Universität Rostock Traditio et Innovatio

EMship Advanced Design

The application of dual-fuel technology in inland waterway tankers

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Structures & Objectives

- **Structures:**
  - Introduction of the European inland navigation & shipping sectors
  - Review on the typical design of inland vessels & tankers
  - Review on green ship technology
  - Preference for future marine fuel
  - Review on dual-fuel technology
  - ARGONON
  - Veth Hybrid Drive
  - New design (proposed)

- **Objectives:**
  - To define the preferable engine system for inland vessels
  - To define more efficient propulsion system for inland vessels
  - To propose new design for inland tankers

The European Inland Navigation Sector

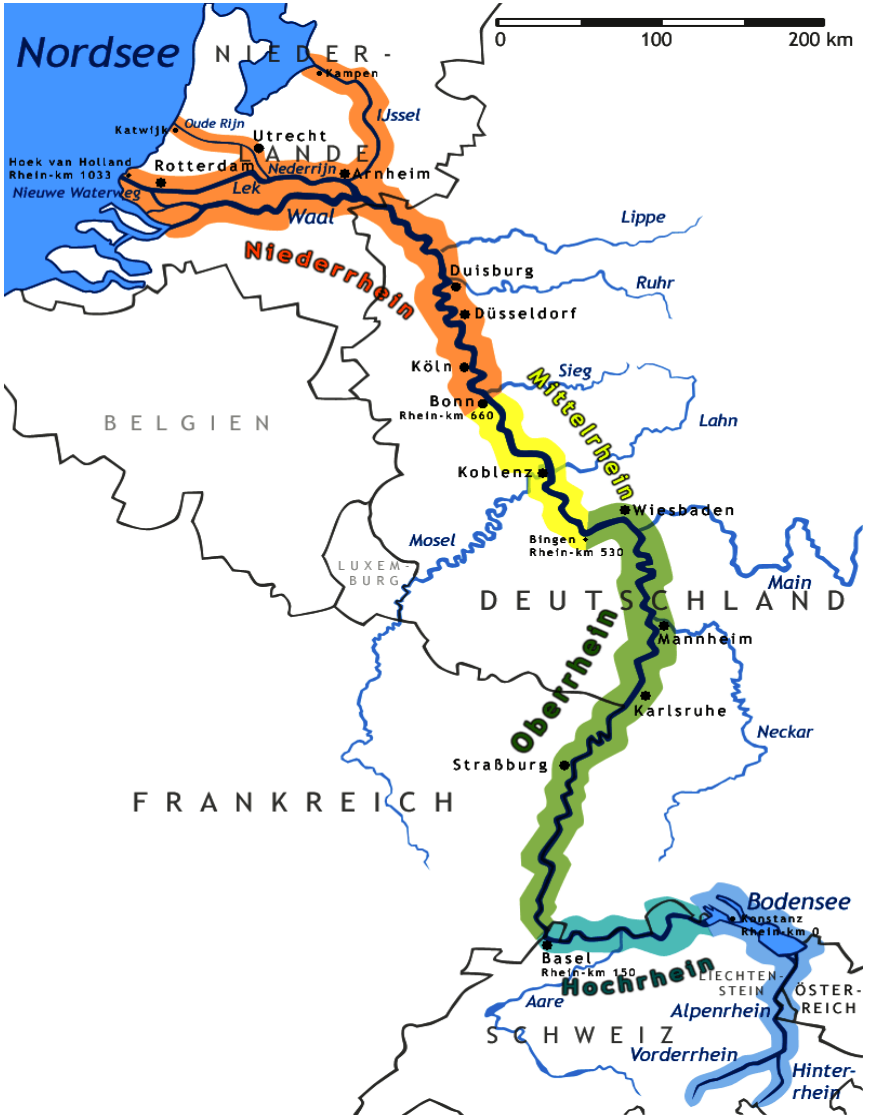
- 20.000 vessels
- 38.000 km navigable inland waterways

- Eurostat 2011: Combined EU transport modes
  - 6.6% - INLAND (with 14.6% - railway and 78.8% road)

