Innovative Danube Vessel

Contribution of Vienna Model Basin

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Considered Items

- Representation of efficiency to match with EEDI (IMO)
- **Variation of design parameters** based on existing model test results of VMB and DST
  - Arrangement of Barge-Combinations
  - Draught Variation
  - Effect of Shallow Water in Practice (maximum draught)
  - *L/B*
  - Weight Reduction
  - Speed-Power Optimization
  - Trim as Limitation
- **Influence of** short sections of **shallower water**
  - Example Calculation for Tug Barge -System Sulina- Linz

Energy Efficiency Design Index

- $EEDI = \frac{CO_2\ emission}{Transport\ work}$ = $\frac{\Sigma(P_B * C_{FME} * SFC_{ME})}{tdw * V_S}$

- P_B installed break horse power
- SFC_{ME} specific fuel consumption
- C_{FME} CO_x Coefficient on engine test bench
- *tdw* transported cargo
- V_S ship speed

Coefficient for Transport Efficiency

$$\frac{Delivered\ Power\ at\ propeller}{Transport\ Work} = \frac{\Sigma P_D}{tdw * V_S} = \frac{\sum P_{D*} time}{tdw * \mathrm{km}}$$

- ΣP_D Power delivered at all propellers [kW]
- *tdw* Transported Cargo [t]
- V_S Ship Speed [m/s]
- Km 1 km distance
- *time* 1 hour

Remark

- All the following considerations do not take into account the operator‘s profit. The investigation concentrates on energy saving (consumption of energy per tdw and km).

- Additional economic considerations regarding the operator‘s benefit should be made by an expert on applied economics.

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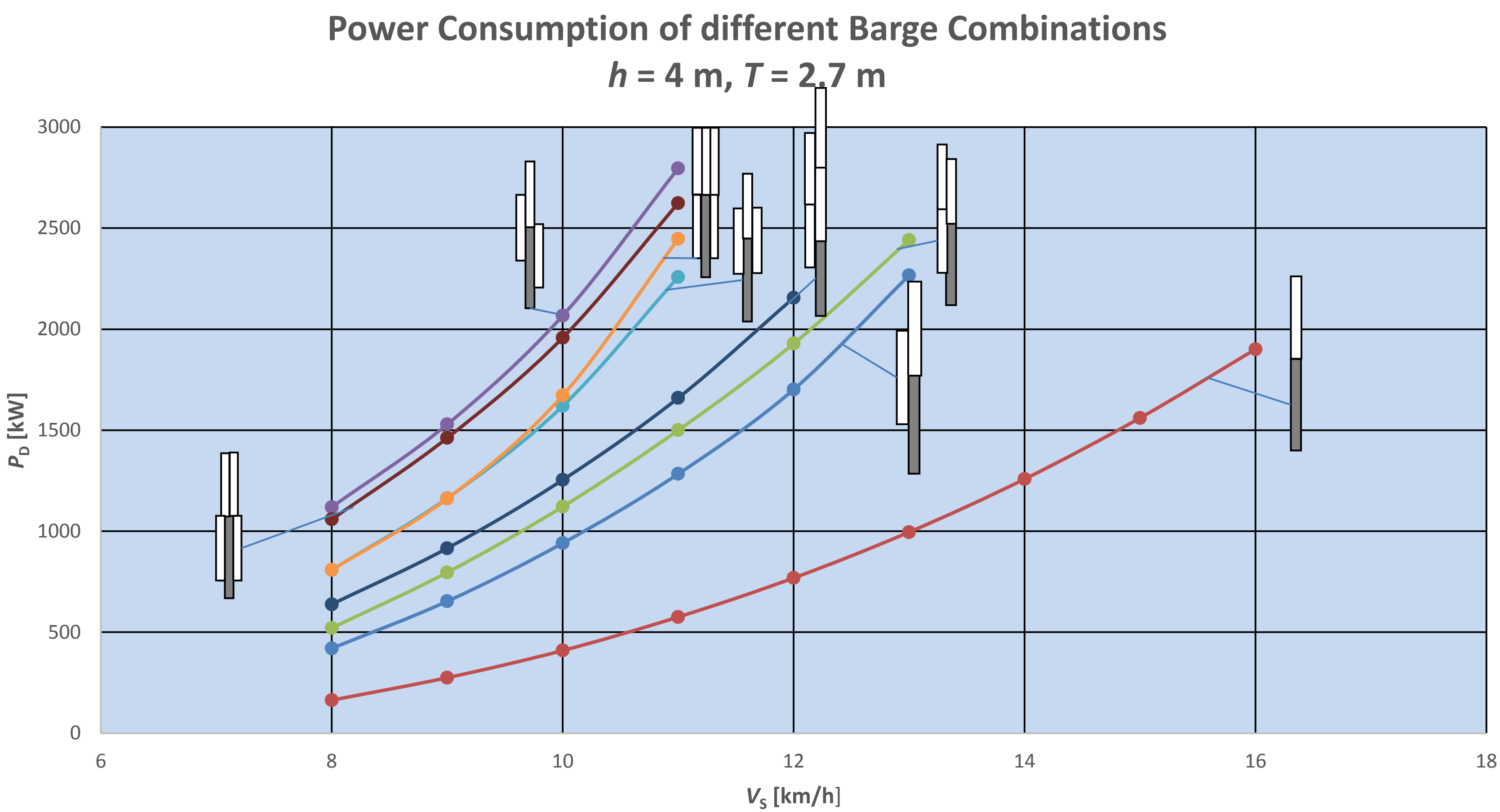
Considered Available Test Results Evaluation and Representation

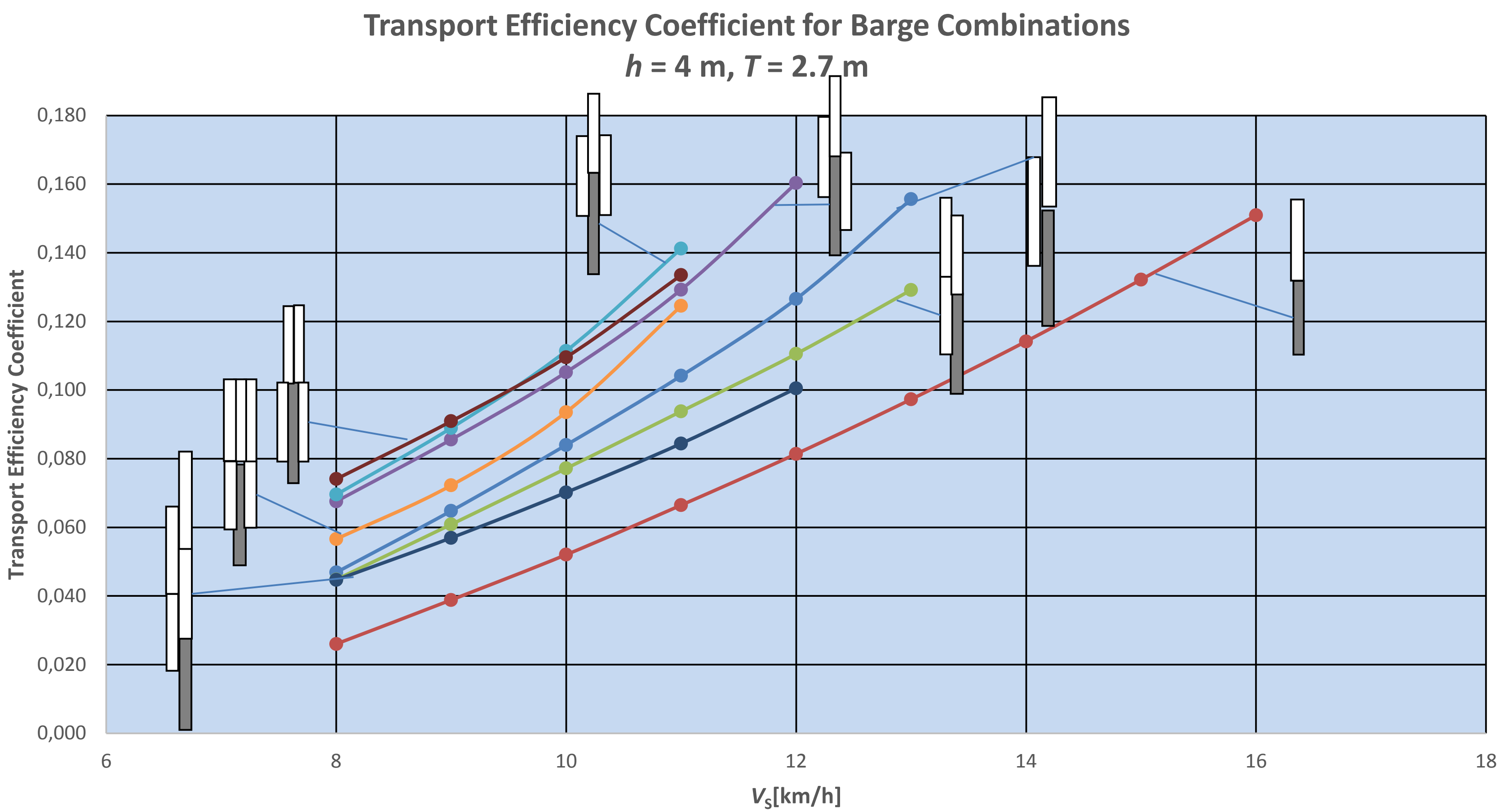
Barge - Barge Combinations(VMB)

Powered Barge			Dumb Barges	
L_{oa}	95.0 m		L_{oa}	76.0 m
B	11.0 m		B	11.0 m
T	2.70 m	2.0 m	T	2.00 m
∇	2520 m³	1795 m³	∇	1548 m³
tdw	1634 t	909 t	tdw	1280 t
Weight	886 t		Weight	268 t
Weight of structure estimated: 420 t				

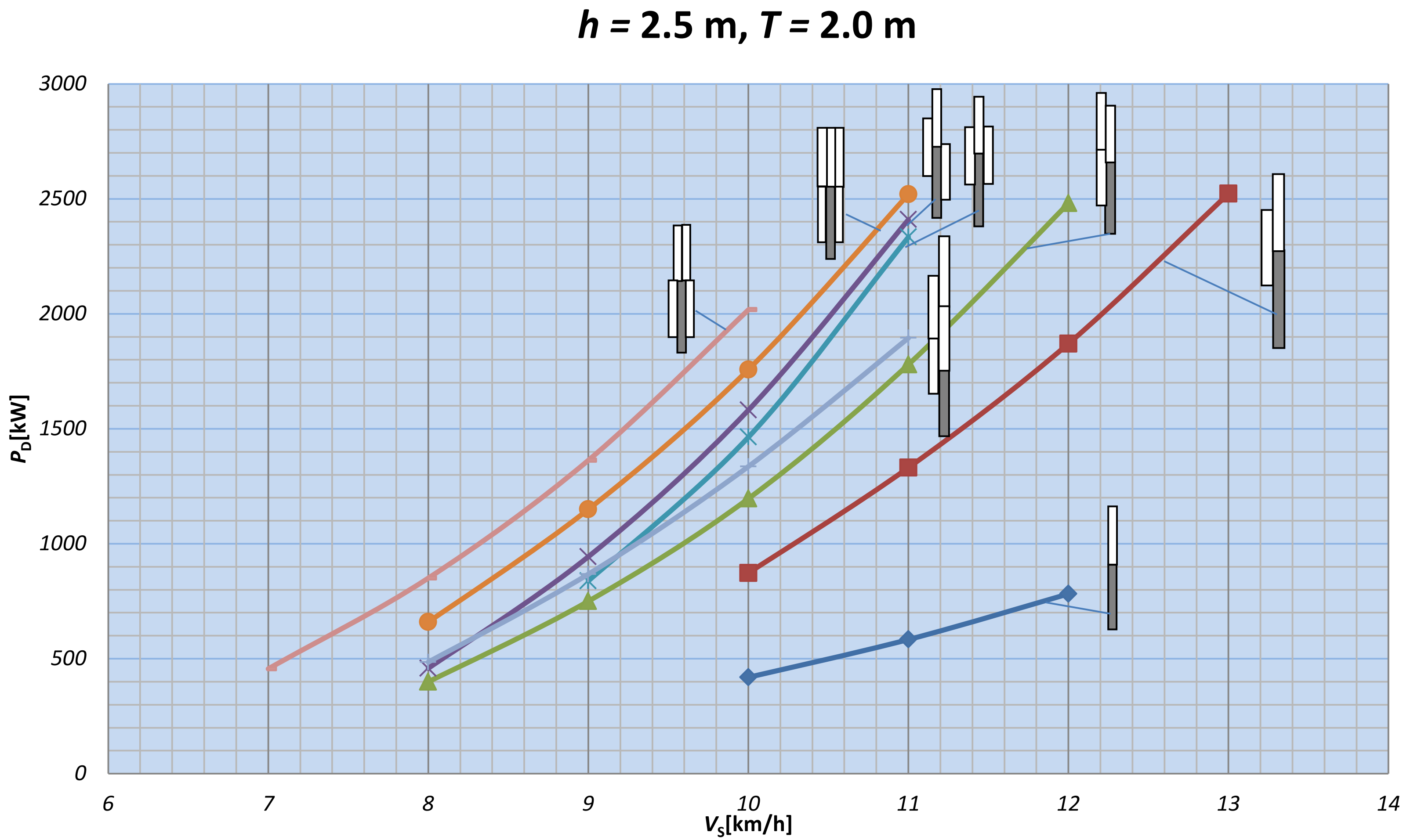
Power Consumption of Different Barge – Barge Combinations, h = 4 m, T_{Barge}= 2.7 m



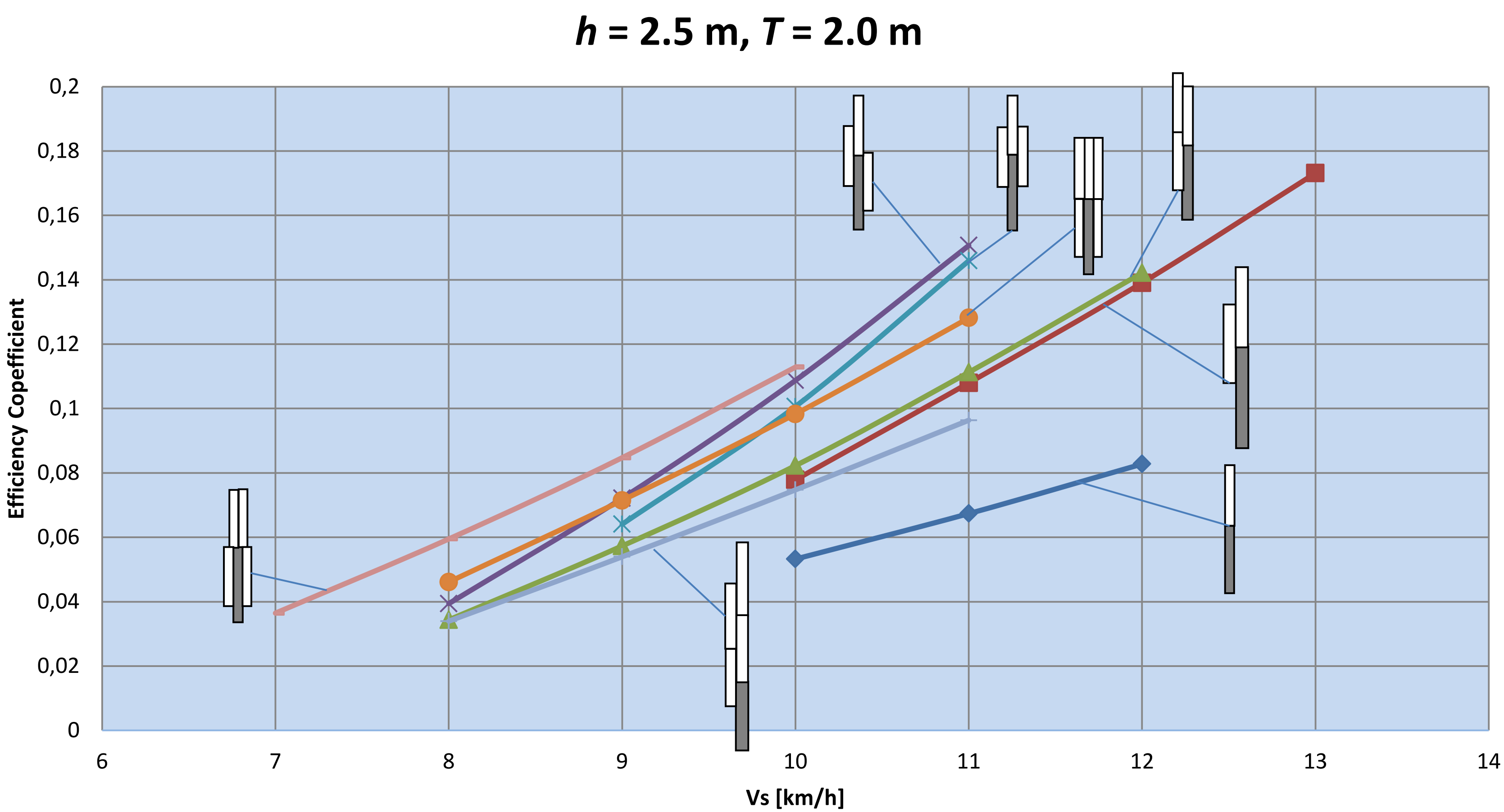
Transport Efficiency Coefficient of Barge – Barge Combinations, h = 4 m, T_{Barge} = 2.7 m



Power Consumption of Different Barge - Barge Combinations, *h* = 2.5 m, T_{Barge}= 2.0 m



Transport Efficiency of Different Barge - Barge Combinations, h = 2.5 m, T_{Barge} = 2.0 m



Tug - Barge Combinations (VMB)

