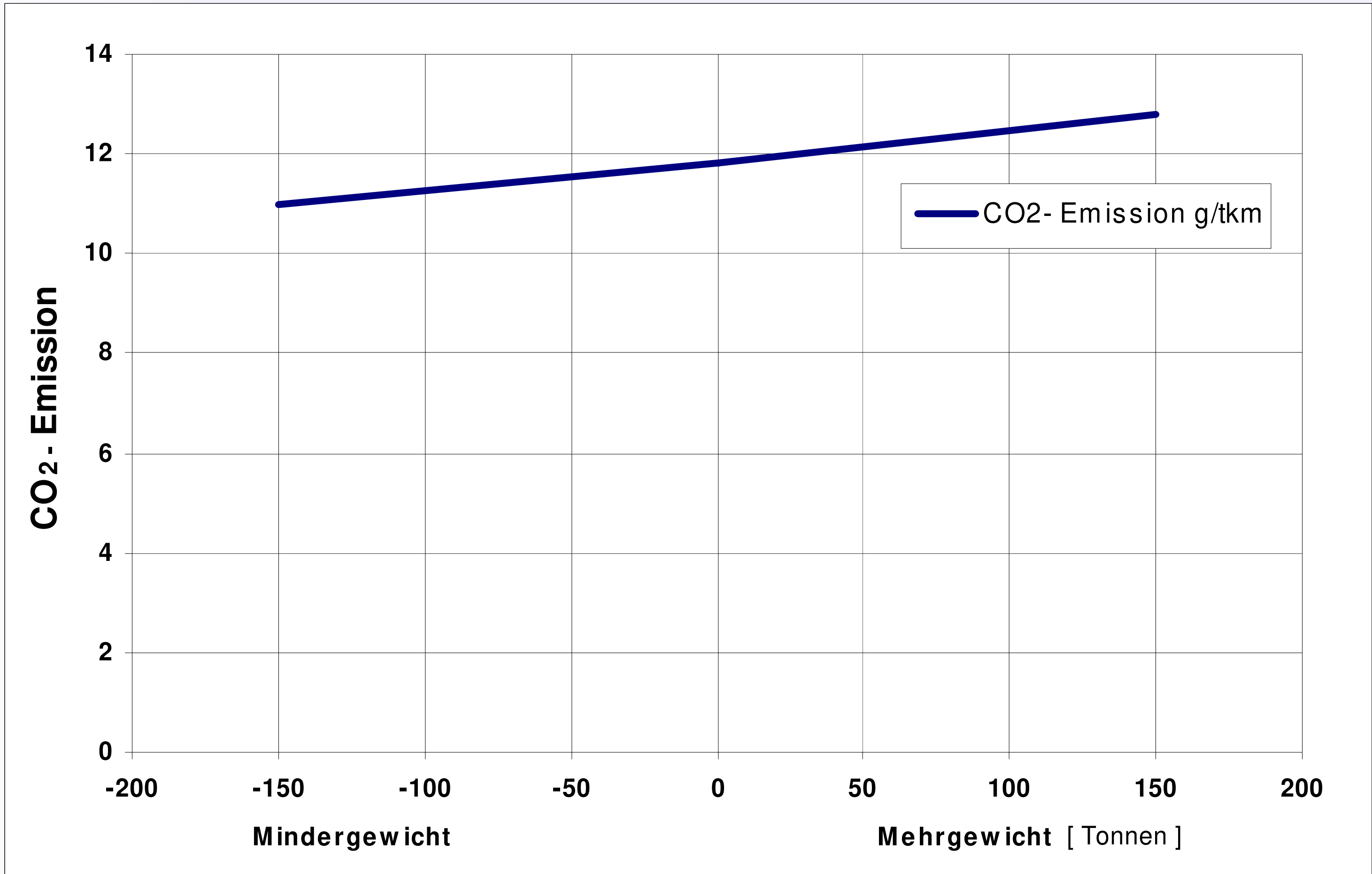
Improving transport efficiency

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 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