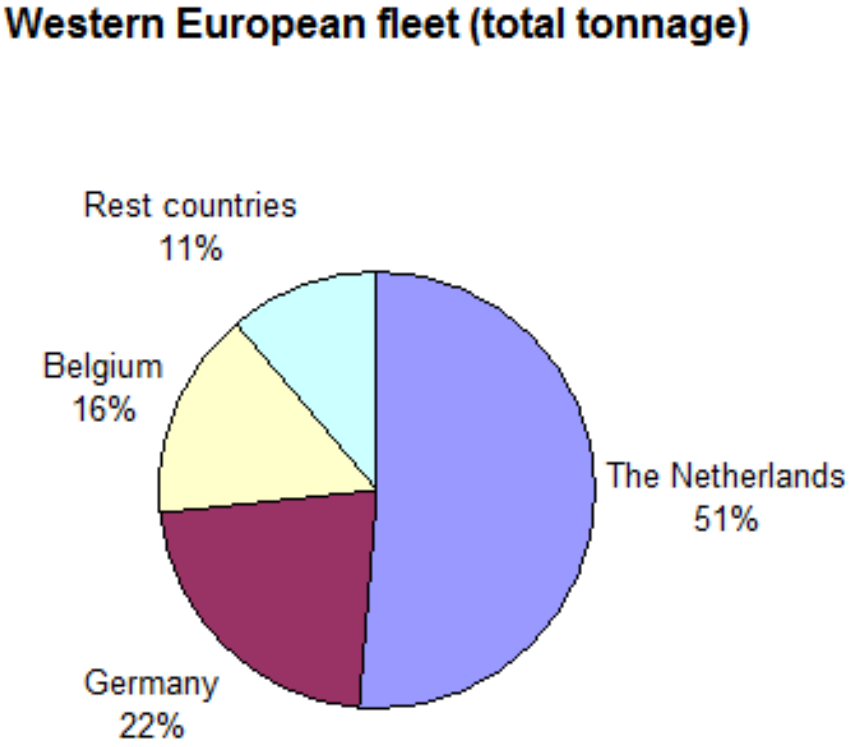
- Subdivision: Western European and Eastern European areas
  - Eastern European Area
    - Along the Danube
  - Focus: WESTERN EUROPEAN AREA
    - Along the Rhine

Main Characteristics of European Inland Navigation Sector

- **Western European Area**
  - Along the Rhine, its canals and tributaries
    - between Rotterdam – Basel
  - In 2007:
    - No of vessels EAST: 2726
    - No of vessels WEST: 11445
  - Vibrant growth of new building vessels (Germany and the Netherlands)



- **Western European Inland Shipping Sector**
  - **Crucial for trading in North-West (NW) Europe due to:**
    - Full road capacity
    - Slow growth of road transportation mode
  - **Vibrant growth induced by:**
    - Full road capacity
    - Capacious advantage of inland navigation



Main Characteristics of European Inland Navigation Sector

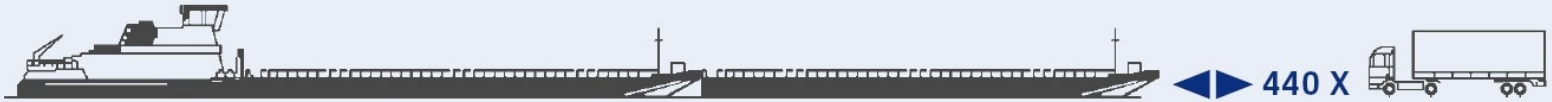
- **Capacious advantage:**
  - Assuming that the load capacity of 1 truck = 25 tons

Even the smallest Péniche can load the capacity of 14 trucks. Plus: Five liters of fuel last 500 kilometers per ton in a ship compared to only 100 kilometers per ton in a truck

Spits - Péniche:
length 38.50 m/width 5.05 m/draft 2.20 m/loading capacity 350 t

Tank ship:
length 110 m/width 11.40 m/draft 3.50 m/loading capacity 3,000 t

Container ship:
length 110 m/width 11.40 m/draft 3 m/loading capacity 200 TEU*



Push convoy (with 4 barges):
length 193 m/width 22.80 m/draft 2.50/ 3.70 m/loading capacity 11,000 t