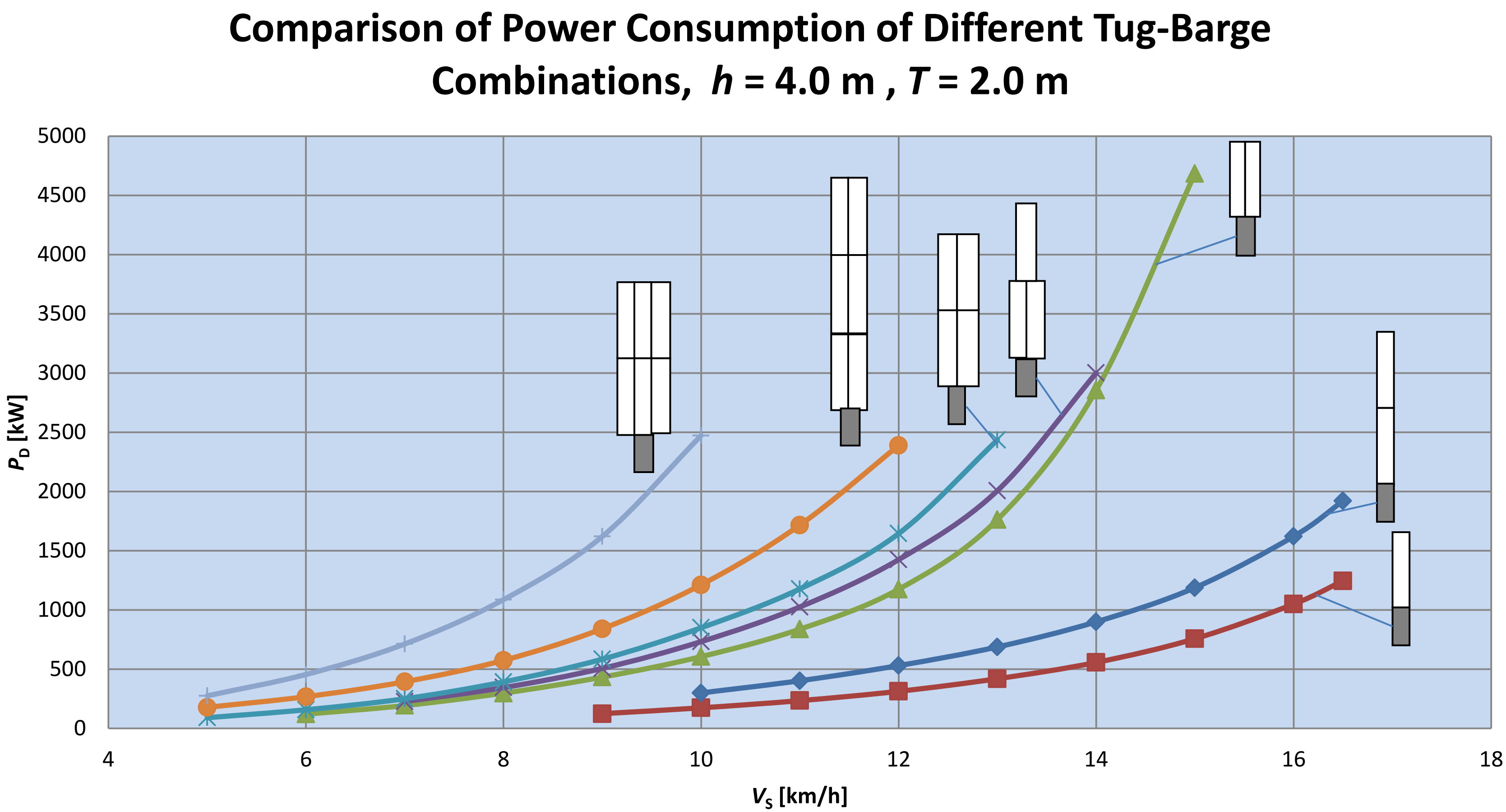
Tug

- L_{oa} 32.0 m
- B 11.0 m
- T 1.40 m
- ∇ 335 m^3

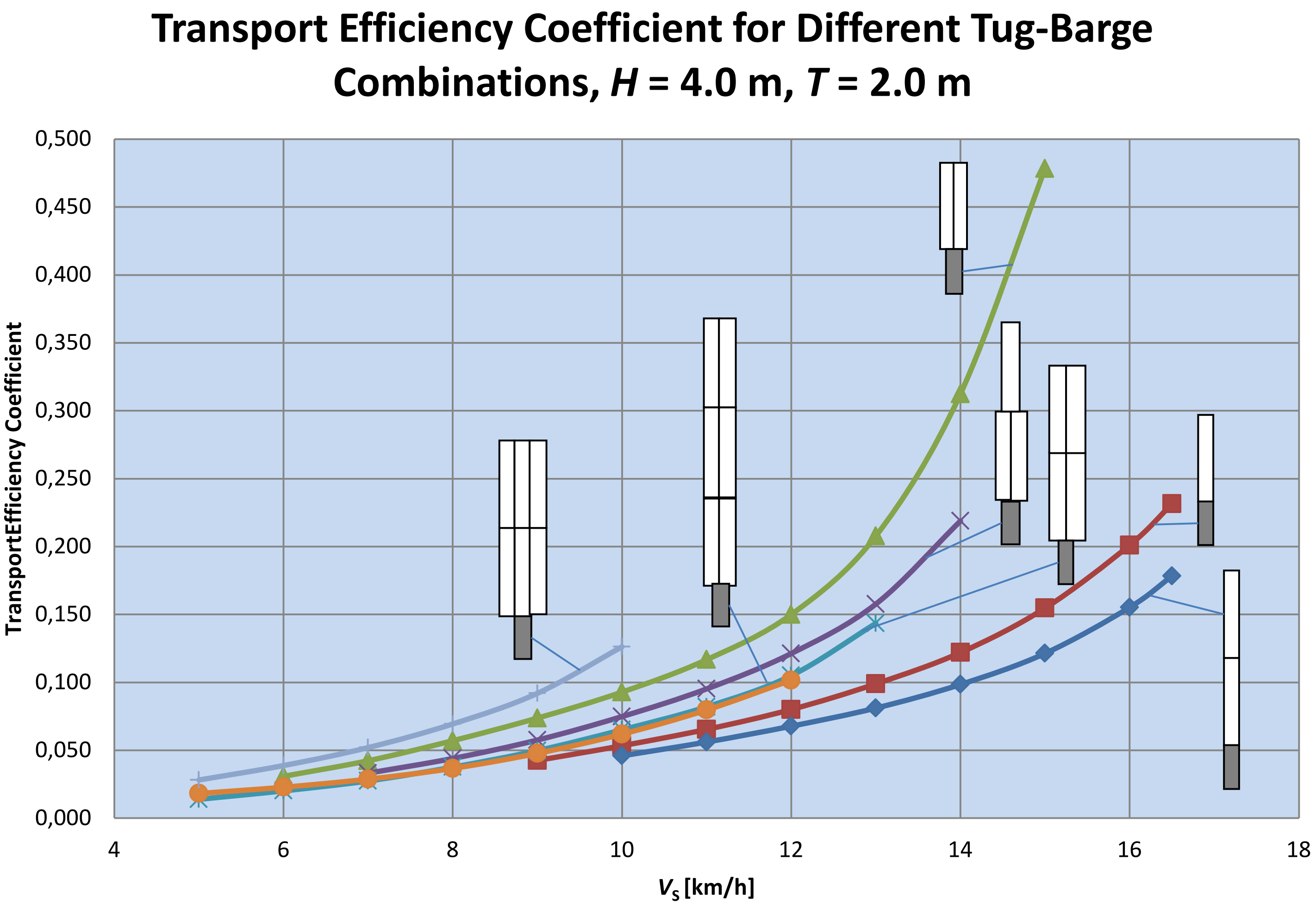
Dumb Barges

- L_{oa} 71.5 m
- B 11.0 m
- T 2.00 m
- ∇ 1455 m^3
- tdw 1175 t

Power Consumption of Tug - Barge Combinations, h = 4.0 m, T = 2.0 m



Transport Efficiency Coefficient of Tug - Barge Combinations, H = 4.0 m, T = 2.0 m



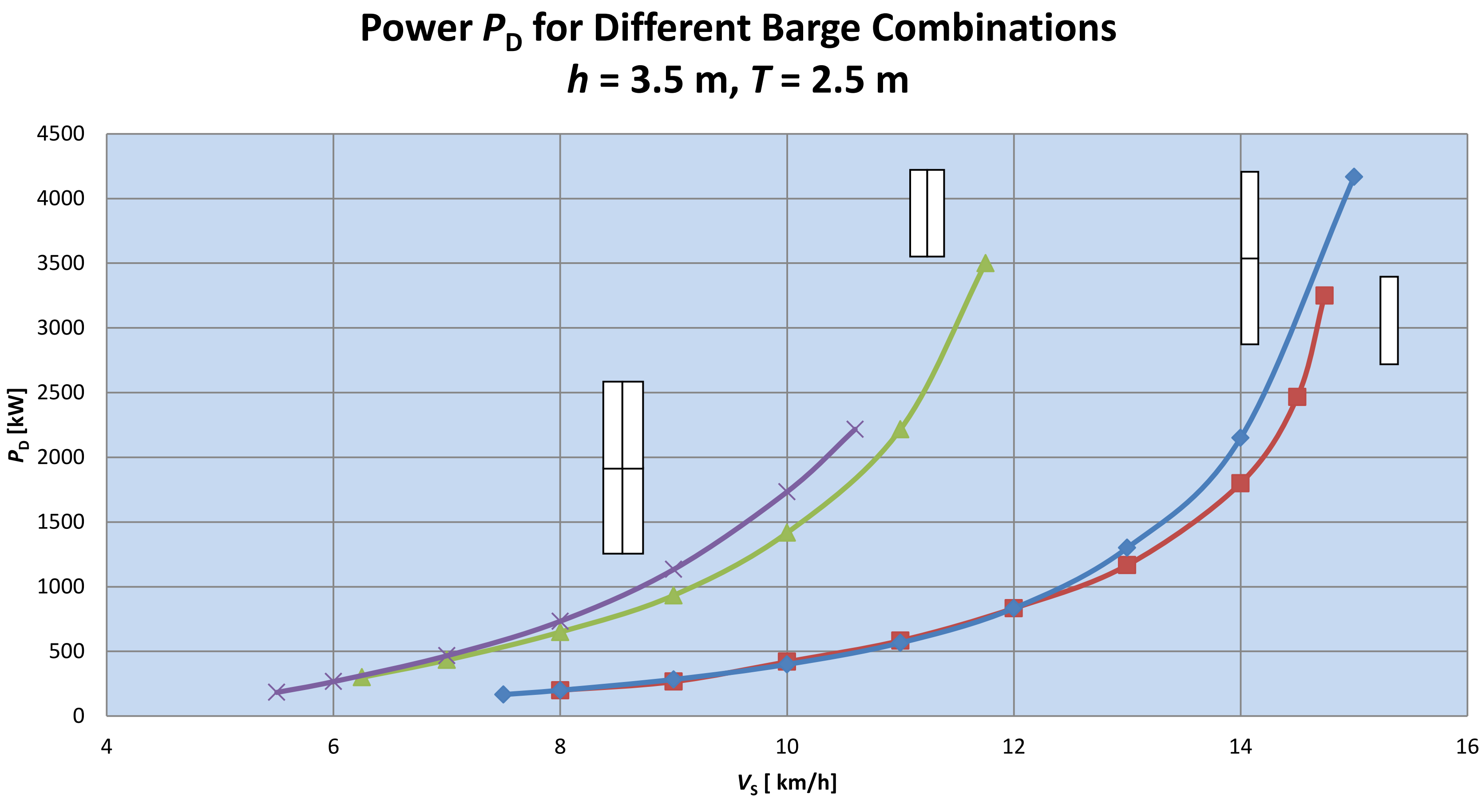
Barge ELBE (DST)

- **Barge ELBE**
  - L_{oa} = 76.5 m
  - B = 11.4 m
  - T_{max} = 2.65 m
  - ∇ = 2187 m^3
  - tdw = 1931 t
- **Tug OBERELBE**
  - L_{oa} = 27 m
  - B = 10.5 m
  - T = 0.8 m
  - ∇ = 195 m^3

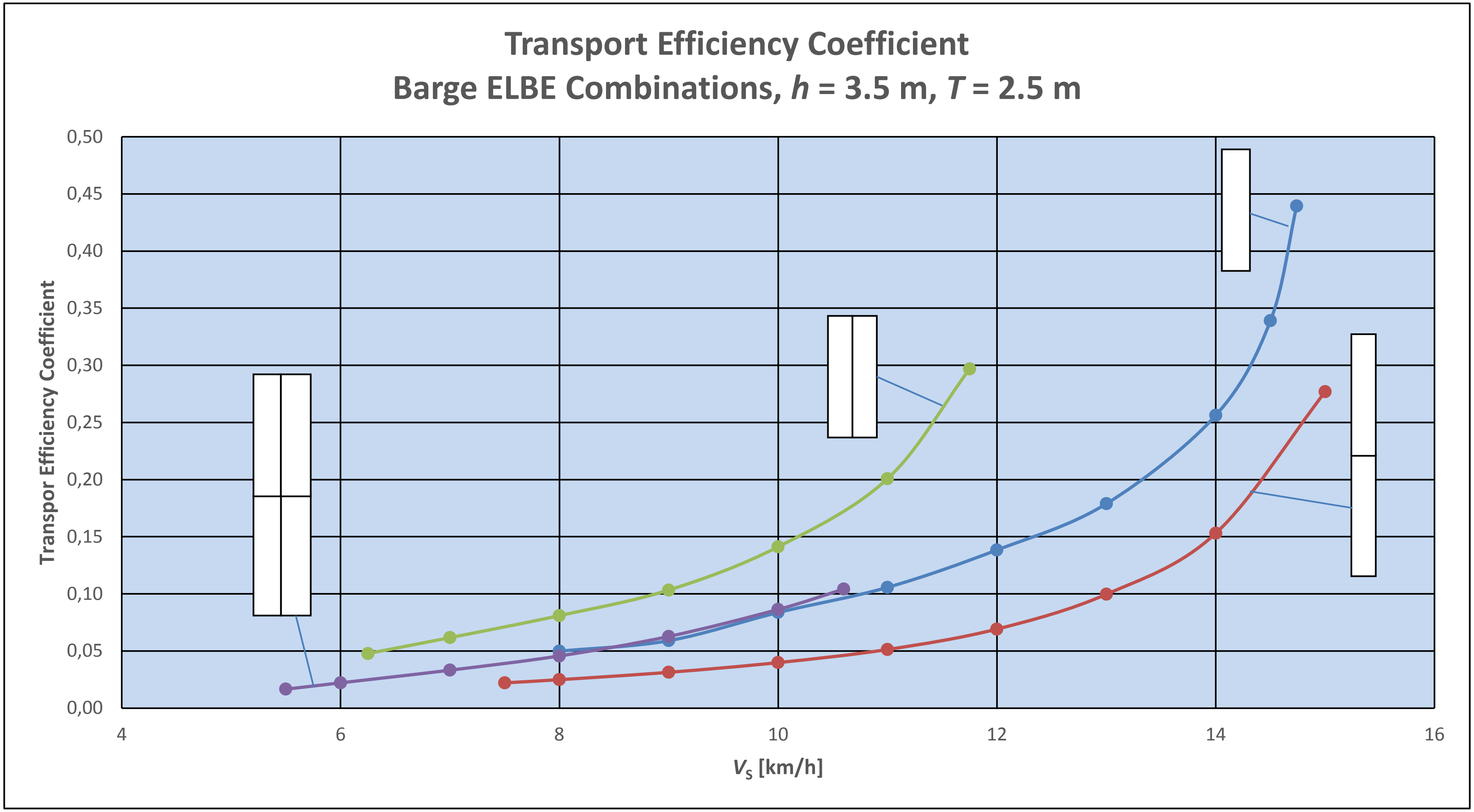
Barge ELBE Displacement - tdw

T [m]	∇ [m³]	tdw [t]
1.2	954	698
1.7	1378	1122
1.9	1550	1294
2.5	2062	1806

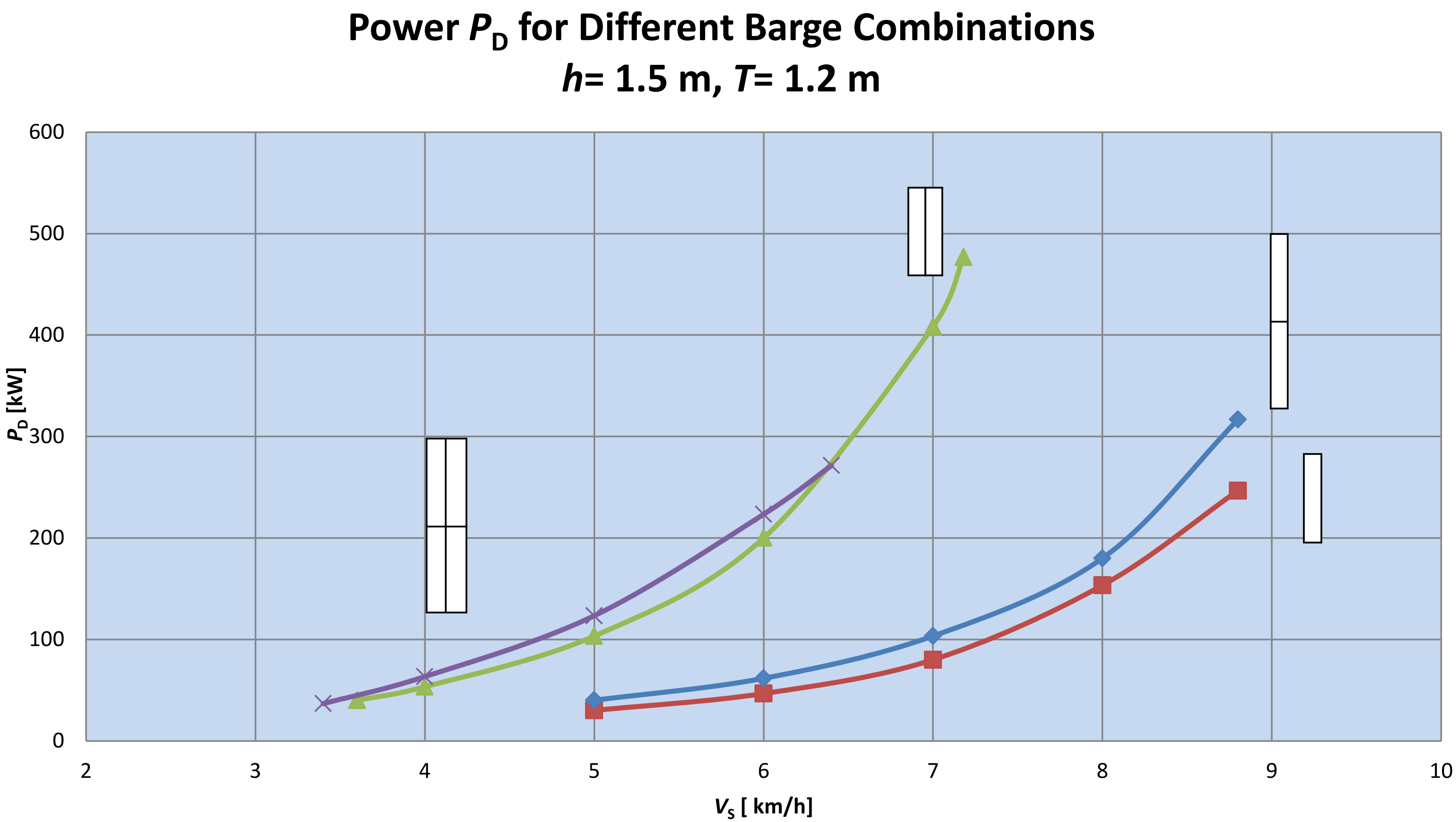
Power P_D for Different Barge Combinations of Barge ELBE, h = 3.5 m, T = 2.5 m



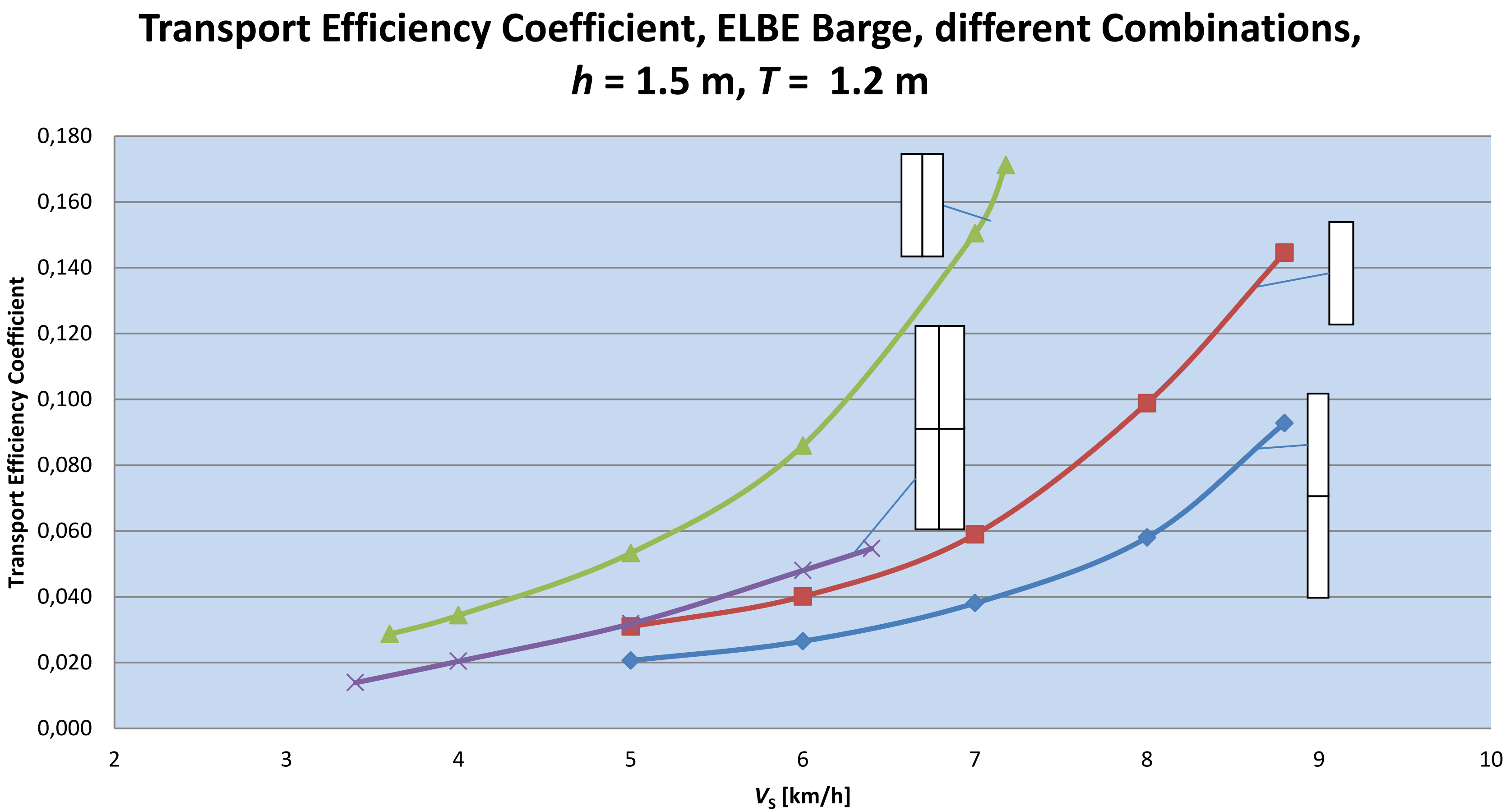
Transport Efficiency Coefficient (TEC) Combinations of Barge ELBE, *h* = 3.5 m, *T* = 2.5 m



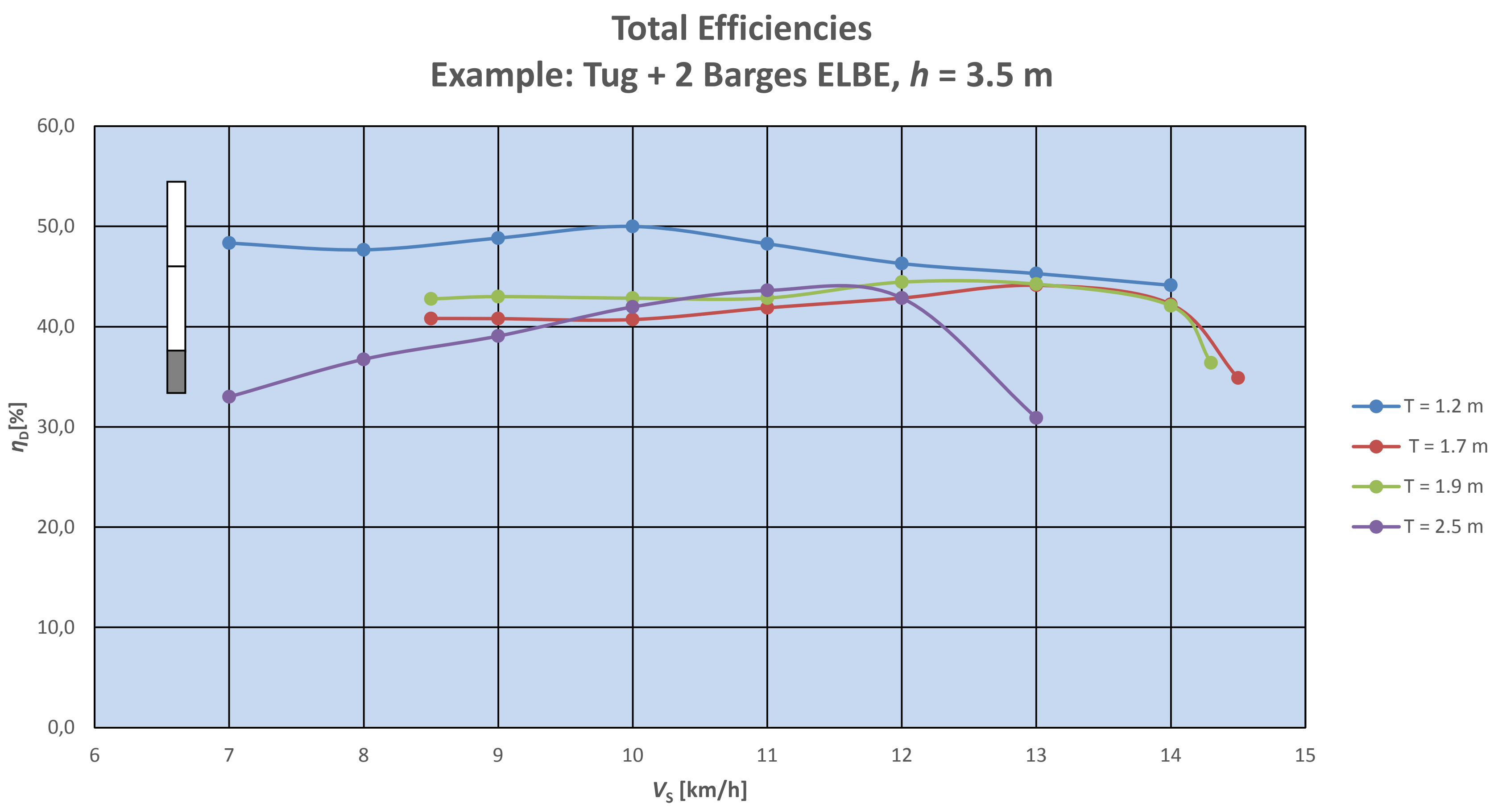
Power P_D for Different Combinations of Barge ELBE, h = 1.5 m, T = 1.2 m