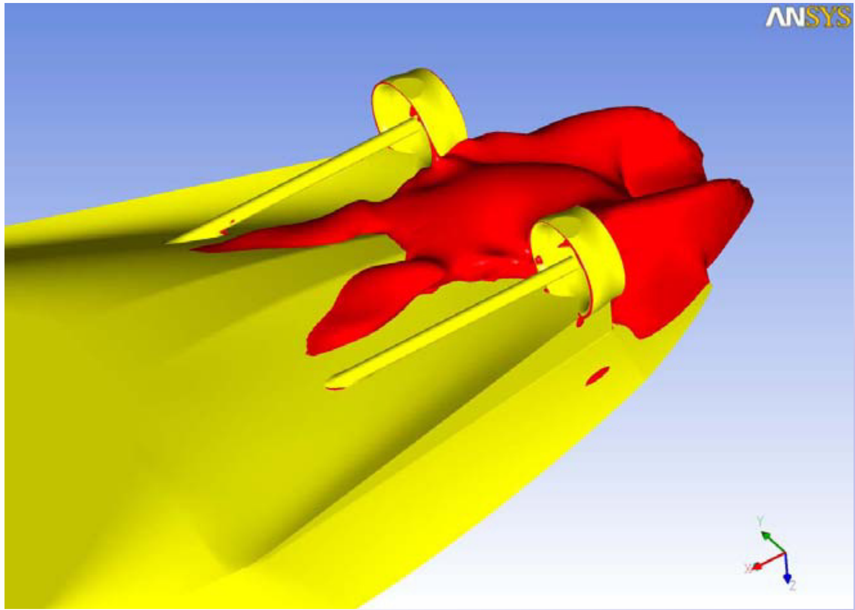
Improving transport efficiency

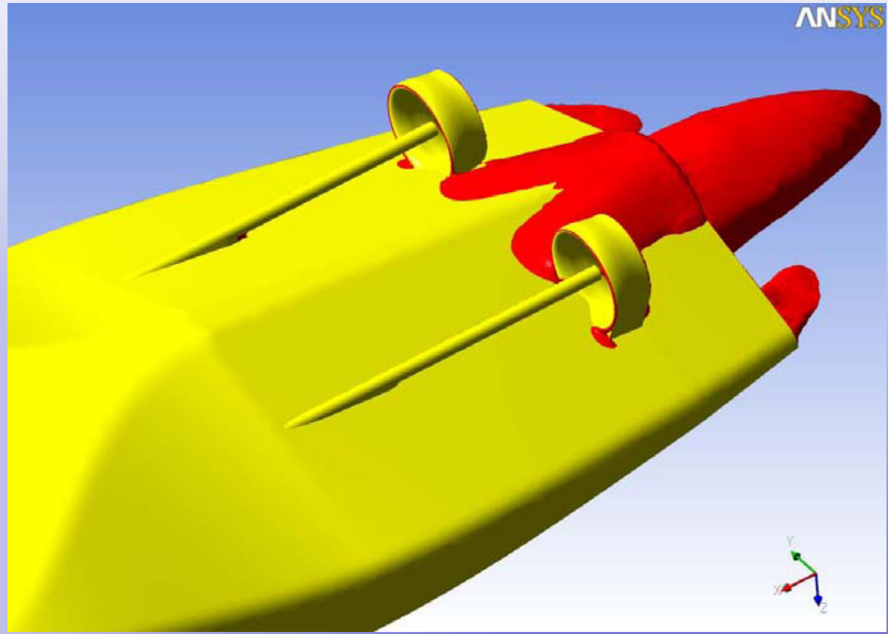
Hull form

Small changes in the hull form may produce a big difference

Improving transport efficiency

Hull form

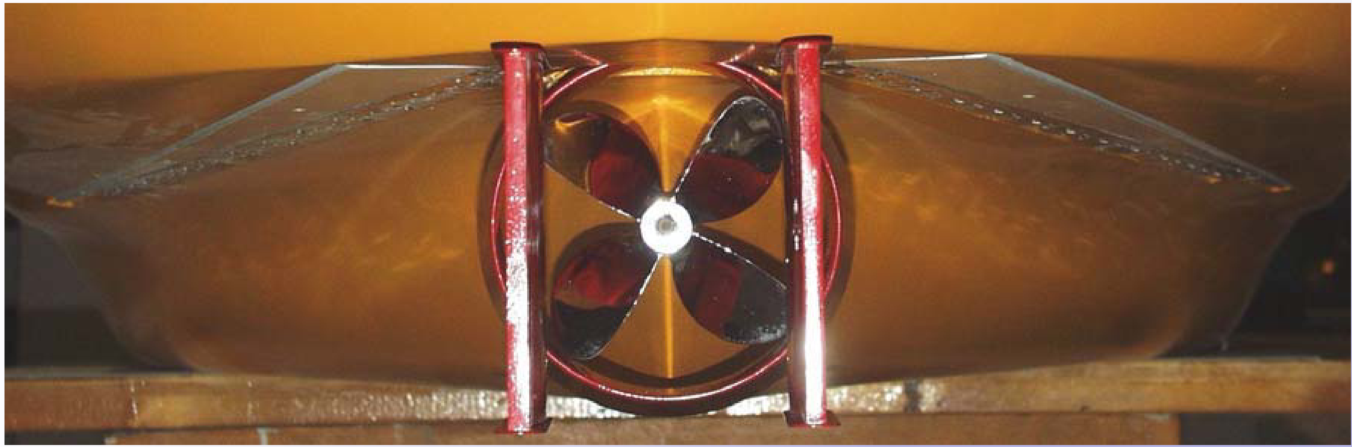


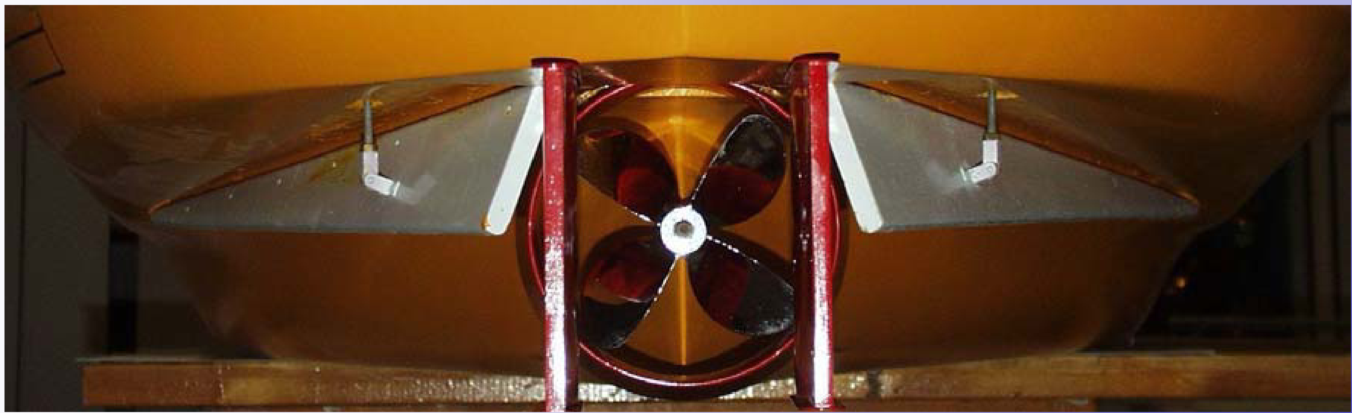


CFD calculations are detecting flow separation areas

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

Innovative Danube Vessel:
Innovative vessel and technology solutions with high potential for implementation