* TEU=Twenty-foot Equivalent Unit Source: INE

- **The capacious advantage leads to next economical benefits:**
  - Time savings
  - Reduction of traffic congestion
  - Reduction of environmental emissions
  - Ensuring “time delivery” of goods

Main Characteristics of European Inland Shipping Sector

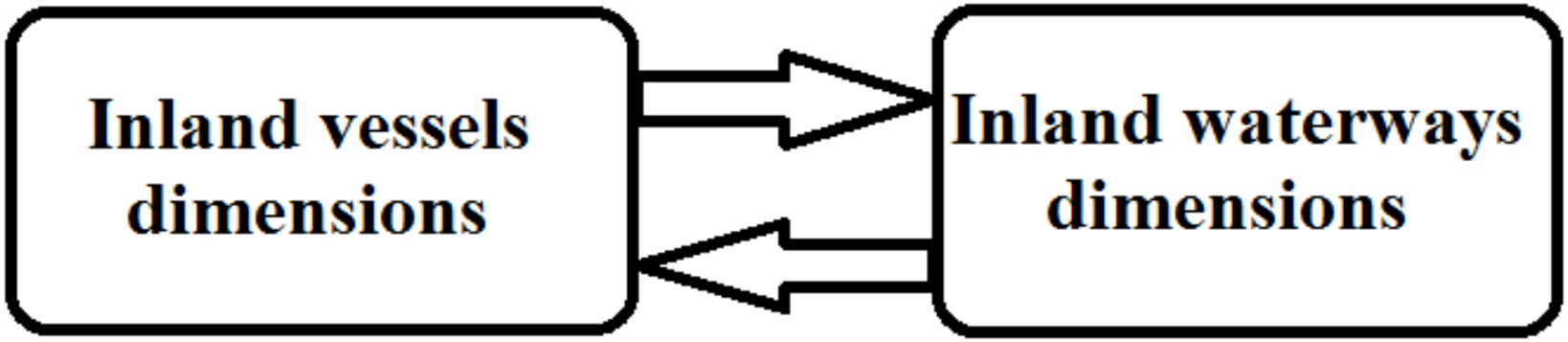
- **Dominated by ship owners with single ship**
  - In the Netherlands: 87% of inland shipping company belongs to ship owners with single ship

- **Small companies:**
  - Minimal research budgets
  - Limited technical knowledge

- **Low technical innovation comparing to sea shipping sector due to:**
  - Limited technical knowledge
  - Limited size of the inland shipping company (limited budgets and risk)

- **Typical design of inland vessels**
  - Mainly defined by the size of the waterways
    - Limitation on the Rhine:

Location	Max L (m)	Max B (m)	Hmax (m)
Along the Rhine	140	22.90	9.10
Rhine canals & tributaries	100	11.50	4.30



Inland Waterway Tankers (Double-hull)

- **According to ADN and ADNR:**
  - Type G: inland gas tanker
  - Type C: inland chemical tanker
  - Type N: inland oil tanker

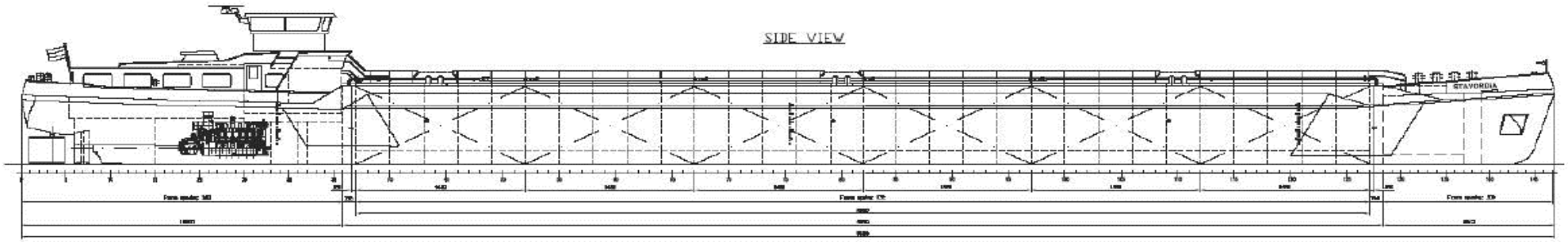
- **Classification (PIANC waterway class)**