TEC for Barge ELBE, Different Combinations
h = 1.5 m, T = 1.2 m



Total Efficiencies



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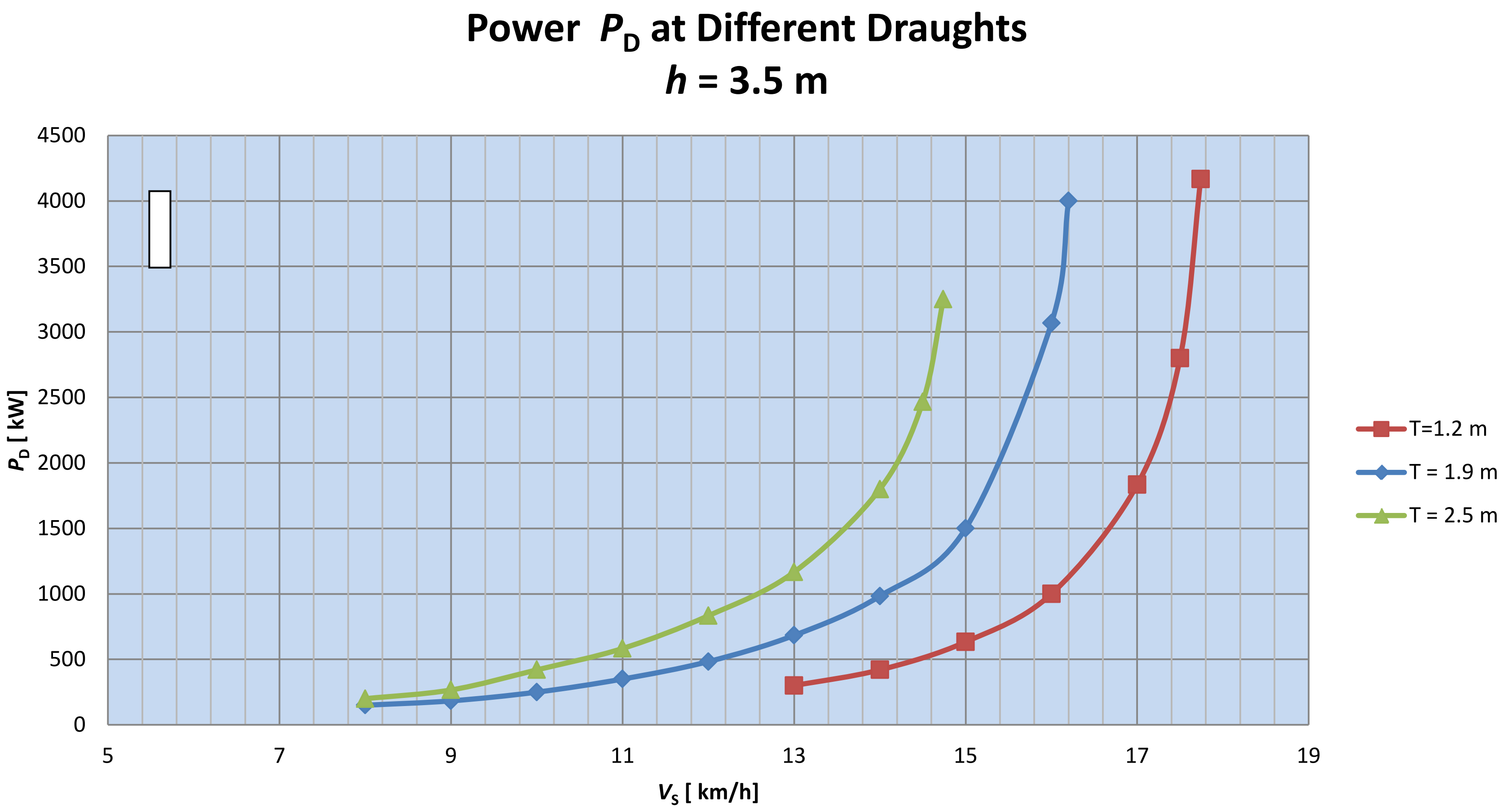
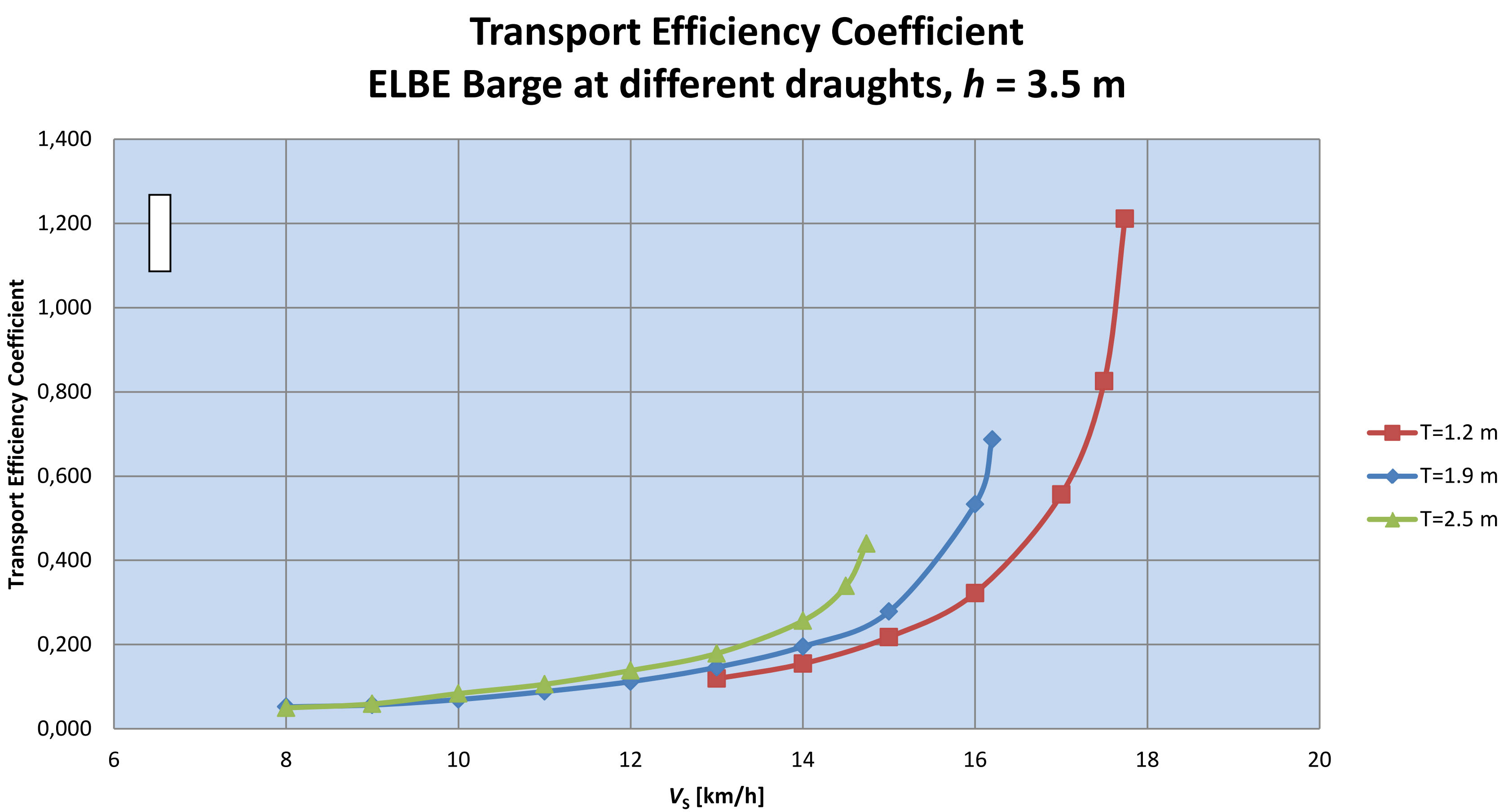
Draught Variation

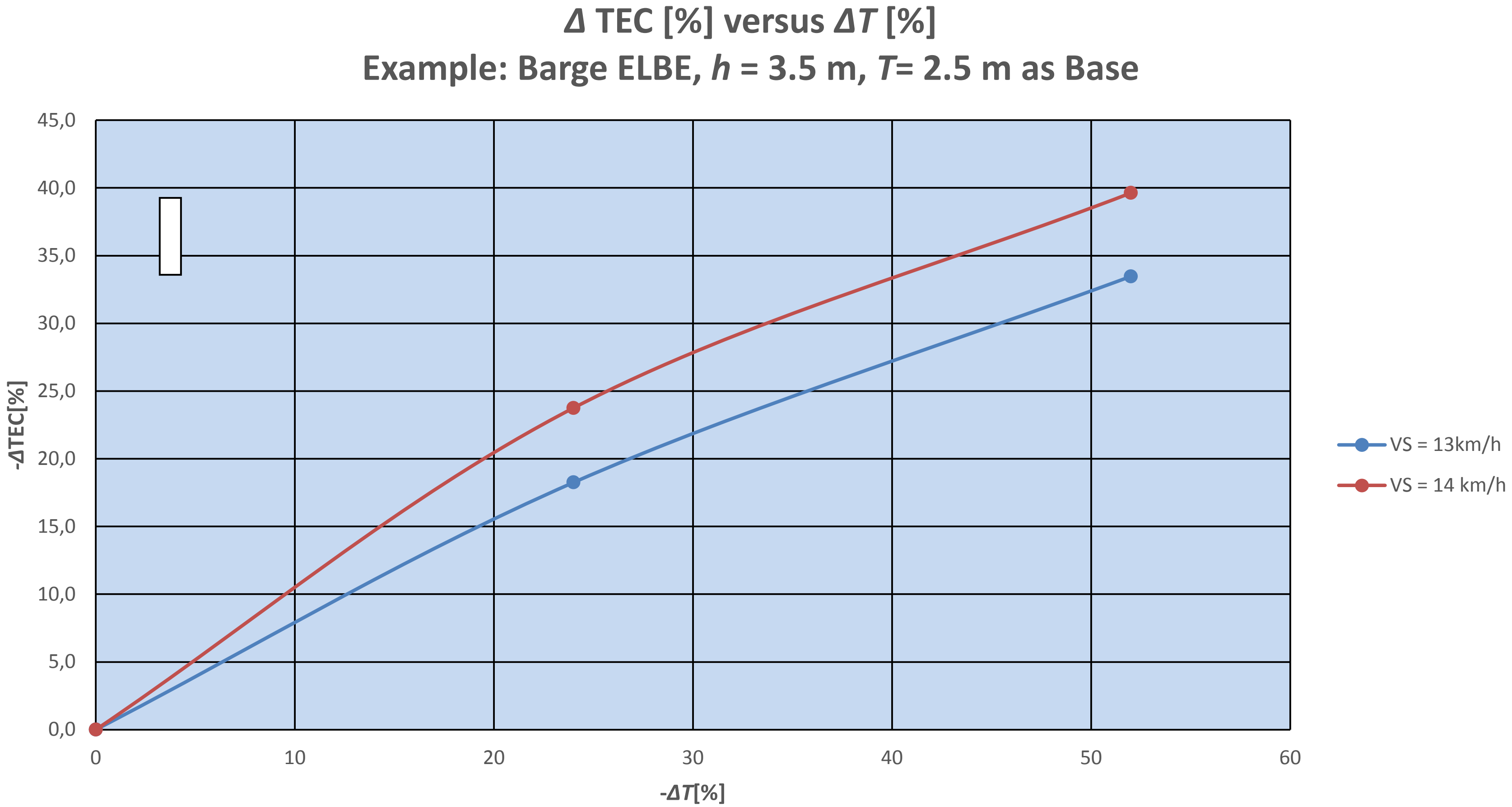
One Barge, Power Consumption at Different Draughts, *h* = 3.5 m



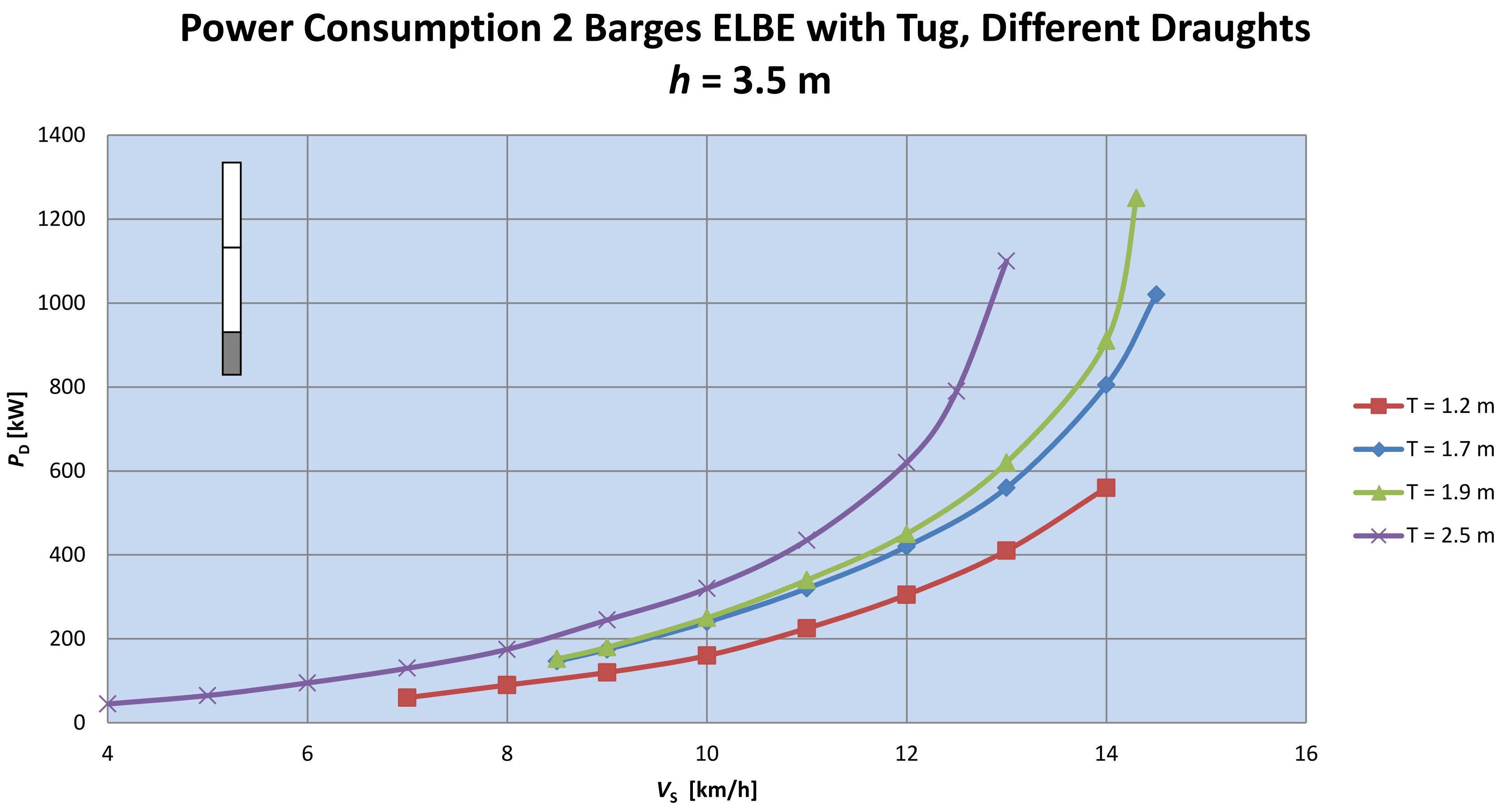
ELBE Barge, Transport Efficiency Coefficient at Different Draughts, *h* = 3.5 m



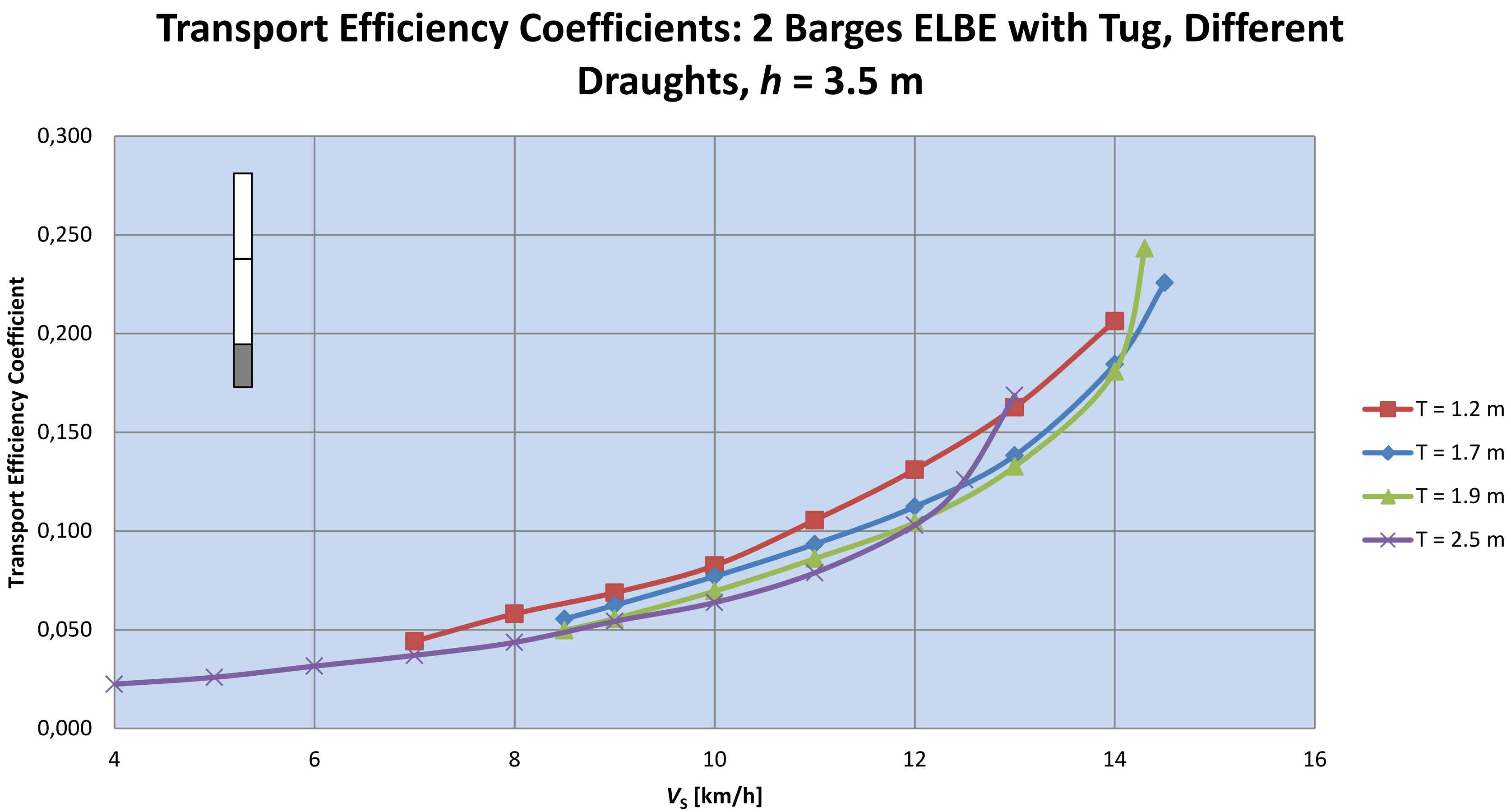
Δ Transport Efficiency Coefficient [%] versus *Δ* Draught[%], *h* = 3.5 m