- Study commissioned by PAC 1a (via donau) on behalf of DG REGIO
- Overall objective: **Elaboration** and **development** of **innovative vessel** and **technology solutions** with high potential for implementation on the Danube
- Analysis of **solutions** derived **from existing R&D projects** with respect to their potential for implementation and further development in the Danube region
- **Provision** of **recommendations** for further **technology development** within the framework of the Danube Region Strategy
- Project concluded within December 2013

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DST

ÖIR
Austrian Institute for Regional Studies and Spatial Planning

SDG

УНИВЕРЗИТЕТ У БЕОГРАДУ МАШИНСКИ ФАКУЛТЕТ | UNIVERZITET U BEOGRADU MAŠINSKI FAKULTET | UNIVERSITY OF BELGRADE FACULTY OF MECHANICAL ENGINEERING

SCHIFFBAUTECHNISCHE VERSUCHSANSTALT IN WIEN GMBH
VIENNA MODEL BASIN LTD

Project coordinator: Dipl.-Ing. Thomas Guesnet, DST

´"**INNOVATIVE**" is understood in this case to be
"BETTER than the existing fleet",
both in terms of
ENERGY EFFICIENCY and
COST EFFICIENCY.

Innovative Danube Vessel

1. Introduction
2. Cost and performance calculation
3. Calculation setup
4. Calculation results
5. Conclusions
6. Recommendations

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The project considers mainly the ships types that are transporting the largest cargo shares on the Danube, as these are:

Transport commodity	Volume year 2010
Iron ore	22.7 million tons
Agricultural products	9.2 million tons
Refined petroleum products	3.4 million tons
Fertilizers including chemical products	3.3 million tons
"Other goods" -incl. high valued finished goods and containers	2.0 million tons

Container ships and RoRo ships will probably have only a marginal importance at mid-term range – and they are not different on the performance point of view.

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The identification and selection of promising technical and operational solutions is based on performance indicators reflecting economic efficiency and environmental performance.

Calculations performed with a software developed by DST to compute cost and performance of an IWS transport. This tool is able to use comprehensive data bases:

- Information on river depth and current speed for different Danube sections
- Economic Ship properties for fixed and variable cost
- Ship powering demand in function of water depth, draught and speed
- Water depth scenario for longer time periods

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Comparison of basic ship types

Short name	Remark	Length	Breadth	Design Draught
		L [m]	B [m]	T [m]
SMV	“Europe” ship class IV	85.00	9.50	2.80
A15	Increased Breadth, low draught	105.00	15.00	2.00
GMS	GMS class V	105.00	11.40	2.80
XGMS	“JOWI” Type	105.00	15.00	2.70
PB	Convoy class VI, push boat + 4 barges	210.00	22.80	2.70

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Comparison of basic ship types

For each basic ship type, specific properties are attributed:

- Speed/power curves for a complete range of water depths and draught, derived from reference ships.
- Payload at small draught and maximum draught.
- Investment cost for a new ship.
- Crew cost for 24/24h operation.

The operation of a motor vessels were also calculated as a convoy in combination with one coupled barge.

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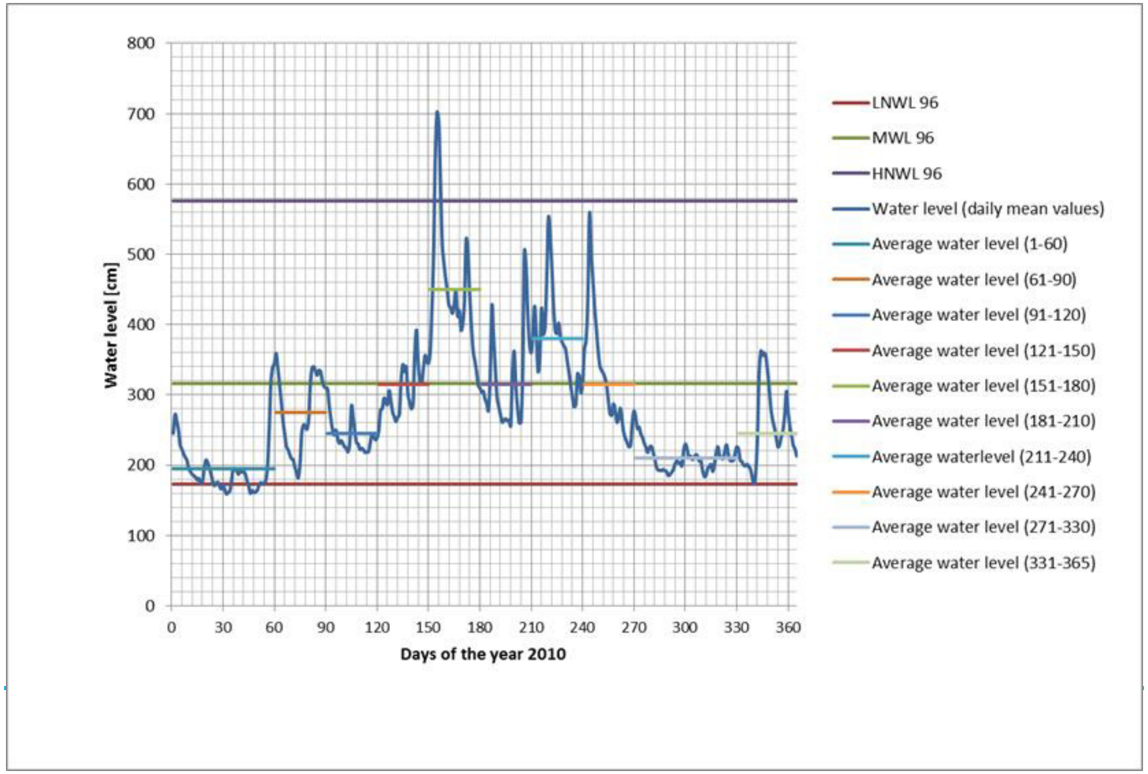
Operation scenario

- A simplified Danube river model was defined, with 23 sections in different water depth and the corresponding current speed.
- A operation scenario on the waterway with low, normal and high water periods was defined.



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Ship performance calculation

- The year 2010 was used as reference year with normal waterway conditions.
- As ships with a beam of 15 m may have more waiting times in locks, the lock passing time was increased from 1 to 1.2 h for these ships.
- Only the loaded upriver voyages were taken into consideration.
- For each voyage, the ship draught was selected according to the water depth that could be expected in the relevant time period. A minimum keel clearance and the influence of squat were taken into account.
- Ship speed and turnaround time was set according to practicable experience.

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Ship performance calculation

Calculation results are obtained for each single voyage of the time period and as cumulated exploitation sum for the complete year.

Results are expressed as:

Criteria	Unit
EEI : Energy efficiency index	grCO_2/tkm
Fuel consumption per year	t / year
Total Cost per year	€ / year
Total Load per year	t / year
Cos	

The numerical values for cost have to be considered as indicative, as fuel cost, investment cost and crew wages are subject large and unforeseeable changes. Also risk and benefit margins, insurance etc. are not considered. The main use of these figures is the **comparison** between different ship types**.**

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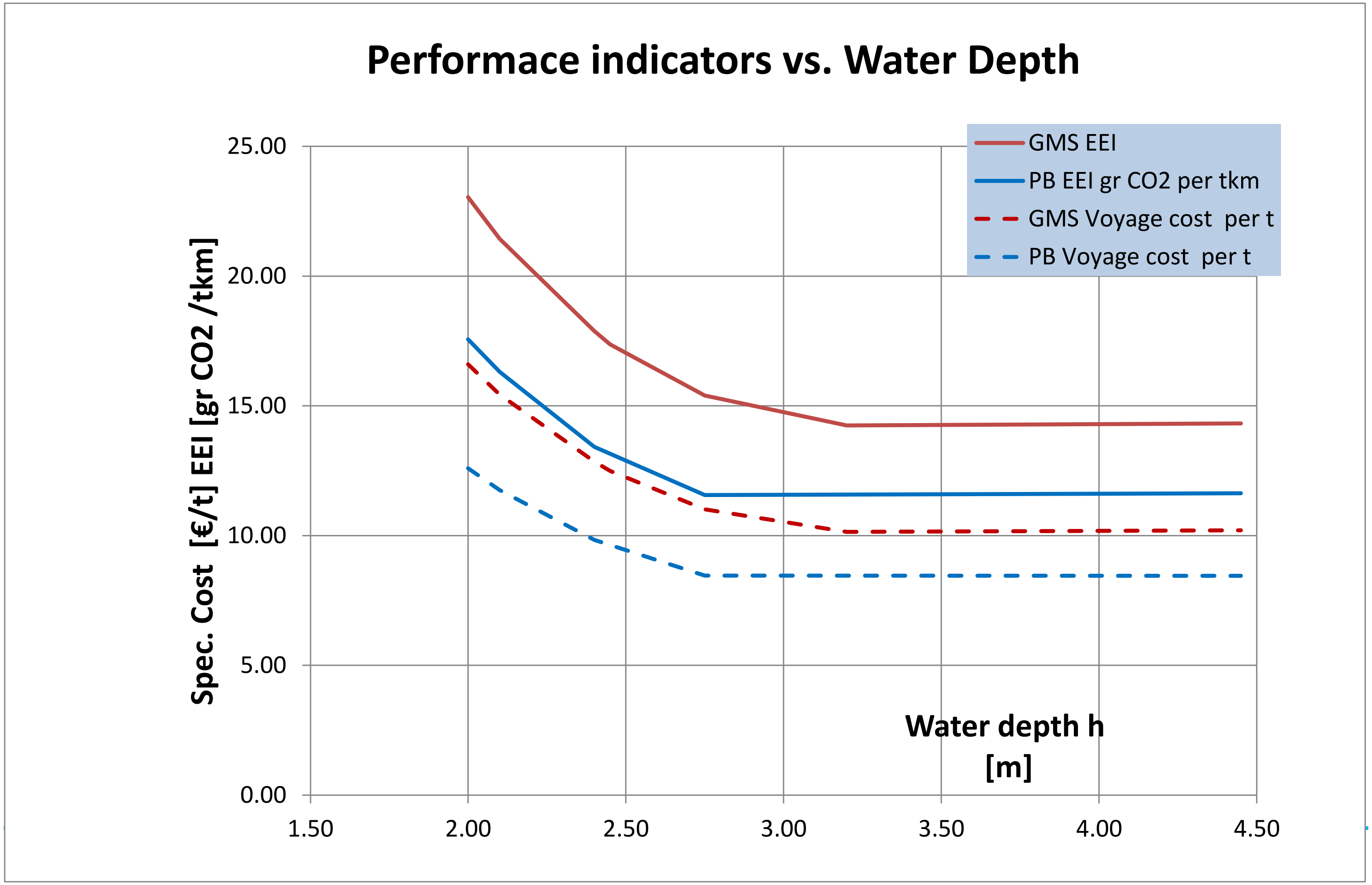
Results:
1. Ship performance depends mainly on the available water depth