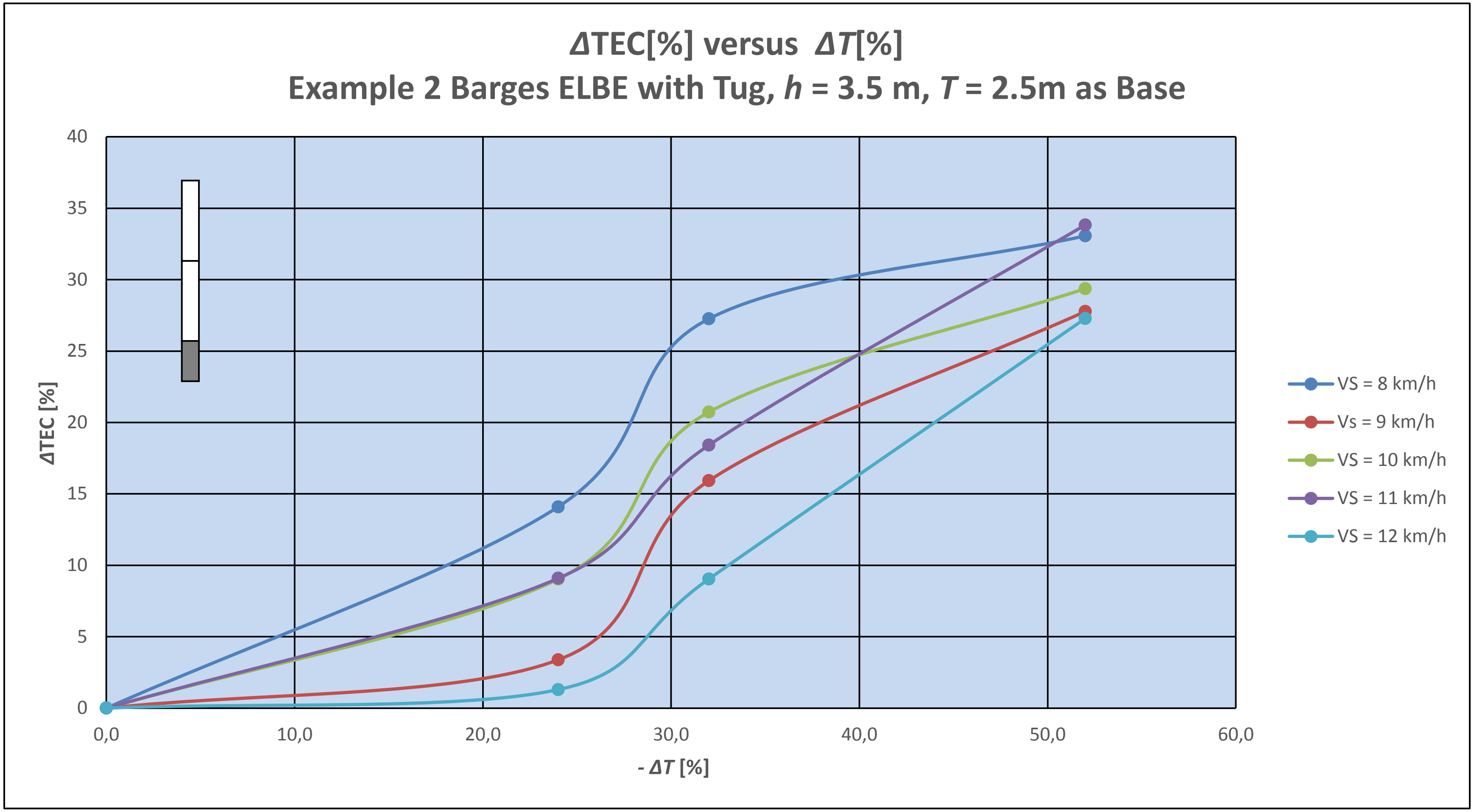
Power P_D for Tug-Barge System, 2 Barges ELBE, Different Draughts, h = 3.5 m



Transport Efficiency Coefficients, 2 Barges ELBE + Tug, Different Draughts, *h* = 3.5 m



Δ Transport Efficiency Coefficient [%] versus Δ Draught[%], *h* = 3.5 m



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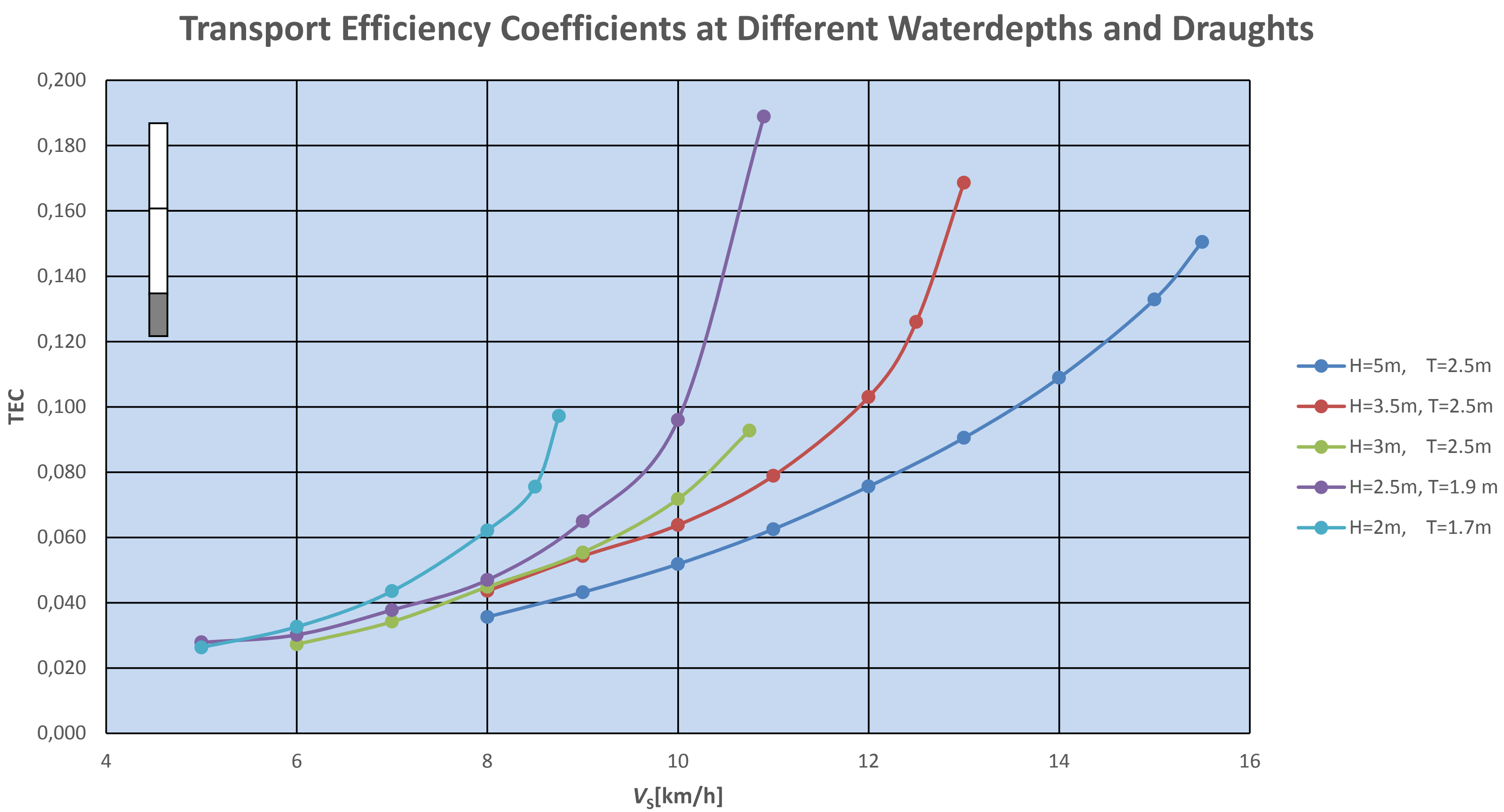
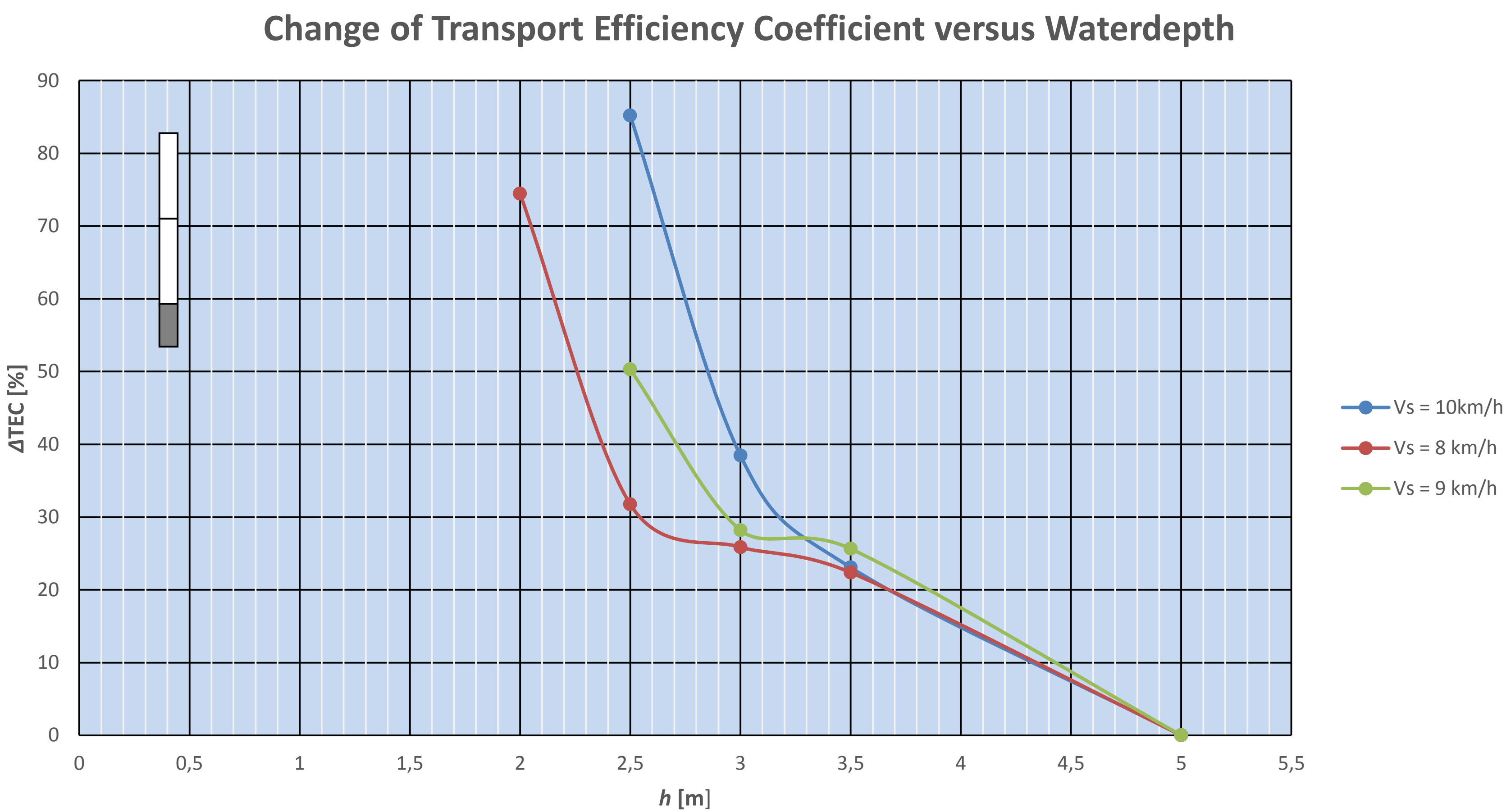
Practical Effect of Shallow Water on the Transport Efficiency Coefficient (Always using the maximum possible draught)

Practical Effect of Water Depth



Practical Effect of Water Depth



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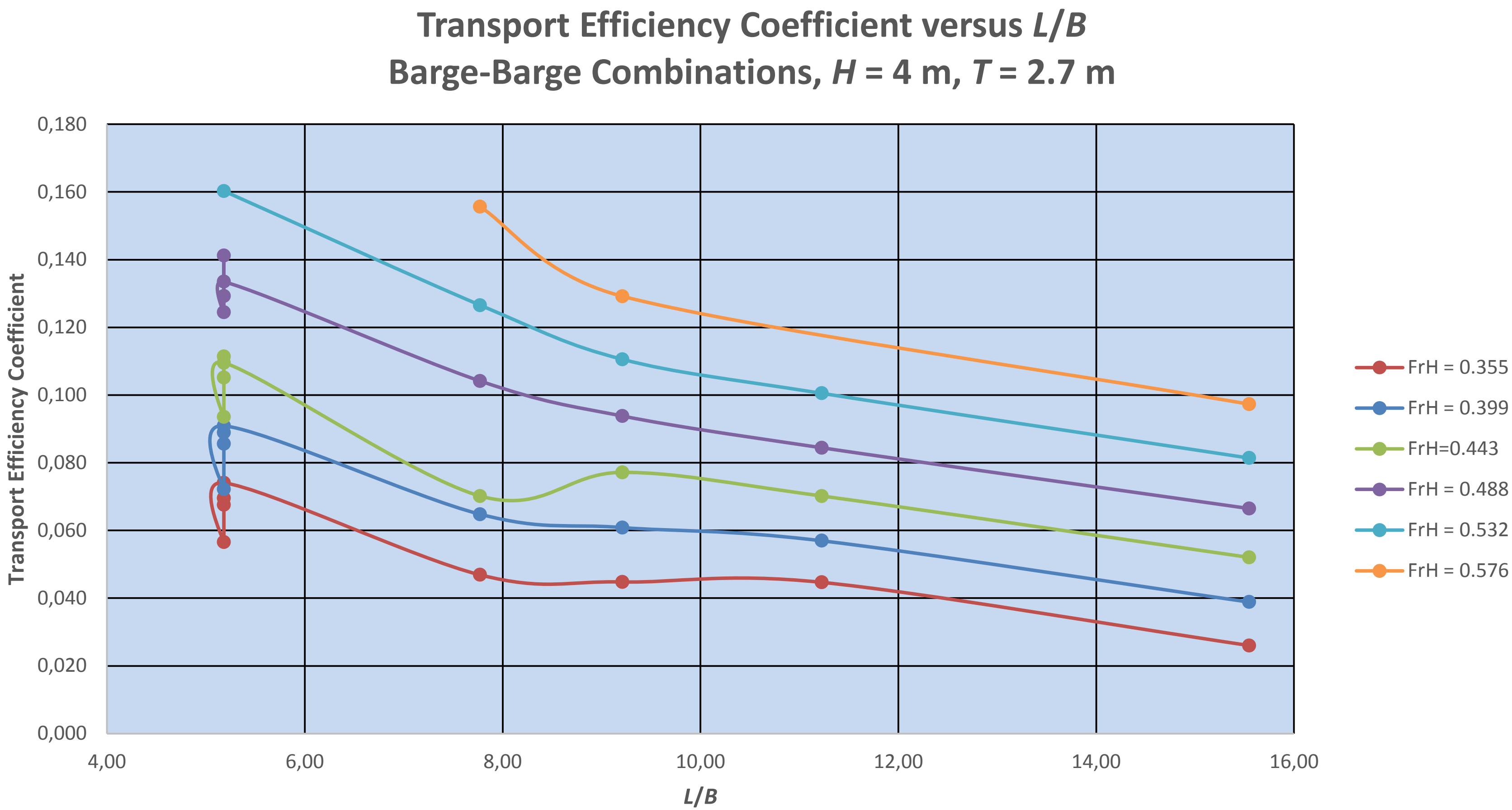
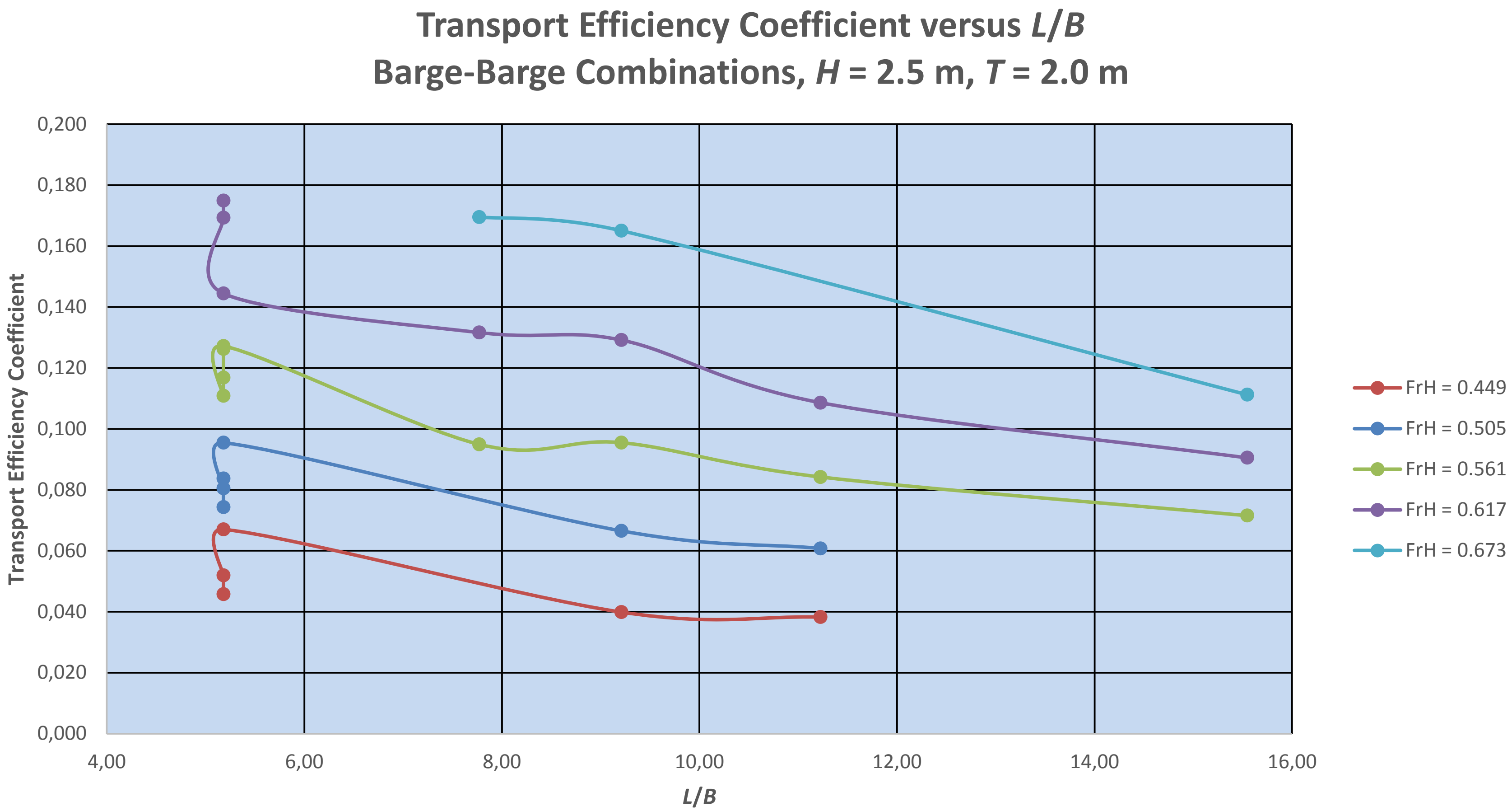
Influence of *L/B*

Investigation of Barge-Barge and Tug-Barge Combinations

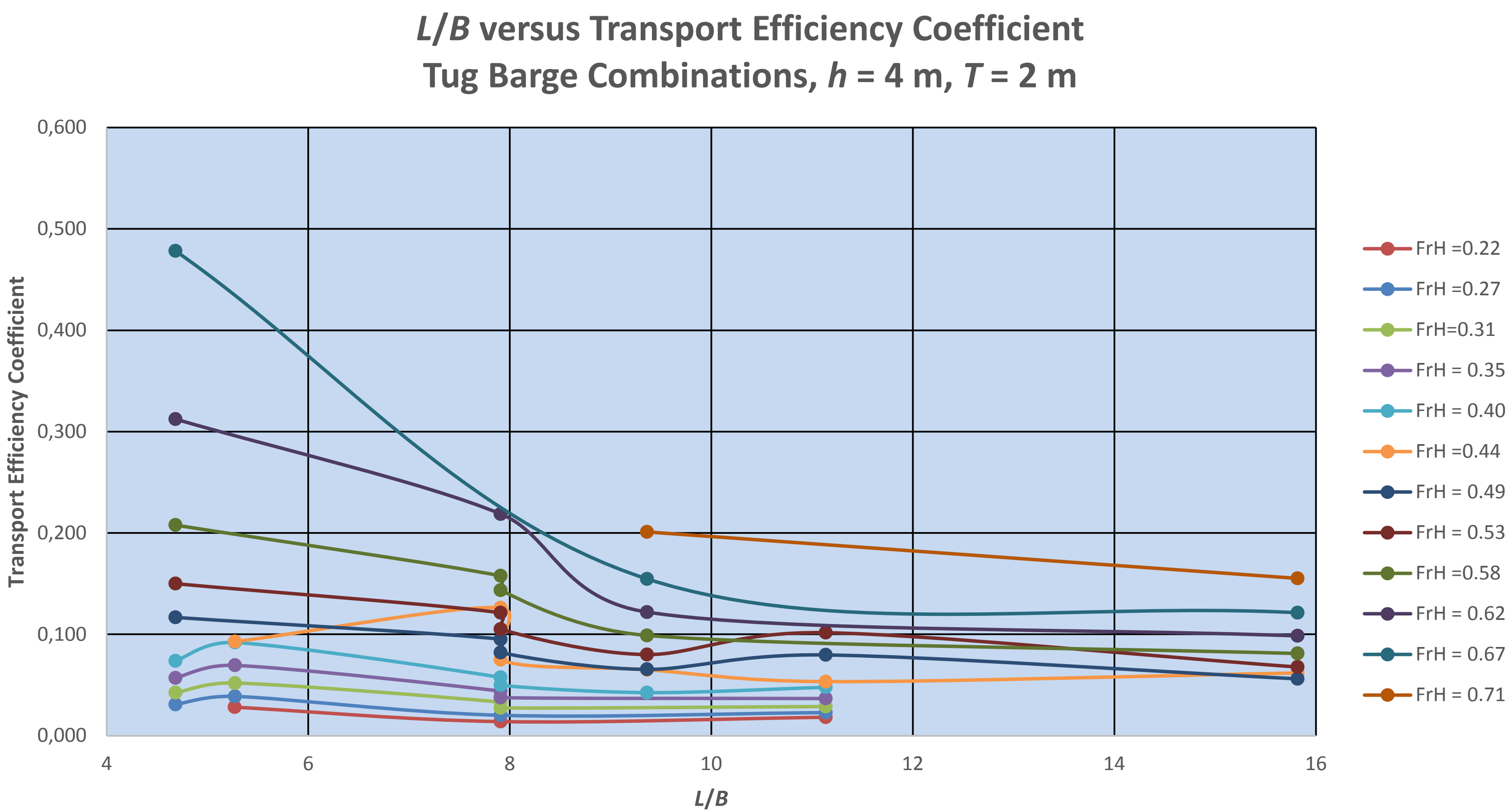
Transport Efficiency Coefficient versus *L*/*B*, Barge-Barge Combinations, *h* = 4.0 m, *T* = 2.7 m