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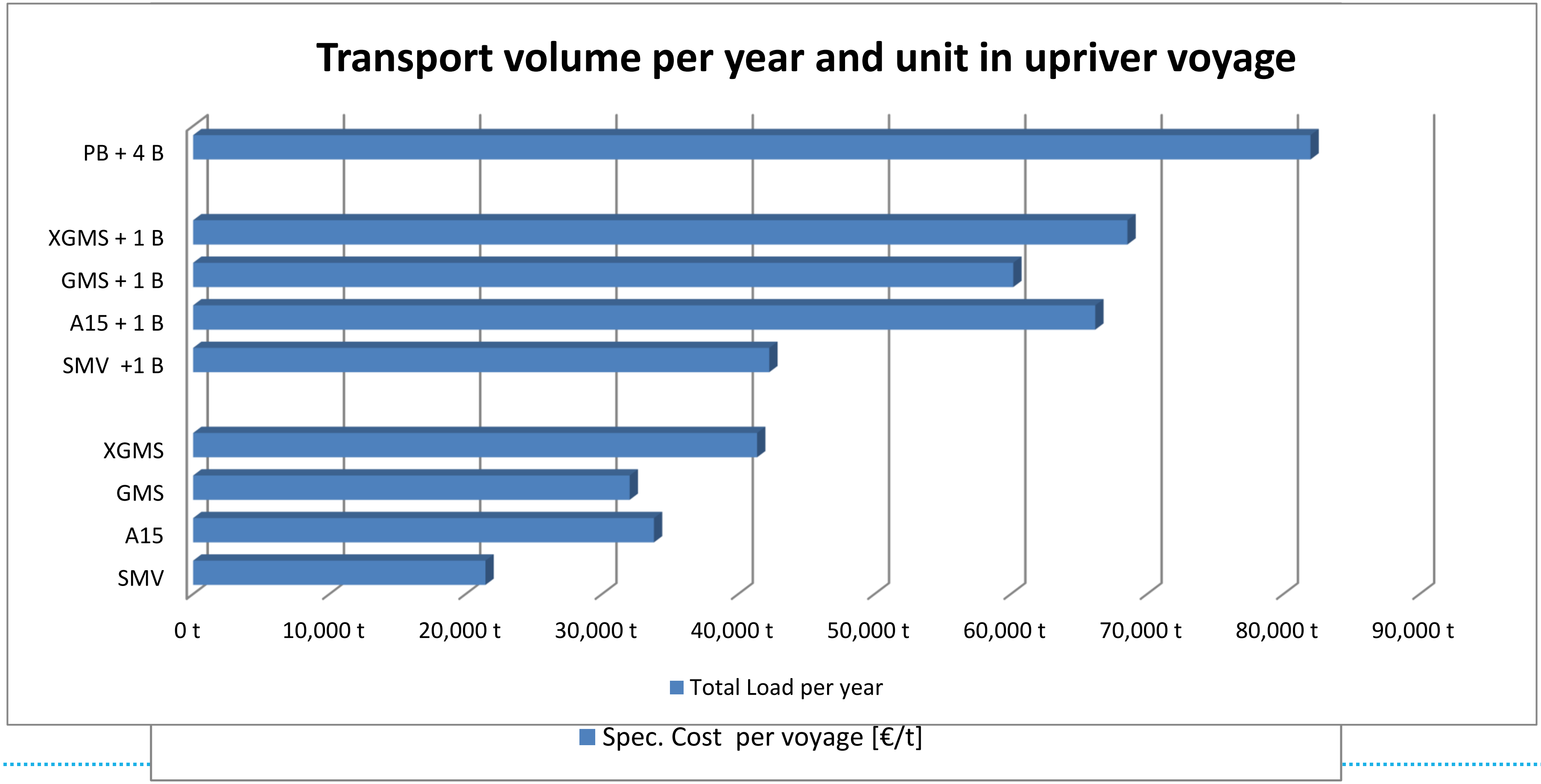
Results:
2. Basic ship types reach different performance.