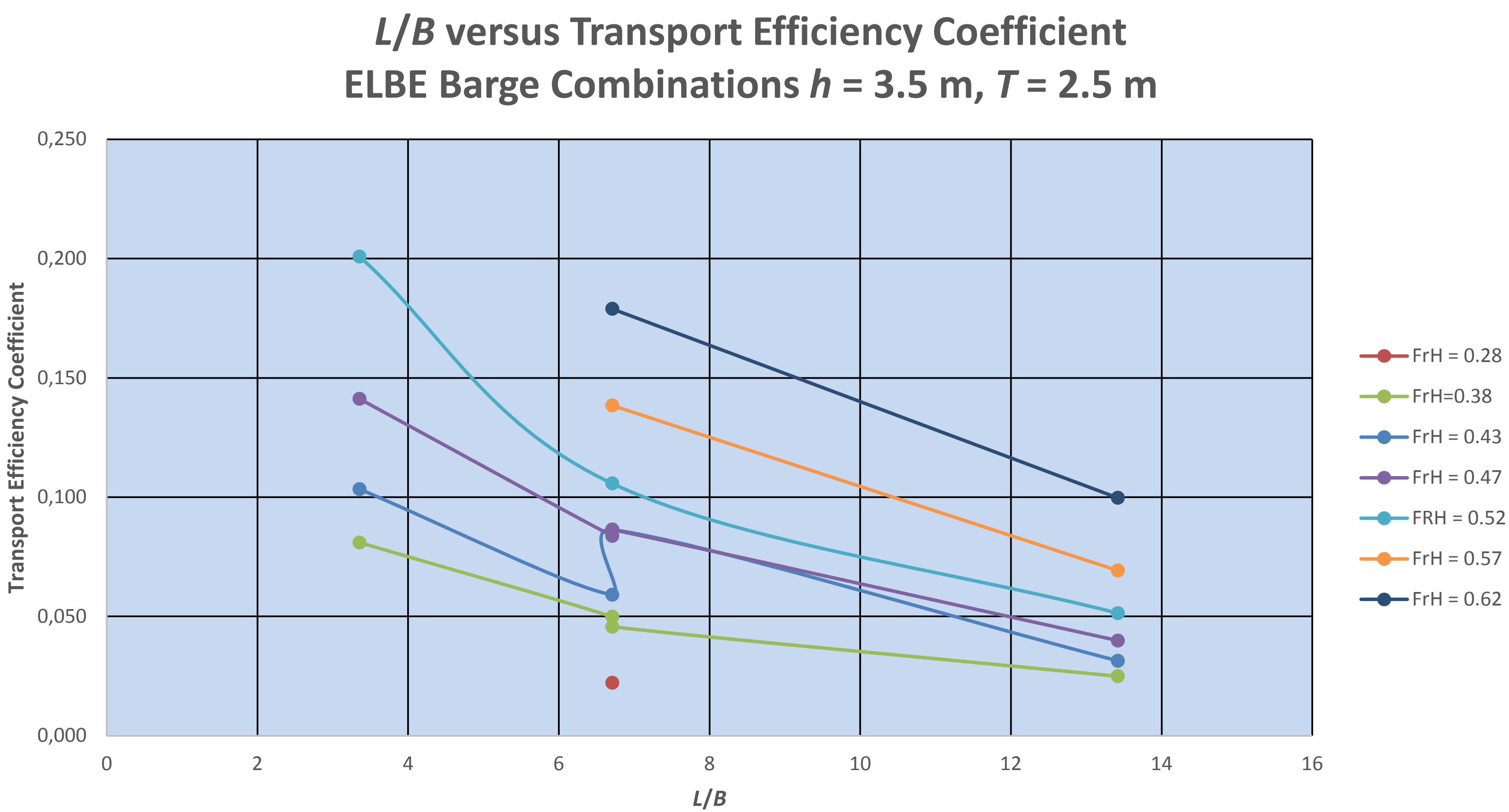
Transport Efficiency Coefficient versus *L*/*B*, Barge-Barge Combinations, *h* = 2.5 m, *T* = 2.0 m



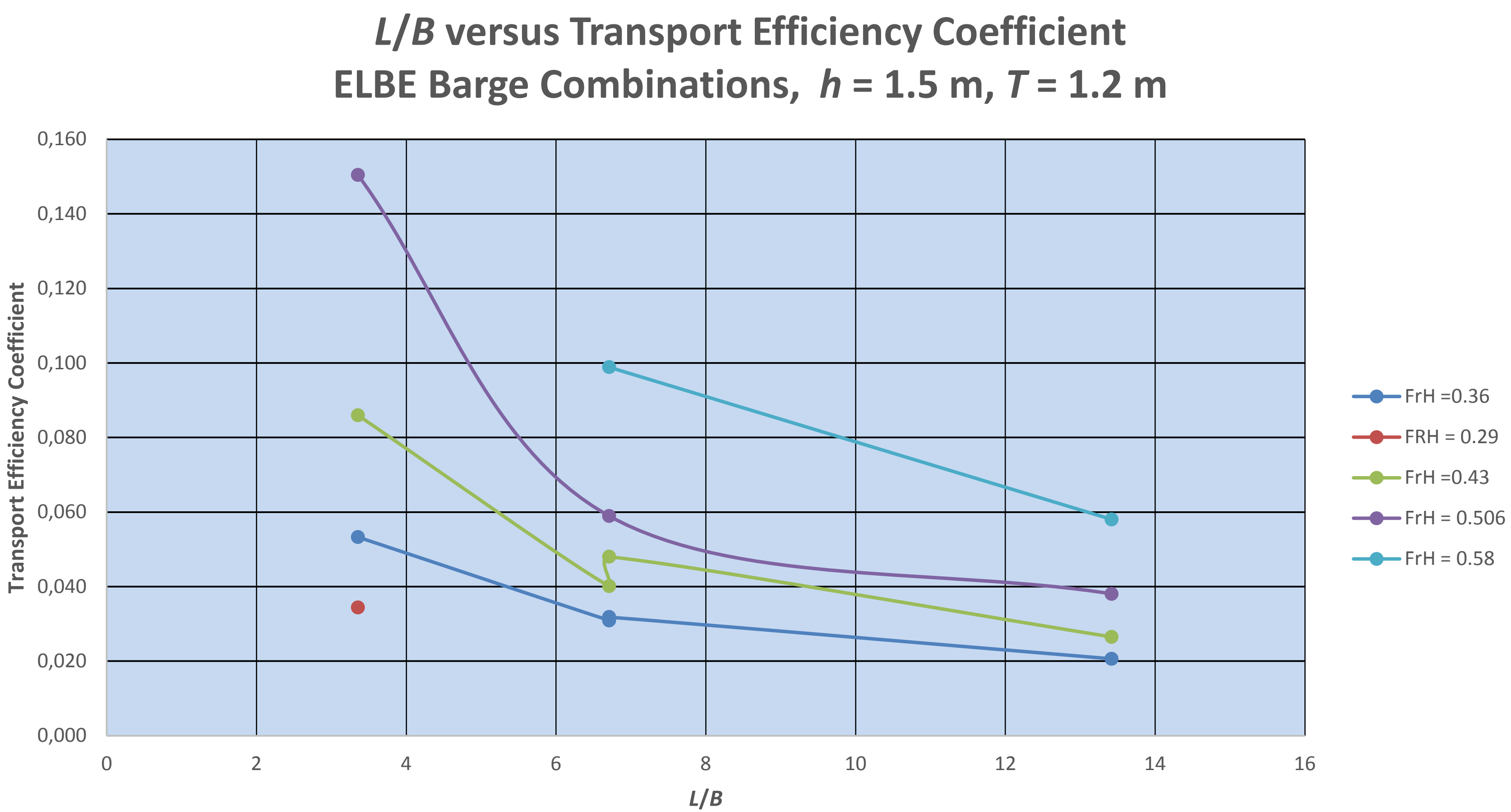
Transport Efficiency Coefficient versus *L*/*B*, Tug-Barge Combinations, *h* = 4.0 m, *T* = 2.0 m



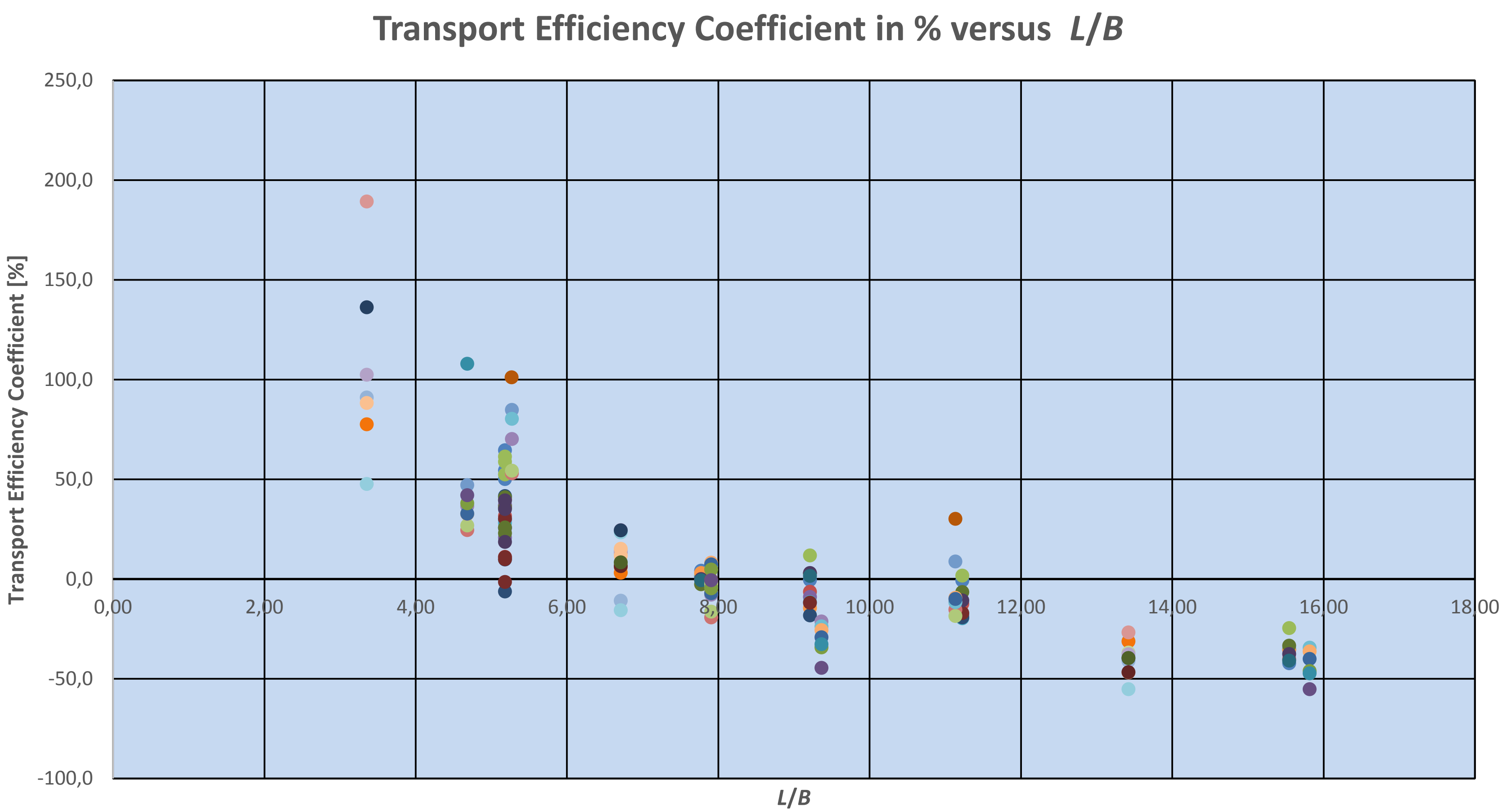
Transport Efficiency Coefficient versus *L*/*B*, ELBE Barge Combinations, *h* = 3.5 m, *T* = 2.5 m



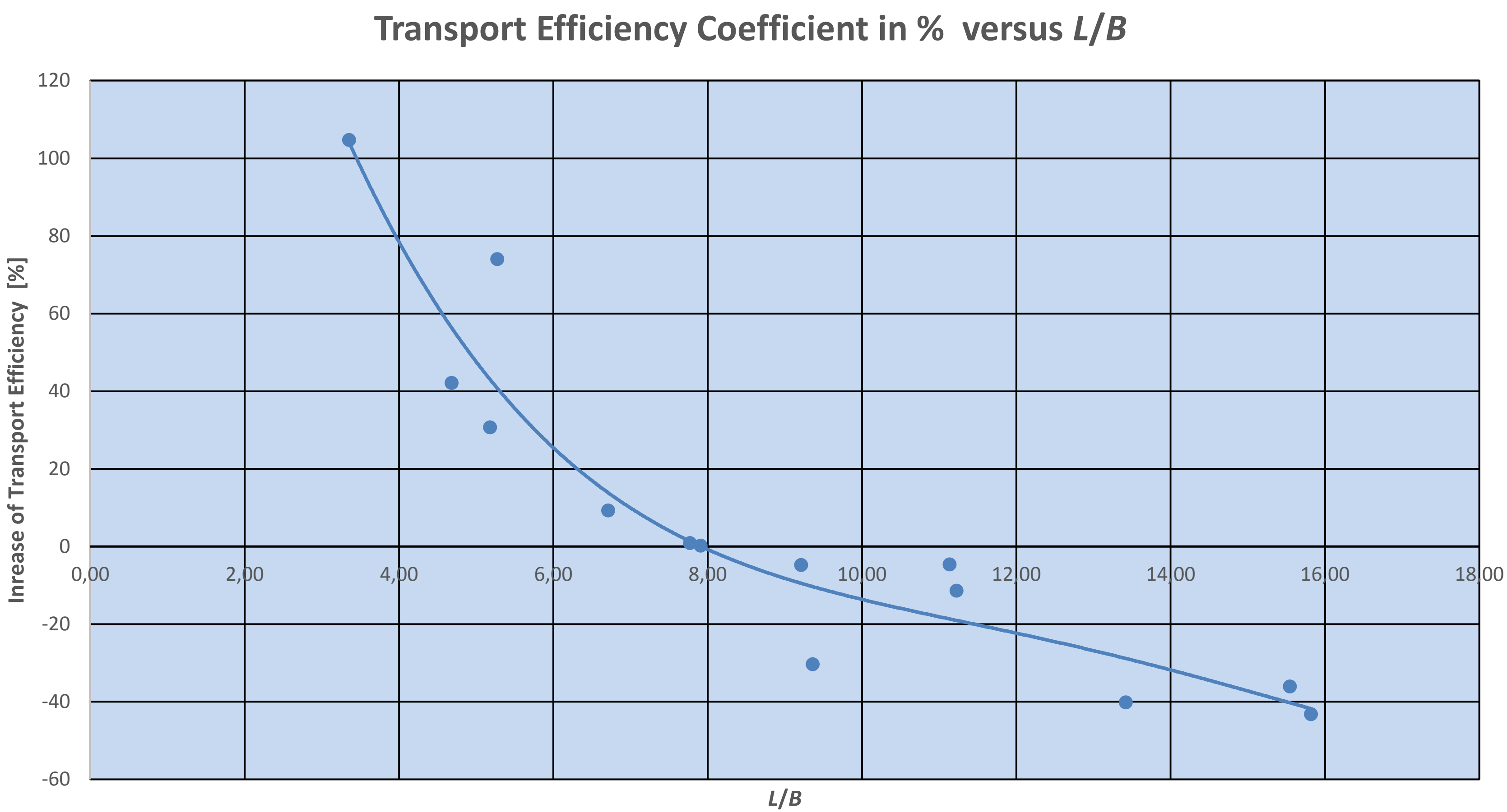
Transport Efficiency Coefficient versus *L*/*B*, ELBE Barge Combinations, *h* = 1.5 m, *T* = 1.2 m