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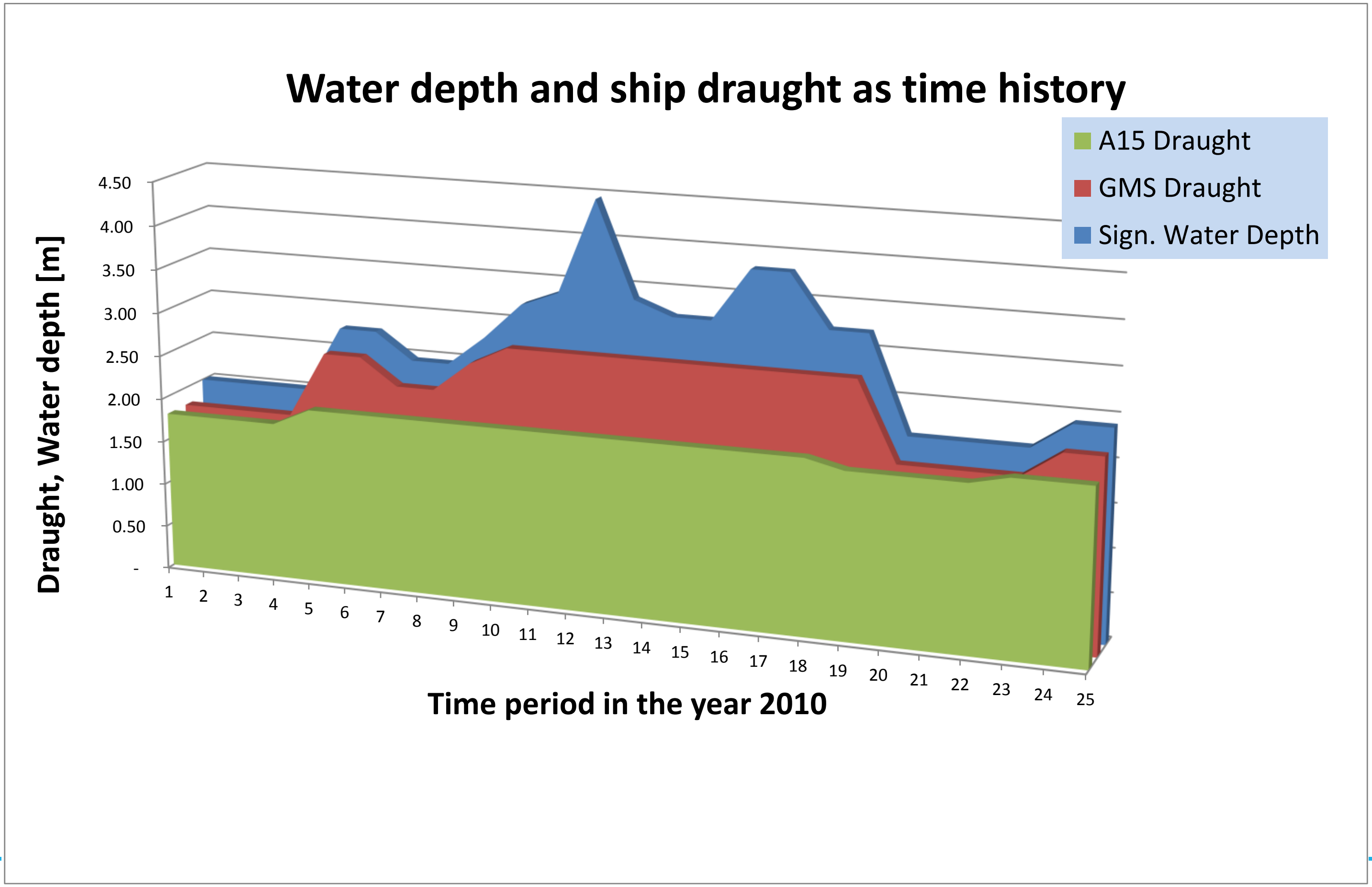
Results:
3. Ships with a limited design draught are disadvantaged in transport performance