L/B Variation, all investigated Barge-Barge and Tug-Barge Combinations

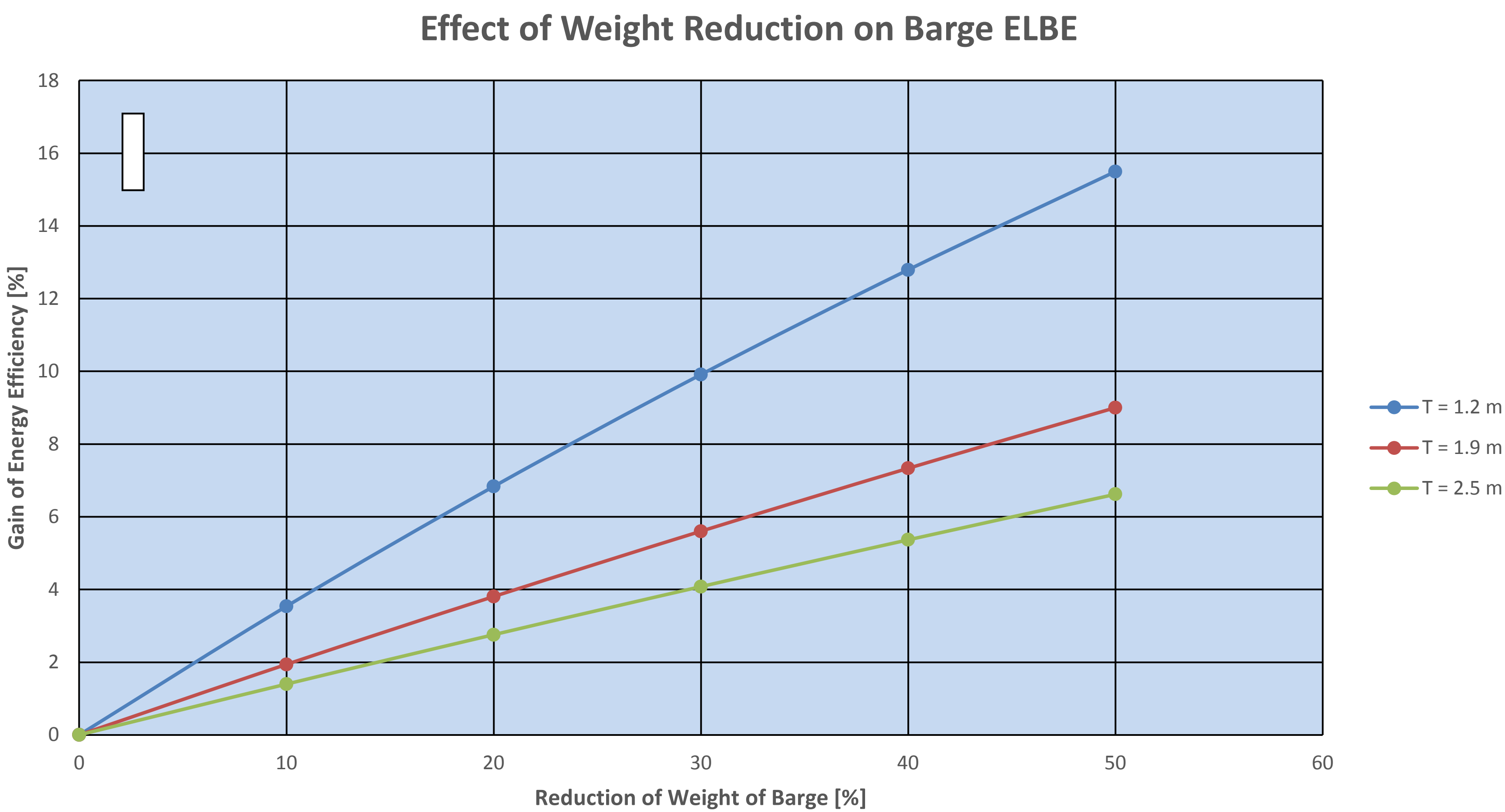


L/B Variation, all Combinations

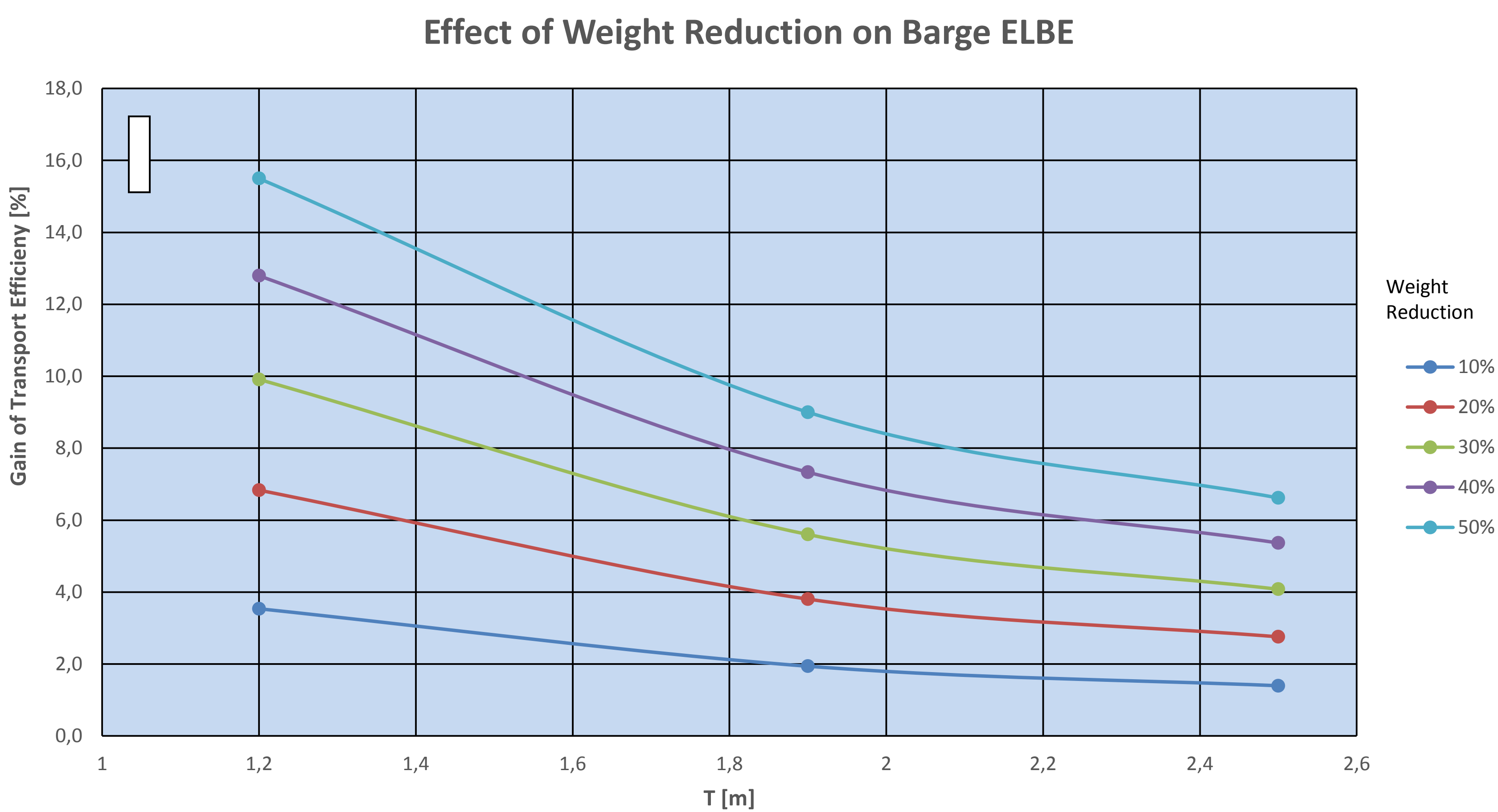


Effect of Weight Reduction

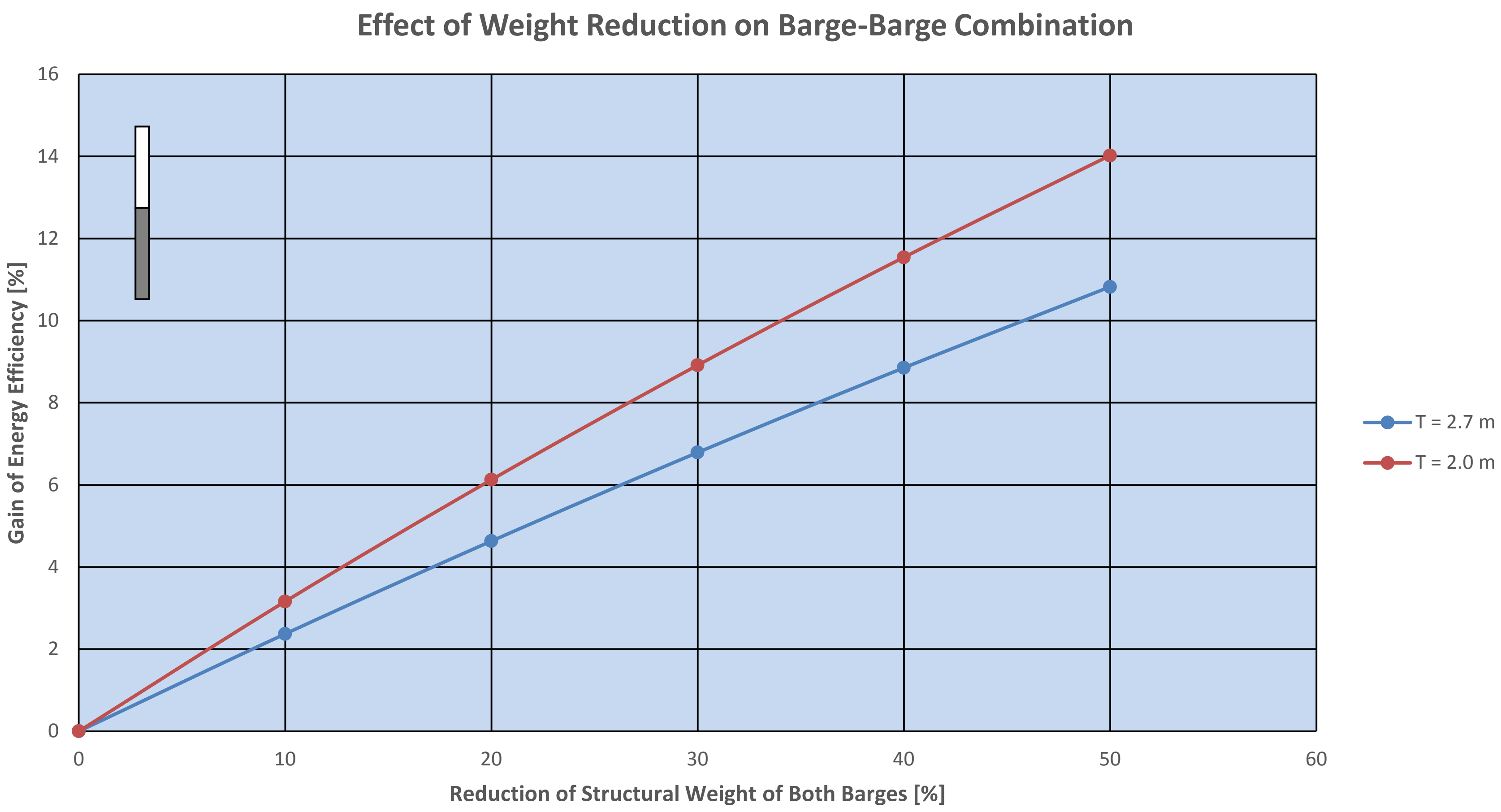
Weight Reduction of Barge



Gain by Weight Reduction of Barge ELBE



Gain by Weight Reduction of Barge - Barge Combination



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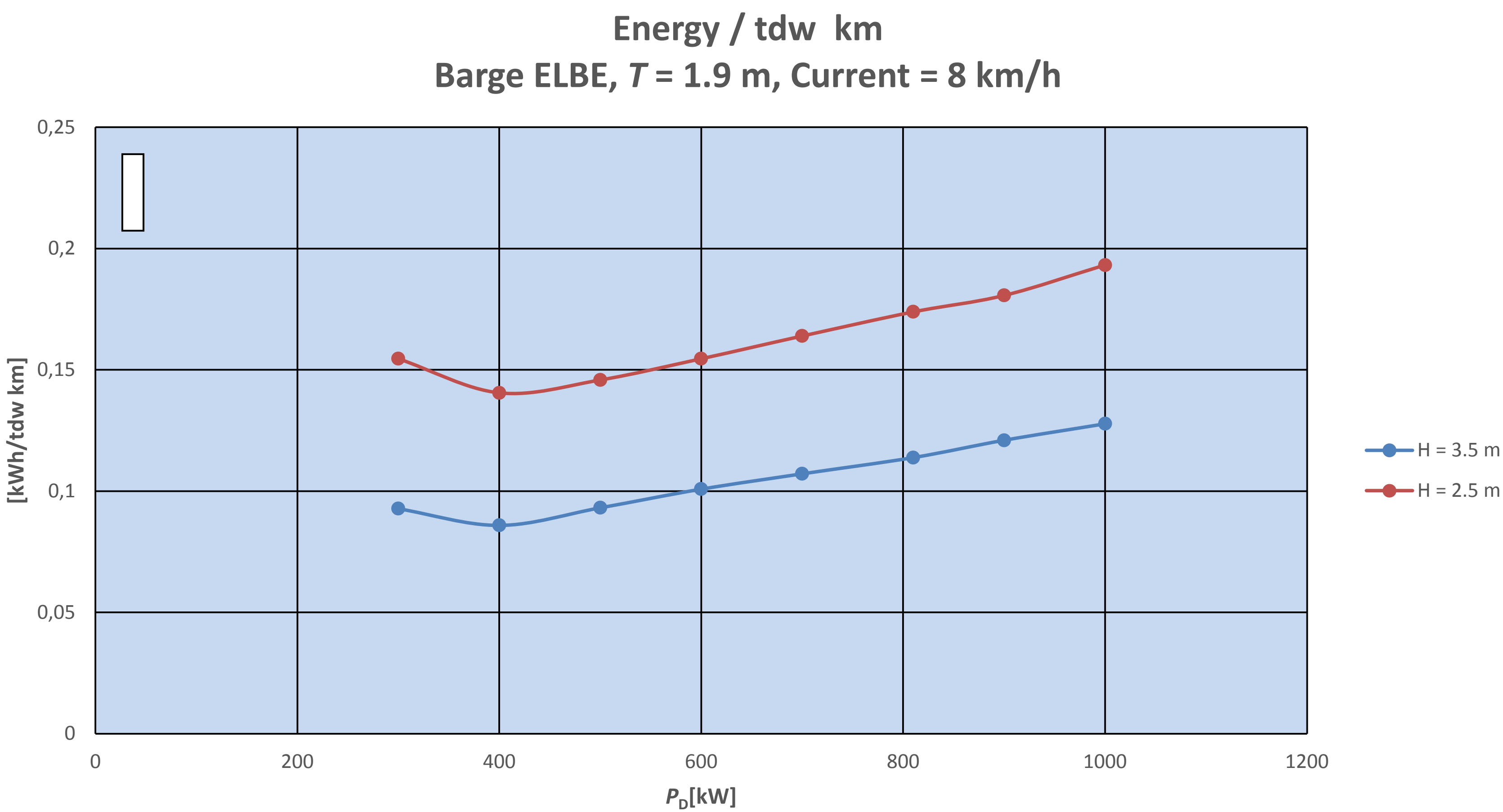
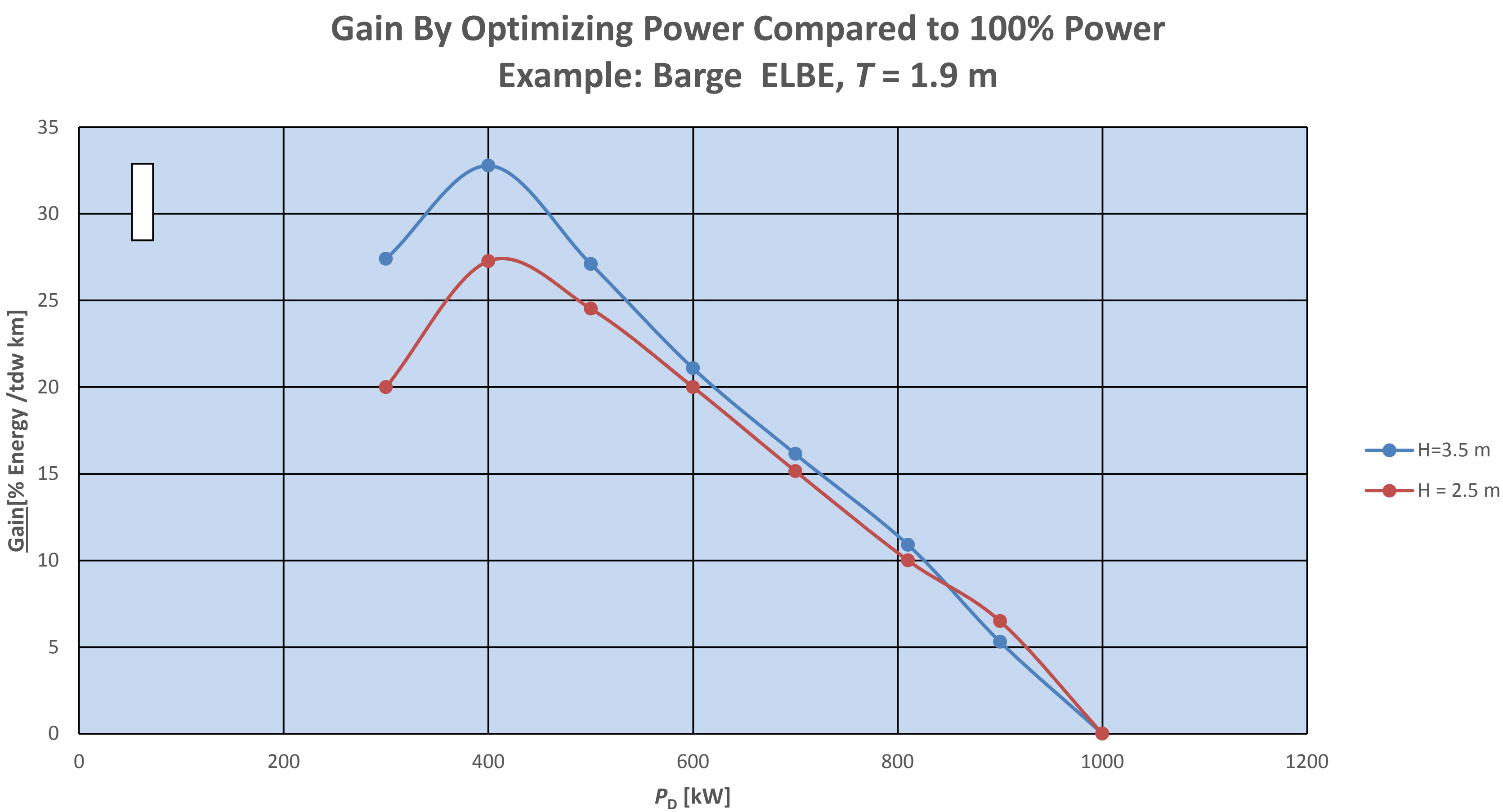
Speed - Power Optimization

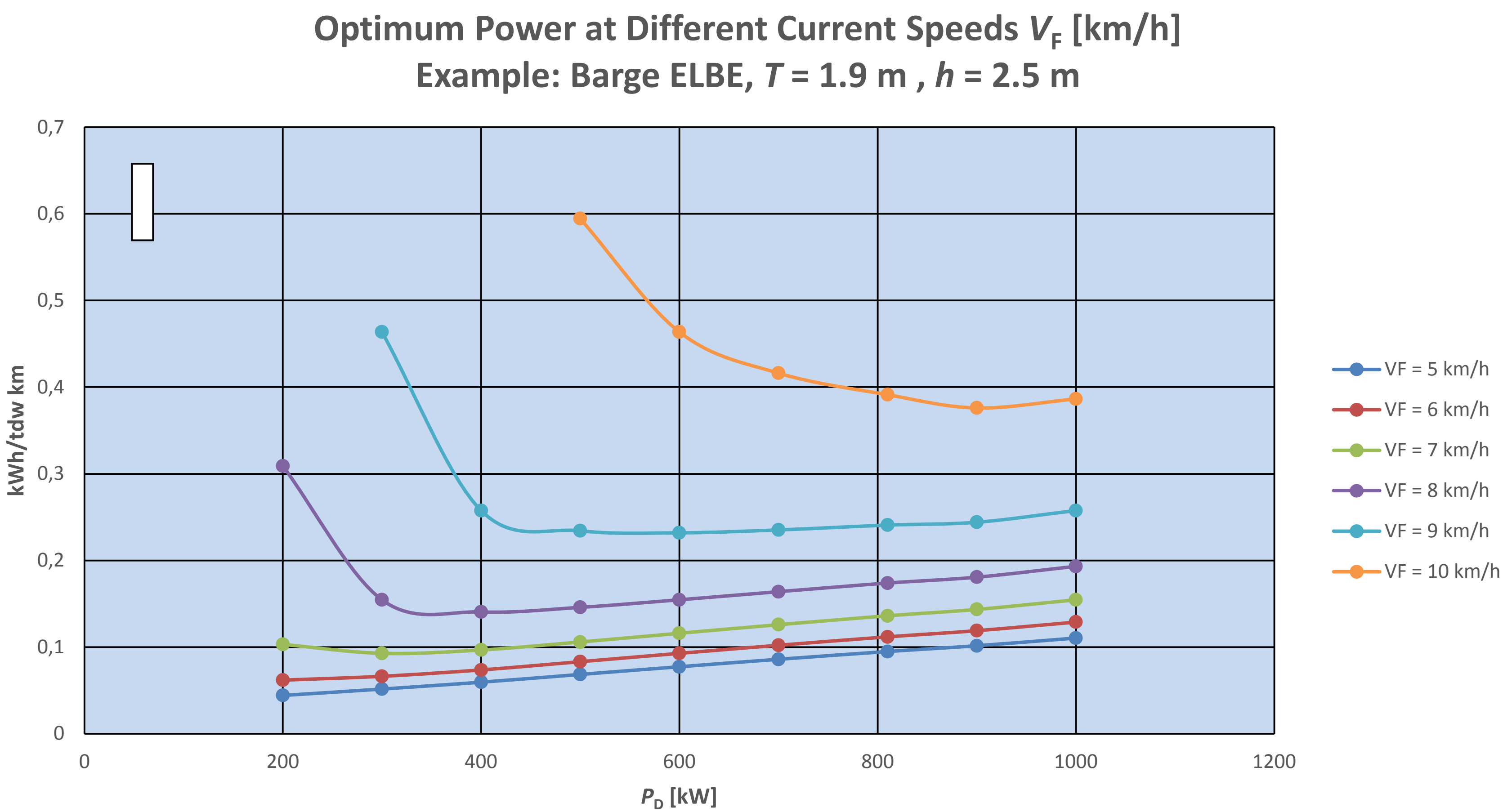
Energy per tdw and km,
Example: Barge ELBE, T = 1.9 m, V_F = 8 km/h



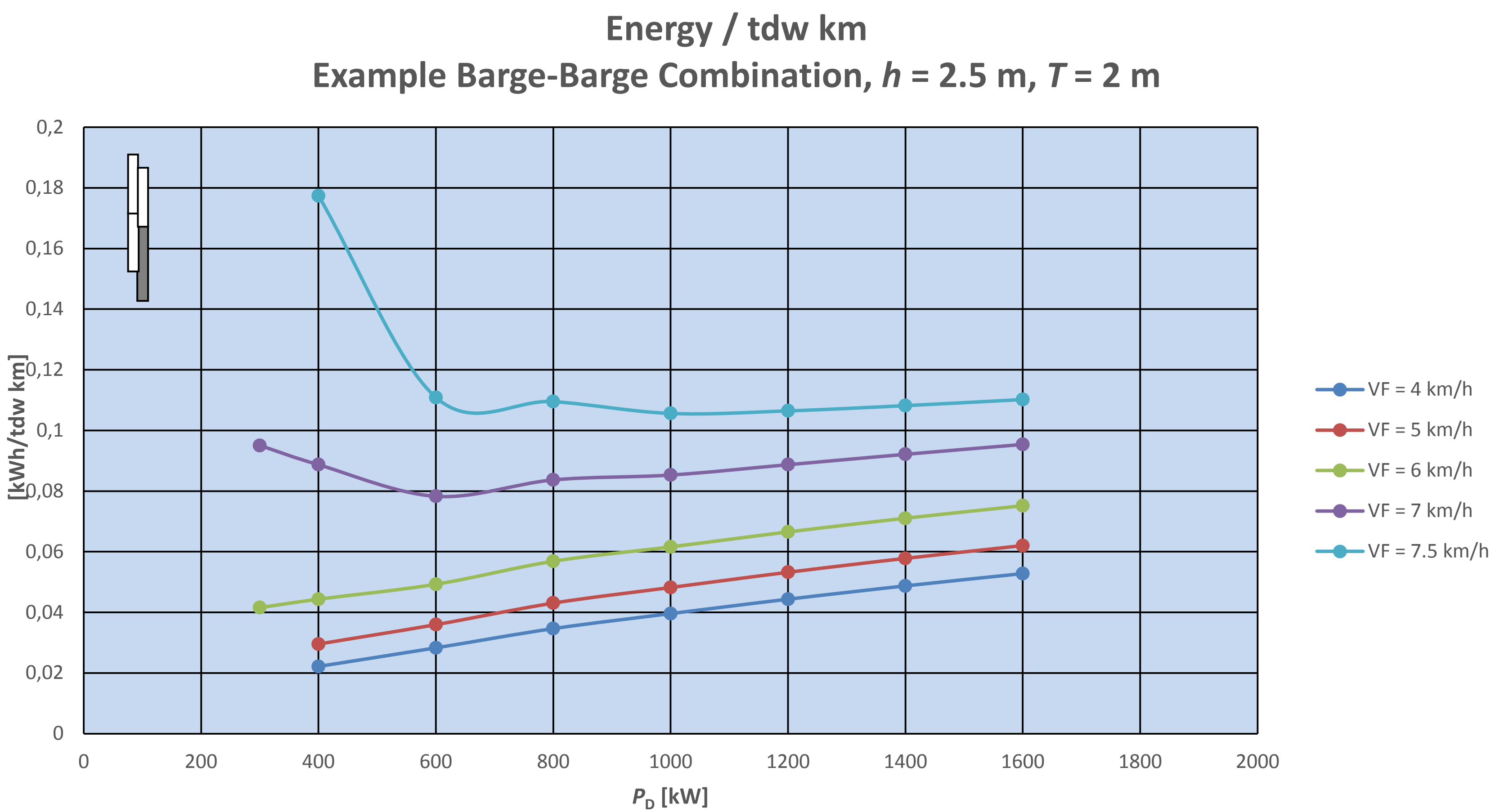
Energy/(tdw x km) Gain Depending on P_D (1000 kW base)
Example: Barge ELBE, T = 1.9 m, V_F = 8 km/h



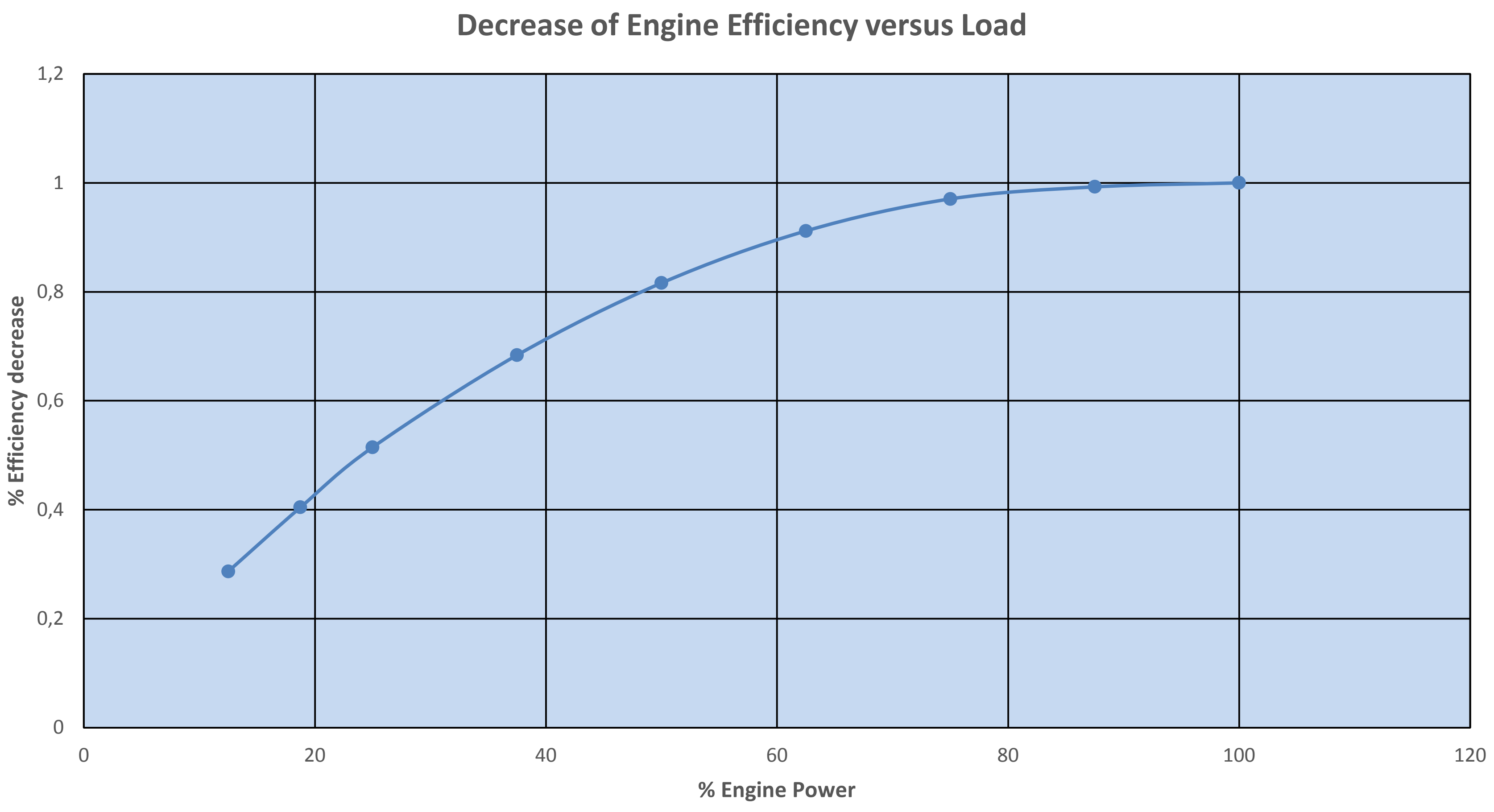
Energy/(tdw x km) for Different Current Speeds
Example: Barge ELBE *T* = 1.9 m, *h* = 2.5 m



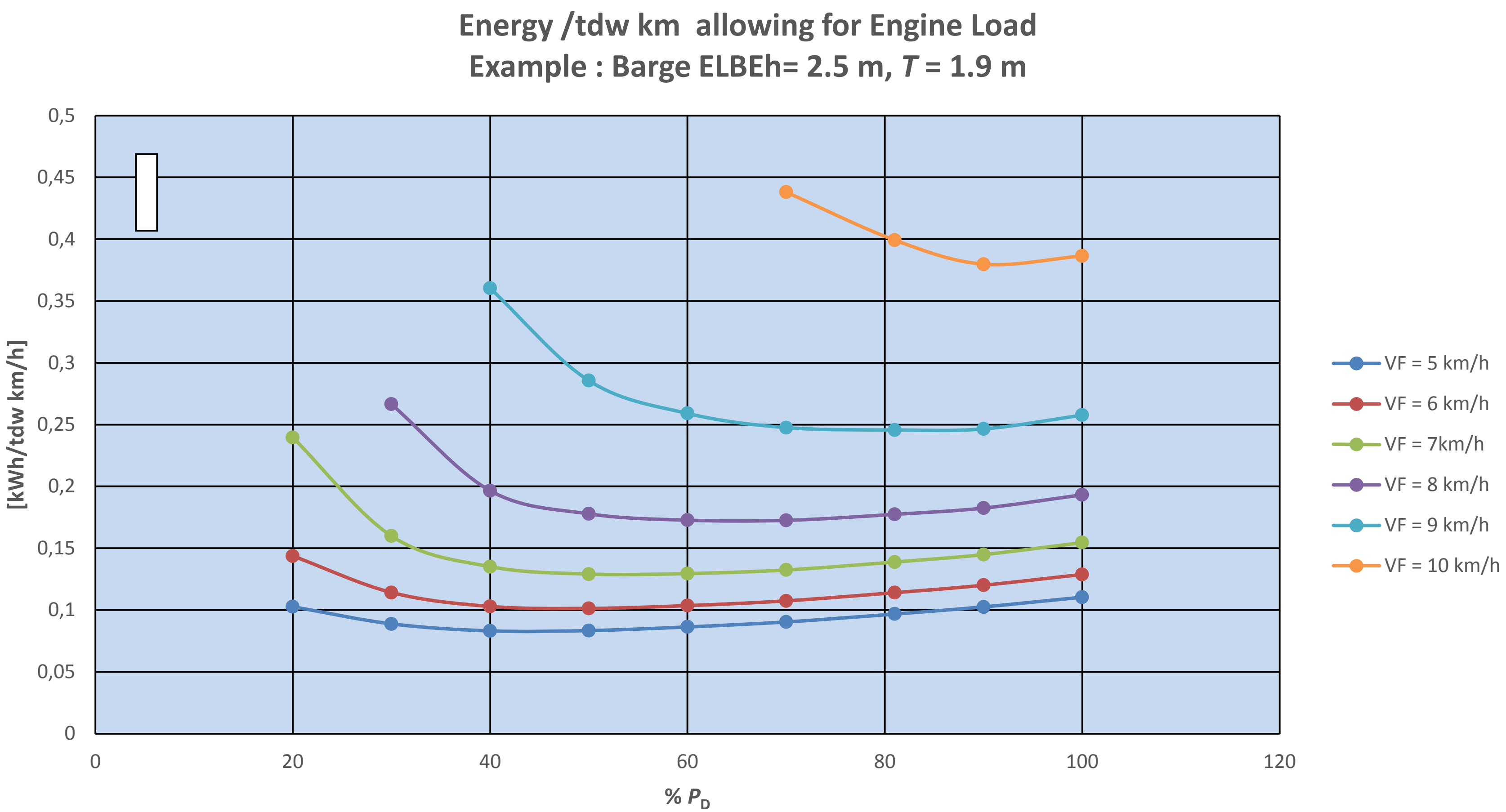
Energy/(tdw x km) for Different Current Speeds Example: Barge-Barge Combination, *h* = 2.5 m, *T* = 2m



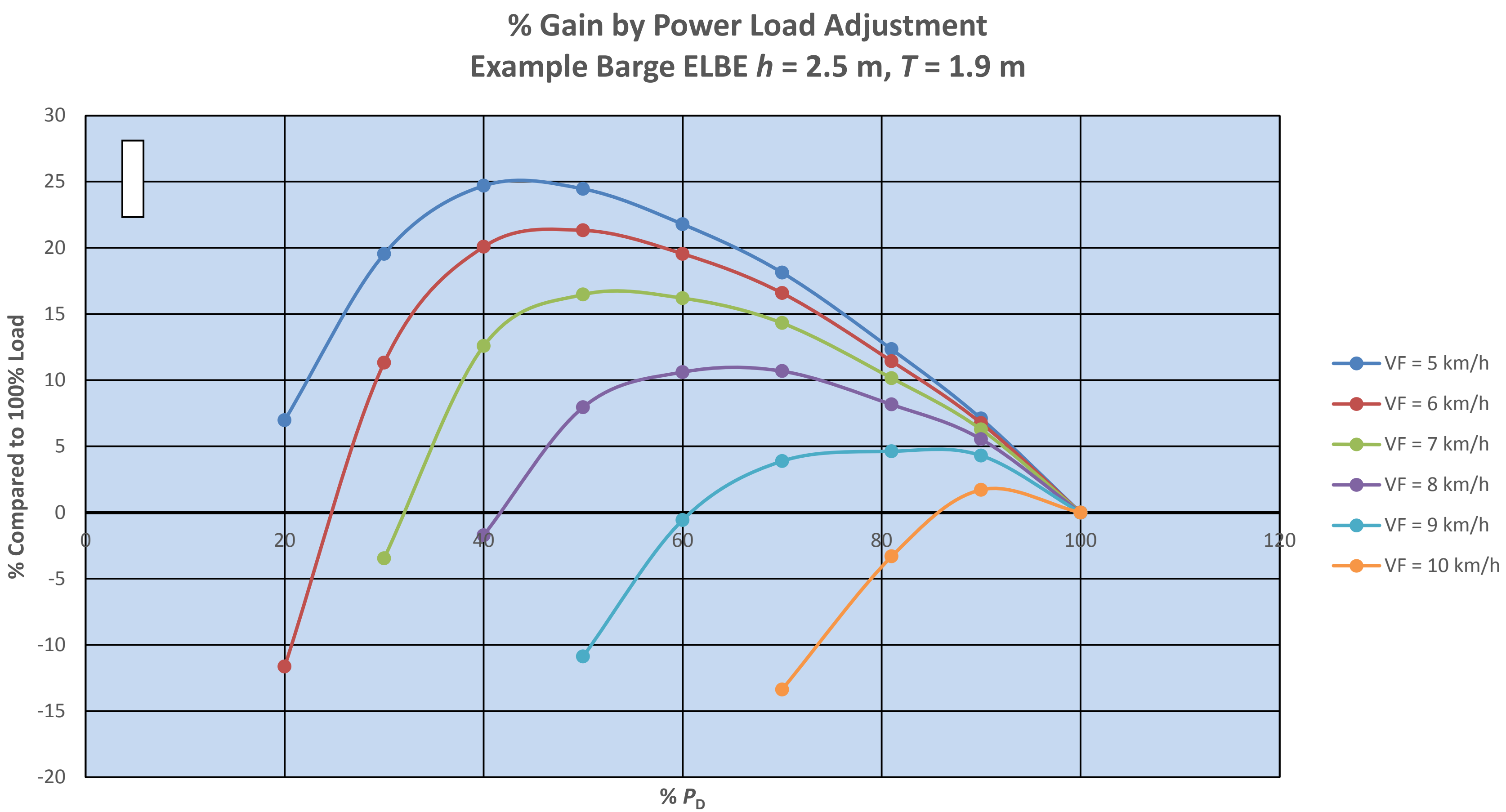
Decrease of efficiency of a Diesel Engine versus Load



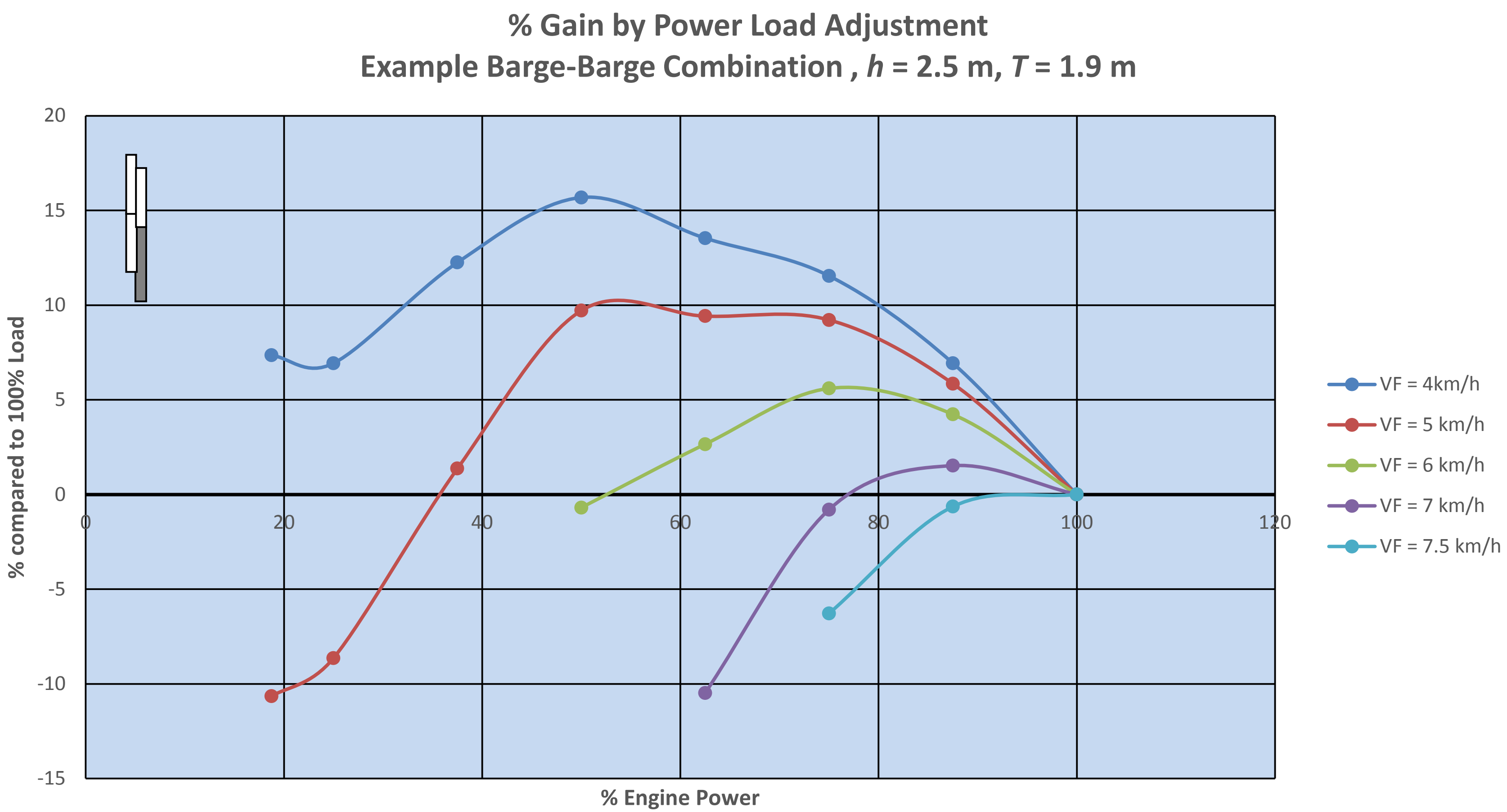
Energy/(tdw x km) allowing for Engine Load Example: Barge ELBE, *h* = 2.5 m, *T* = 1.9 m



Gain by Power Load Adjustment
Example: Barge ELBE, *h* = 2.5 m, *T* = 1.9 m



Gain by Power Load Adjustment
Example: Barge-Barge Combination, *h* = 2.5 m, *T* = 1.9 m



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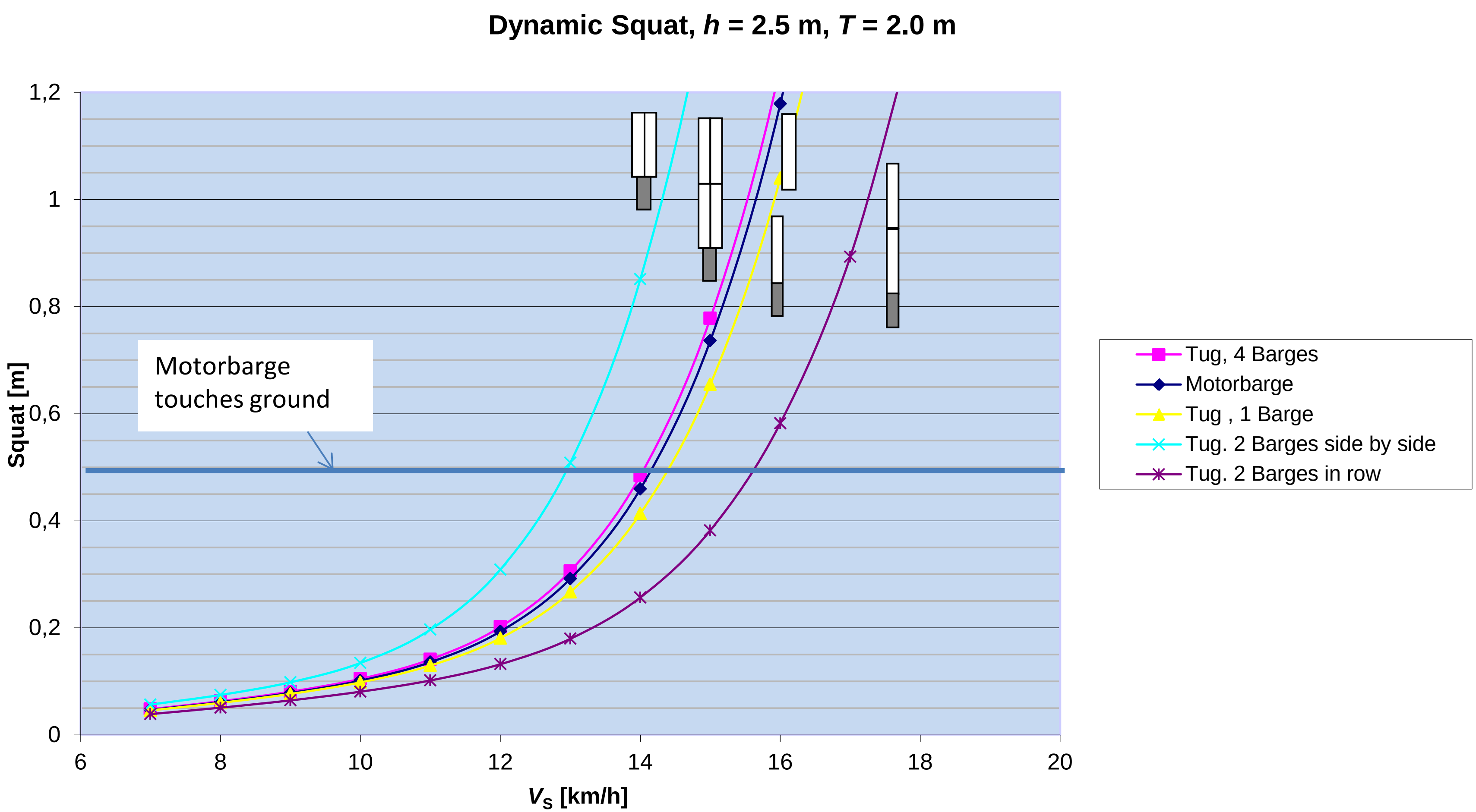
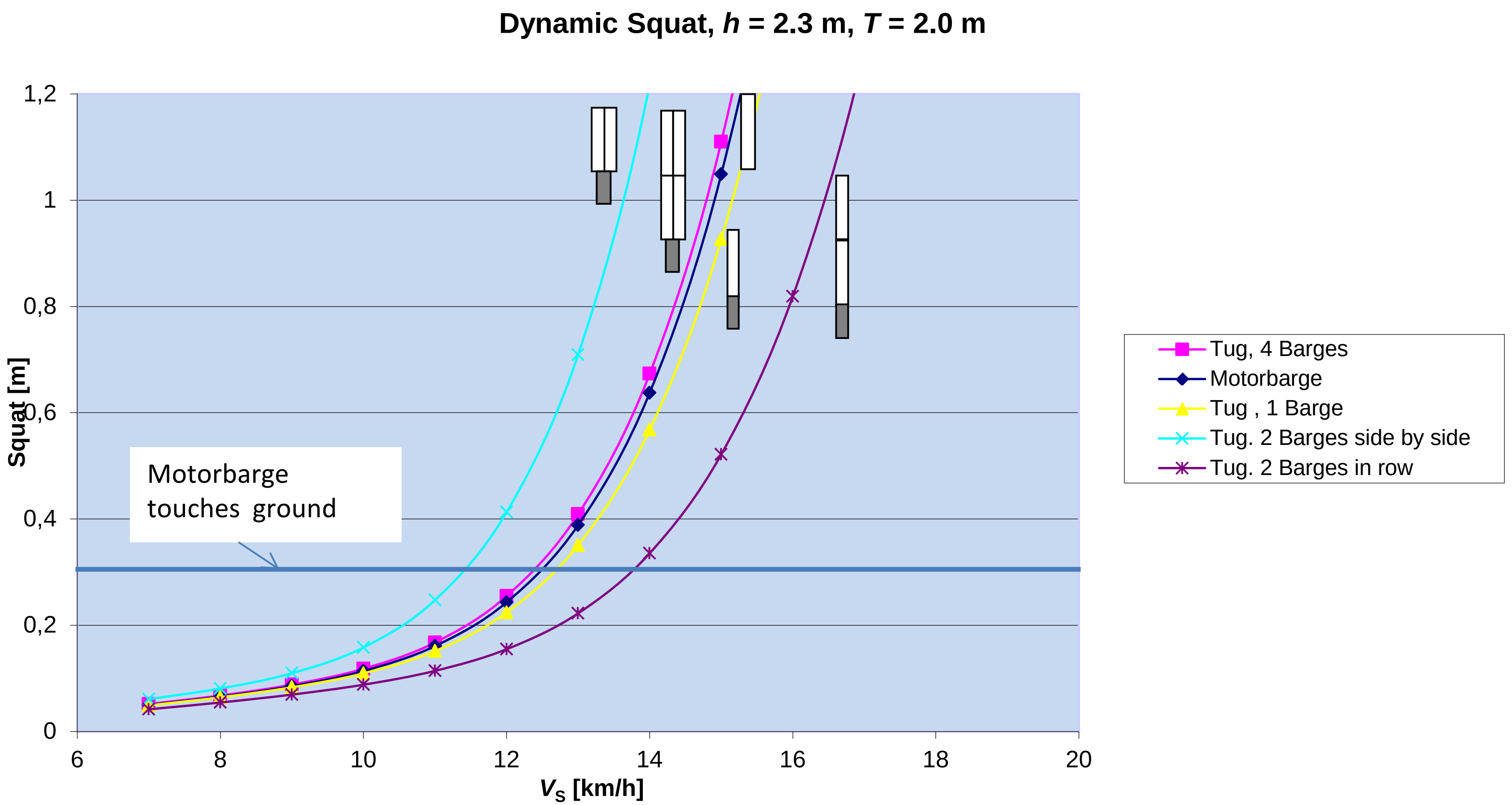
Speed Limitation by Squat