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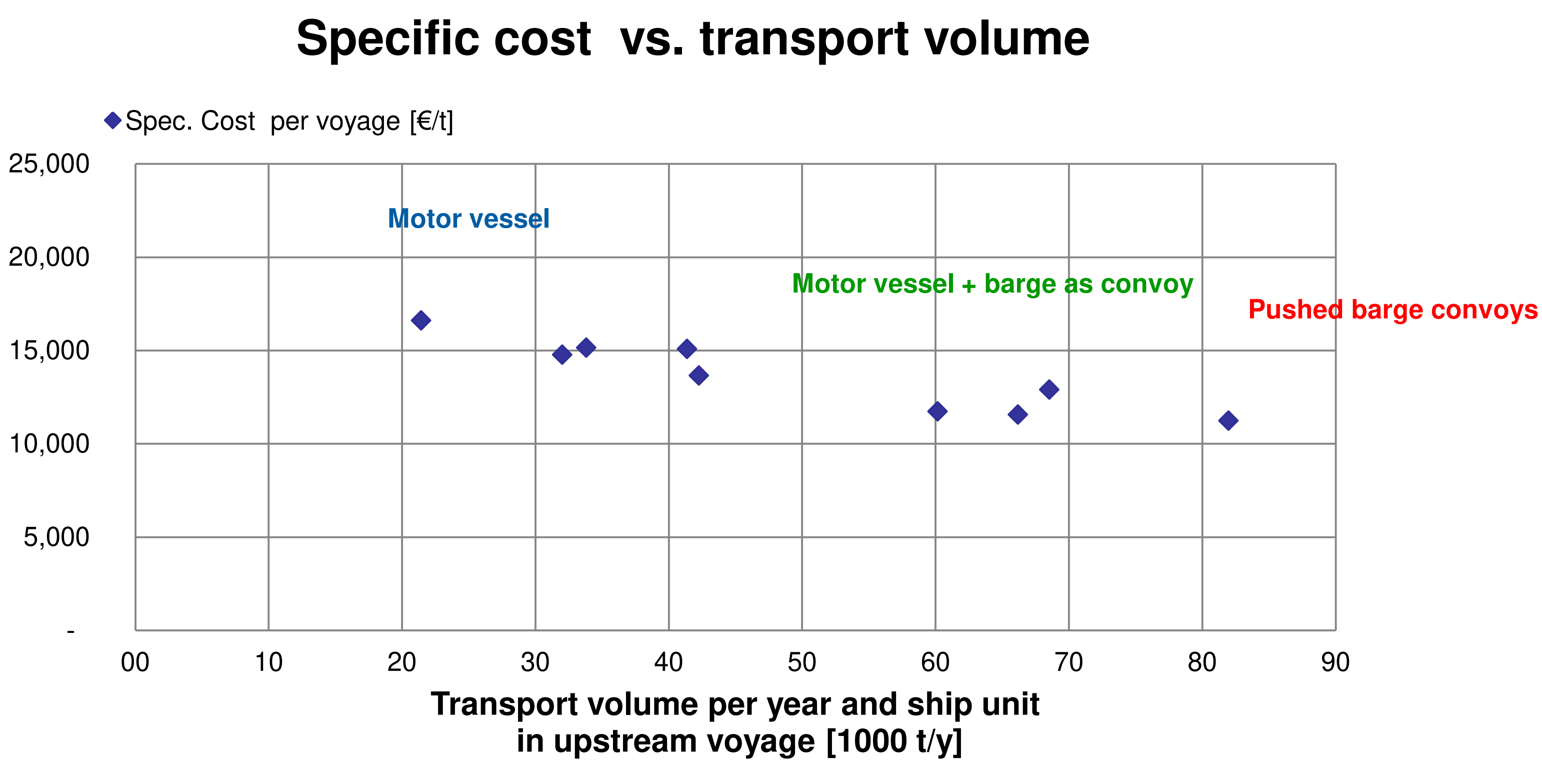
Results:
4. The pushed barge convoys have excellent performance



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Results:
The pushed barge convoys have excellent performance in cost and energy efficiency, and there are clear reasons for this:

- Dump barges are of light construction and reach high payload at low draught.
- The configuration of the convoy is easily adopted to voyage and fairway conditions.
- The convoy takes best advantages of the specific Danube infrastructure:
  - Locks with class VII dimensions in 33 m and 24 m (upper Danube) breadth,
  - The fairway is at locations shallow, but always large.
- At any water depth, the pushed barge convoy reaches the highest possible payload compared to all other ship types.

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Recommendations:
Innovative designs have to be prepared for different ship types:

A) The self-propelled motor vessel

Viable option for the commodities available in lower quantities – e.g. containers, agricultural products, manufactured goods.

Requirements on new designs:

- **Fully operational at a draught of less than 1,60 m**
- **Highest propulsion efficiency**
- **Essential: Ability to push a single barge, or even three barges**

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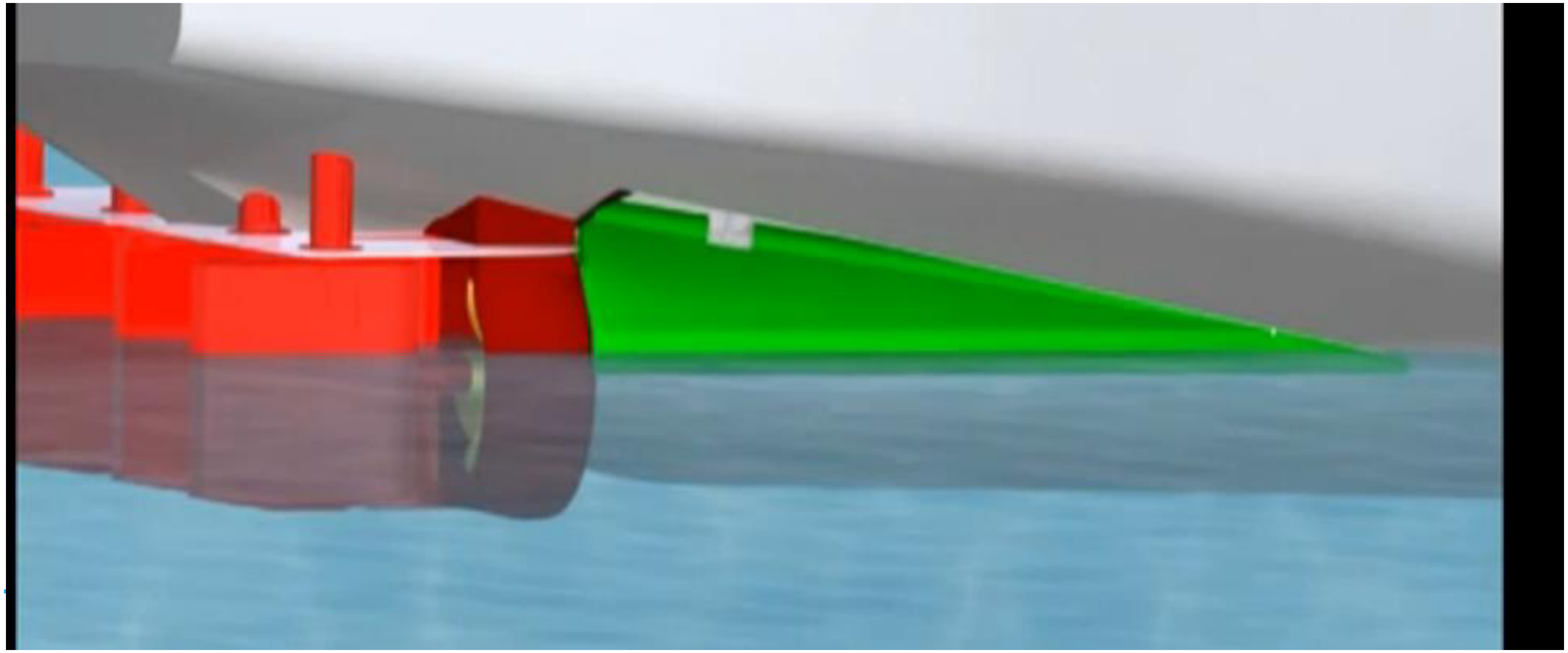
From the shortlist, 3 innovations appear to be the most promising:

1. Adjustable tunnel at the propellers, a product of Van der Velden Marine Systems /NL

May be applied to all types of self-propelled barges.



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From the shortlist, 3 innovations appear to be the most promising:

2. Air lubricated ship, promoted by Damen Shipyards Group /NL

Air lubrication can reduce fuel cost and improve energy efficiency. An application of the device on pushed barges should be investigated with priority.

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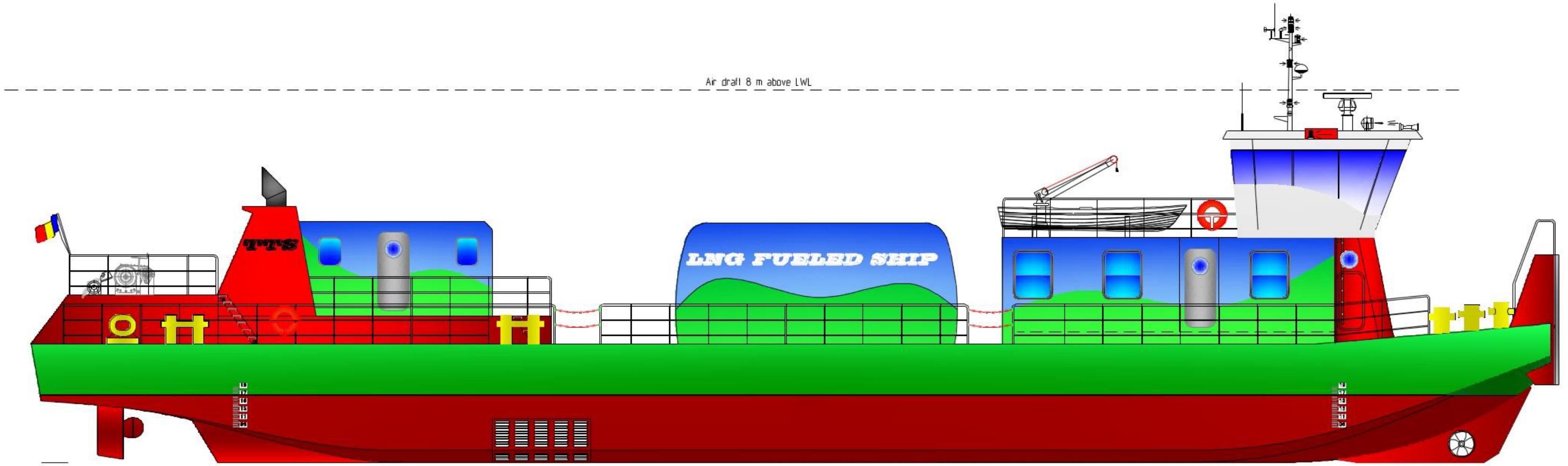
From the shortlist, 3 innovations appear to be the most promising:

3. LNG as fuel for inland navigating vessels

Even taking into account the additional investment, important fuel cost savings and savings in emissions are expected.

Best impact on reduction of emissions, especially NOX, SOX, and soot particles.



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Recommendations:
Innovative designs have to be prepared for different ship types:

C) The push boat

The push boat keeps the essential role in bulk transport

Requirements on new designs:

- 100 % fuel stores at a draught of max. T = 2,0
- Full performance and min sto… T = 1,60 m
- Highest propulsi…
- Ess… 8 barges on the lower Danube

New push boats bring the best improvement in cost and energy efficiency to inland waterway transport on the Danube.

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Recommendations:
Innovative designs have to be prepared for different ship types:

B) Optimized barges

- Optimized convoy dimensions with regard to available lock size and push boat size.
- The steel structure of the barges should redesigned for lower weight at reduced building cost.
- Maneuverability of convoys enhanced by steering devices at the bow of the convoy.

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Further Recommendations:

- Optimized barges
- Voyage speed optimization
- River information systems (RIS)
- Energy efficiency benchmarking

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Conclusion

- Under regular waterway conditions, Danube vessels can reach an excellent cost and energy efficiency for the transport.
- Innovative devices and optimized ship designs will even improve this situation.
- Sufficient water depth is essential for energy- and cost-efficient ship operation.
- Any improvement on the Danube waterway conditions pays off in cost and energy efficiency.
  - Or reversely:

    Ship design and technology will not compensate insufficient waterway conditions.