Calculation of Squat acc. to Römisch for different Barge Combinations, *h* = 2.5 m, *T* = 2 .0 m

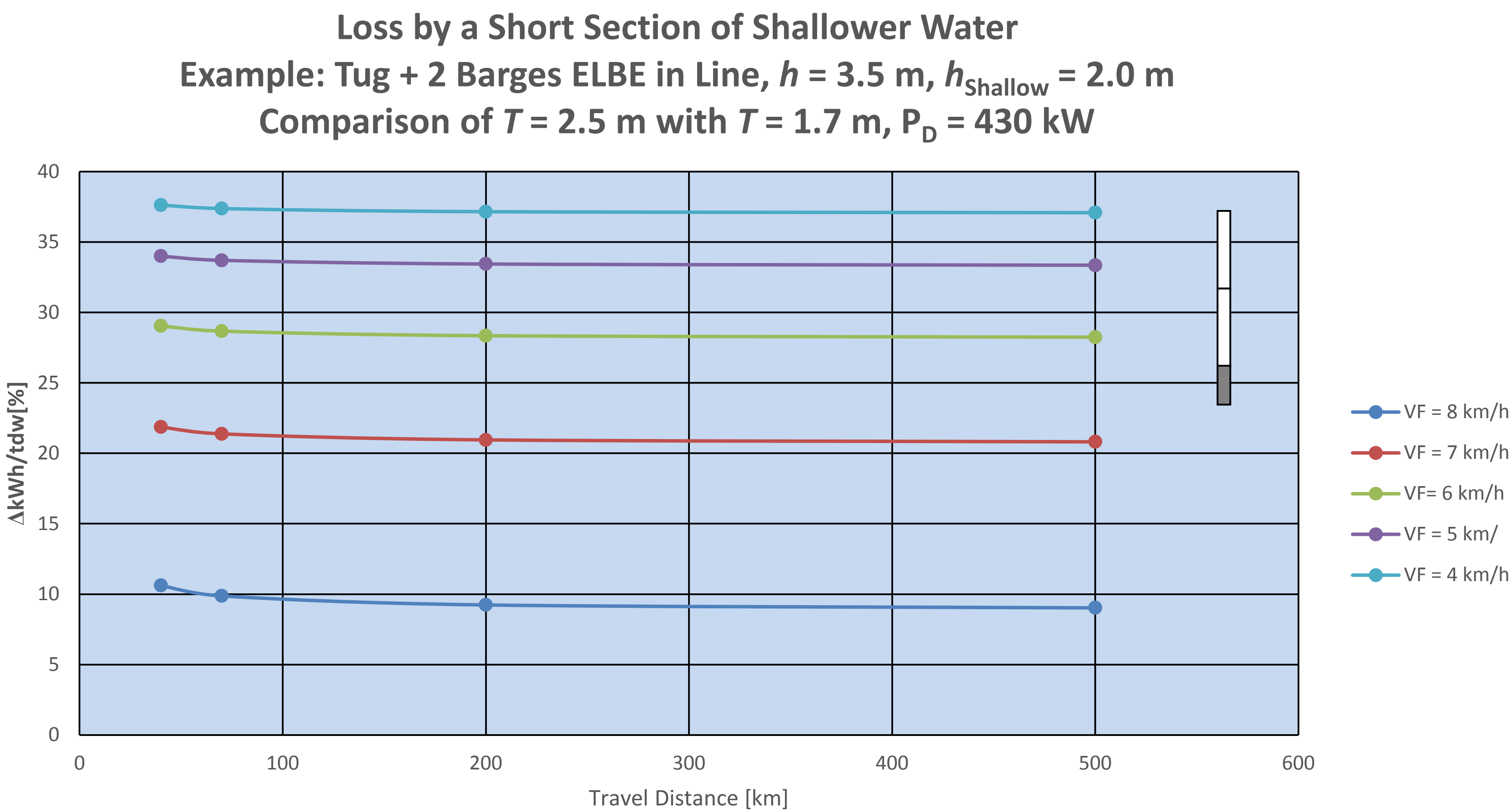


Calculation of Squat acc. to Römisch for different Barge Combinations, *h* = 2.3 m, *T* = 2.0 m

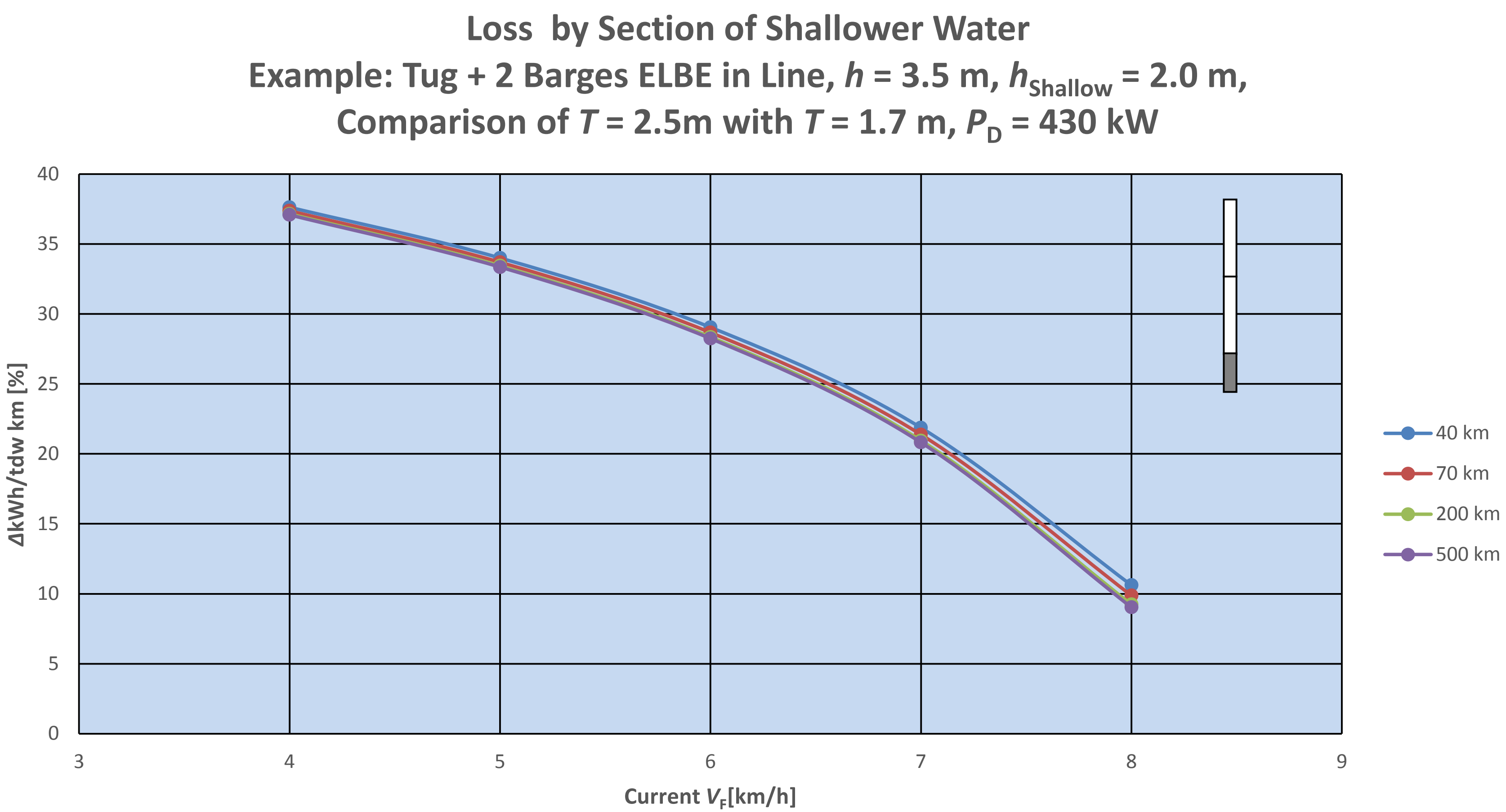


Effect of Short Sections of Shallower Water on Transport Efficiency

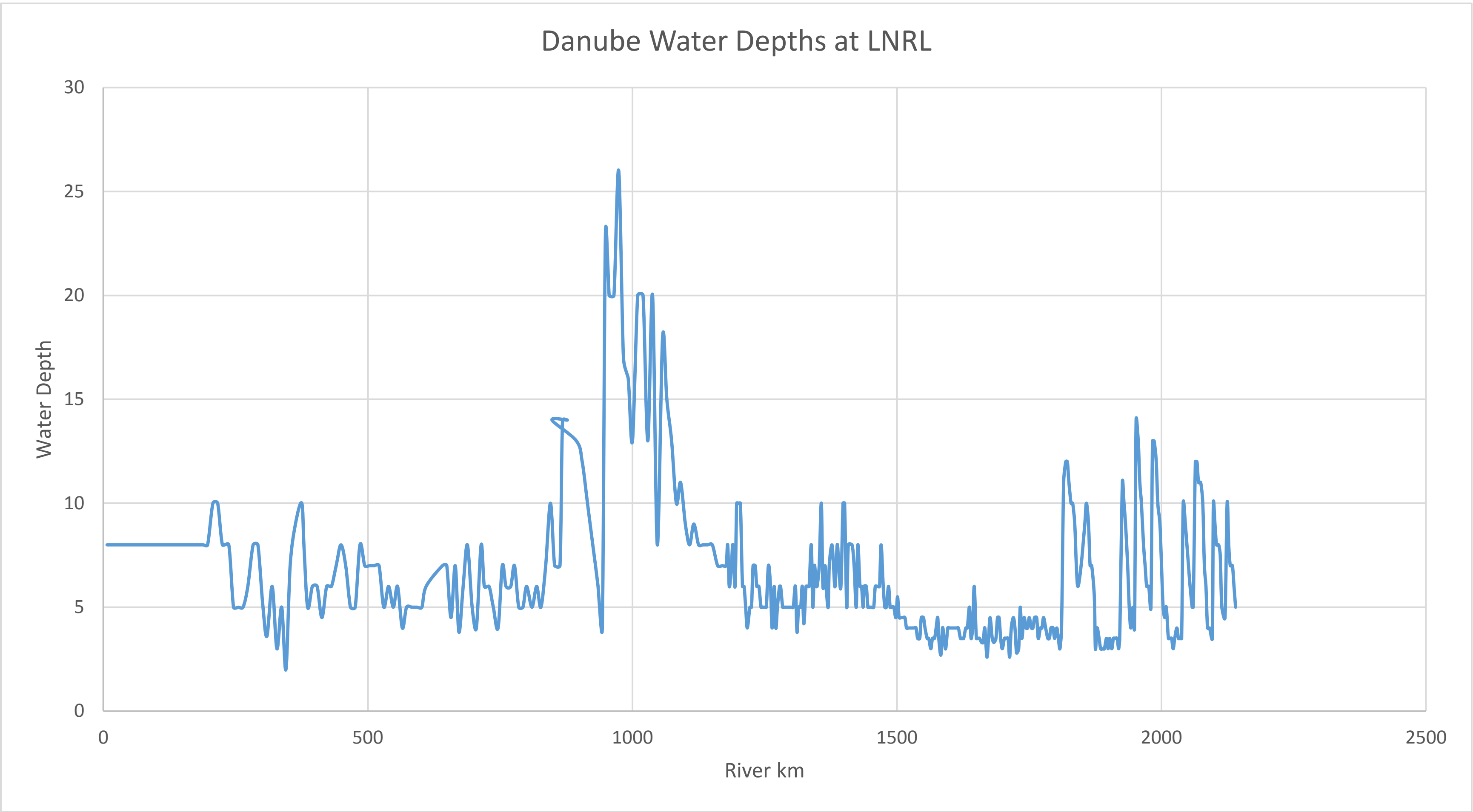
Effect of a Short Section of Shallower Water



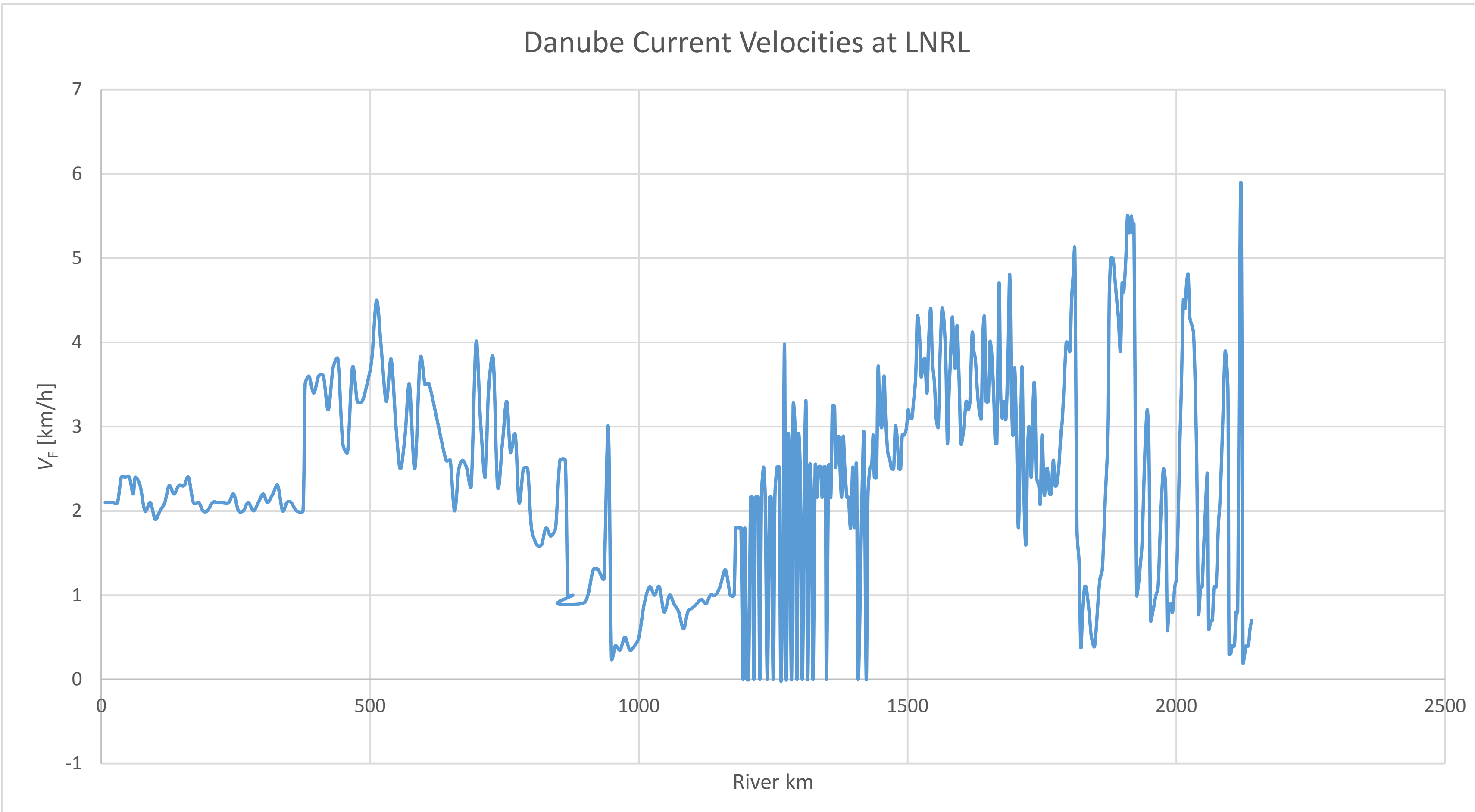
Effect of a Short Section of Shallower Water



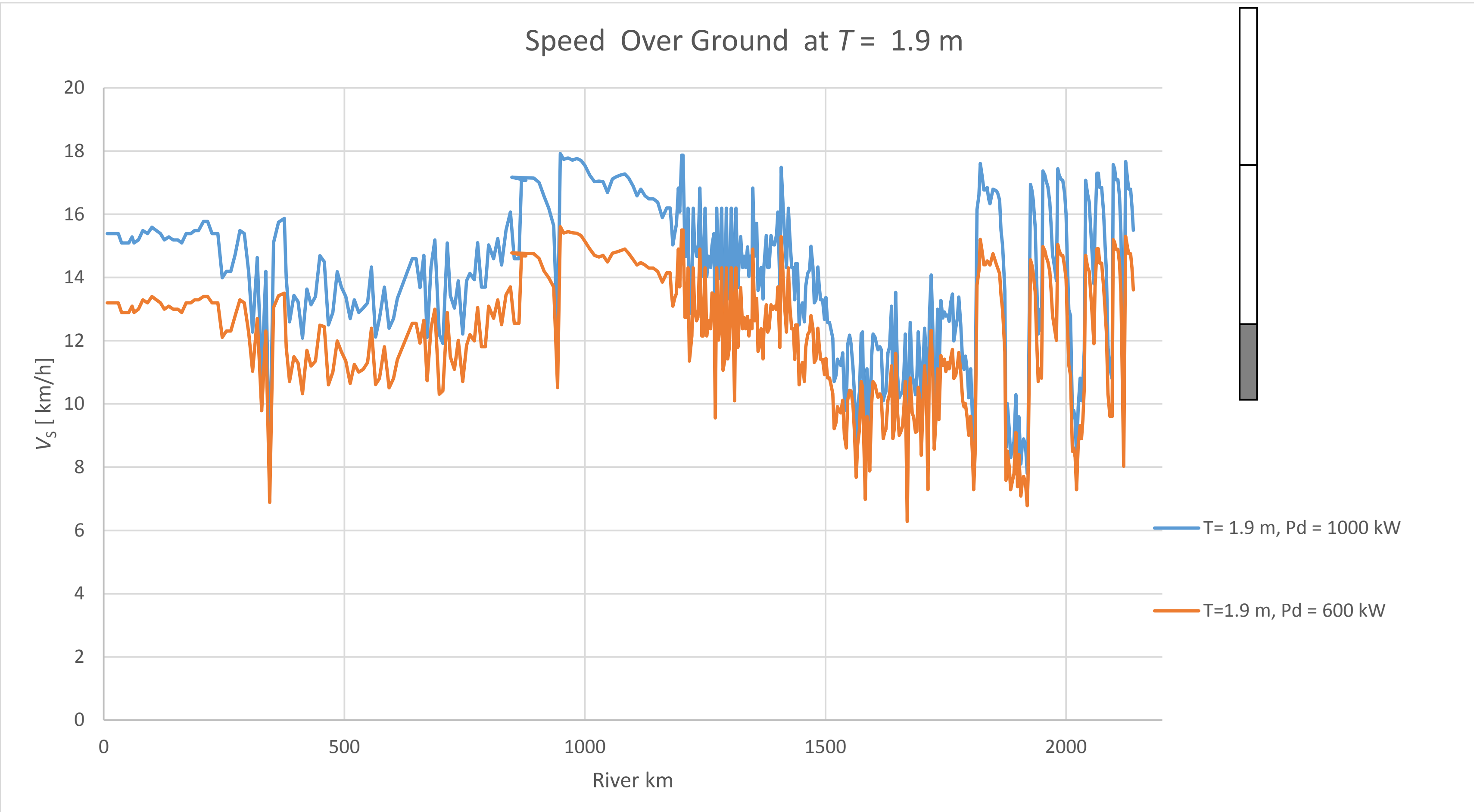
Calculations for Distance Sulina-Linz
Water Depths



Calculations for Distance Sulina-Linz Current Velocities



Calculations for Distance Sulina-Linz
Speed Over Ground of Tug-Barge System , *T* = 1.9 m



Calculations for Distance Sulina-Linz Results

	T = 1.9 m		T = 2.2 m
P_D	1000 kW	600 kW, efficiency reduced by 10%	1000 kW
Time	155 h	179 h	165.4 h
Fuel	30.99 t	23.64 t	33.08 t
Fuel/t km	0.00674 l/t km	0.00514 l/ t km	0.00601 l/ t km
Gain in Fuel Consumption	0.0	23.7 %	10.83 %
Time Difference	100 %	115.5 %	106.7 %

Conclusions

- Transport Efficiency Coefficient (power consumption/ tdw x distance) seems to be a useful parameter for describing the efficiency of a ship.
- The **effect of shallow** increases heavily with decreasing water depth and starts to be more pronounced between 3 m and 2.5 m water depth, depending on the current velocity of the river (up to 70 - 80% in our example between H = 5 m and H = 2.5 m).
- Short **sections of shallower** water have an increasing negative effect on the Transport efficiency due to the limited draught combined with low current velocities of the river (up to 40% in our example). At low current velocity - the effect is greater.

Conclusions Regarding Design Parameter Variations

- **Draught** should be kept as high as possible, The limit is the dynamic squat. Tug Barge Combinations have an advantage compared to self propelled barges as the tug can have clearly less draught with less hazard to the propulsion units.
- Increasing the ***B/L*** has negative effect: Broadening = negative
Lengthening = positive
Tug-Barge arrangement has high effect on the efficiency.
- Decreasing the **weight** of the ship has generally small effect on the efficiency. The effect is higher in extremely shallower water.
- Power Consumption can be **optimized by Load Control of Engine**(s) taking into account Water Depth and Current. This option should be pursued as it opens the possibility to save fuel without high engineering effort.

Final Remarks

- Any **river engineering measures** which increase the water depth, especially in the short sections of even shallower water, has an essentially higher advantage with regard to energy efficiency than any improvement on some river barges.
  Not only that the attainable advantage can be bigger than some design measures on barges, but also the river engineering **affects all ships**, existing (more than 3000 on the river Danube) and new ones, and therefore by far should be given preference with regard to the general economy as a whole.

Final Remarks

- Nevertheless new hydrodynamic designs, powering concepts, engine technologies, different fuels (LPG) etc. which will result in lower exhaust pollution values be should considered in the design of innovative vessels.
  WP2 exclusively investigated the energy efficiency of the design parameters, and any measure which reduces fuel consumption and emission values should be taken into consideration for new and existing ships.

Thank You for Your Attention!