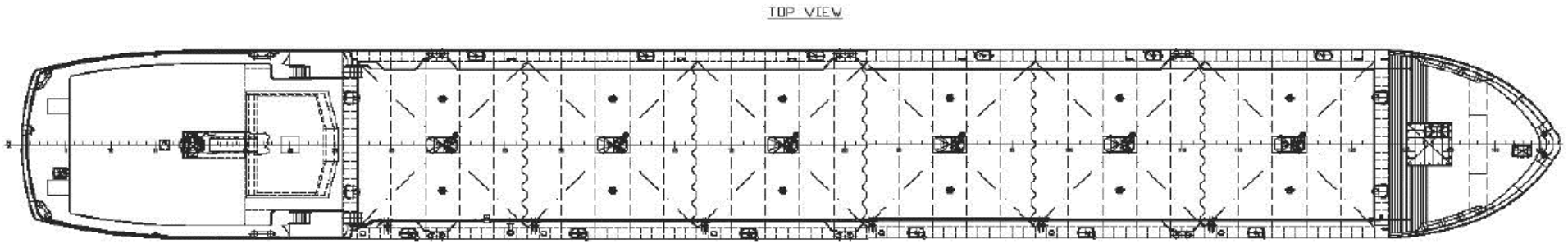
Class	L (m)	B (m)	Hmax (m)	T (m)	Cargo (t)
IV	80 – 87	9.50 – 11.50	3.00 – 6.50	2.80 – 4.50	1000 – 1500
Va	100 – 110	11 – 16.20	3.00 – 6.00	2.80 – 5.80	1500 – 3000

- **Mostly are Type C and Type N tankers of waterway class Va**

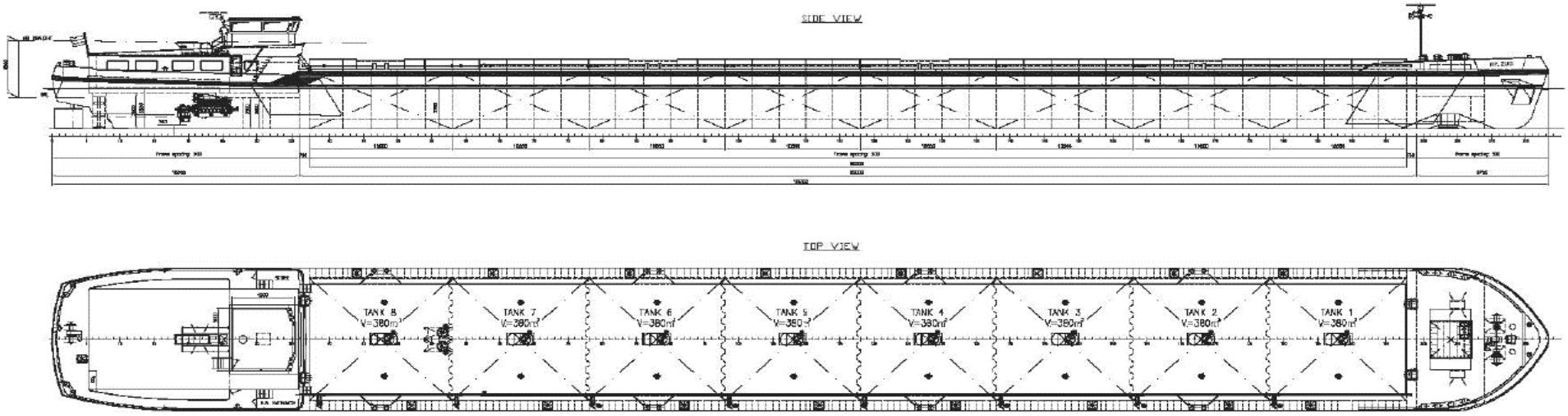
Inland Waterway Tankers (Double-hull)

- **Chemical tanker waterway class IV:**
  - Engine system: 4-stroke medium speed marine diesel engine with average engine power 1000 kW
  - Propulsion system: diesel-electric
  - **Aft-peak part length = 18 m compose 21% of total length**
  - Navigate along the Rhine on its canals and tributaries



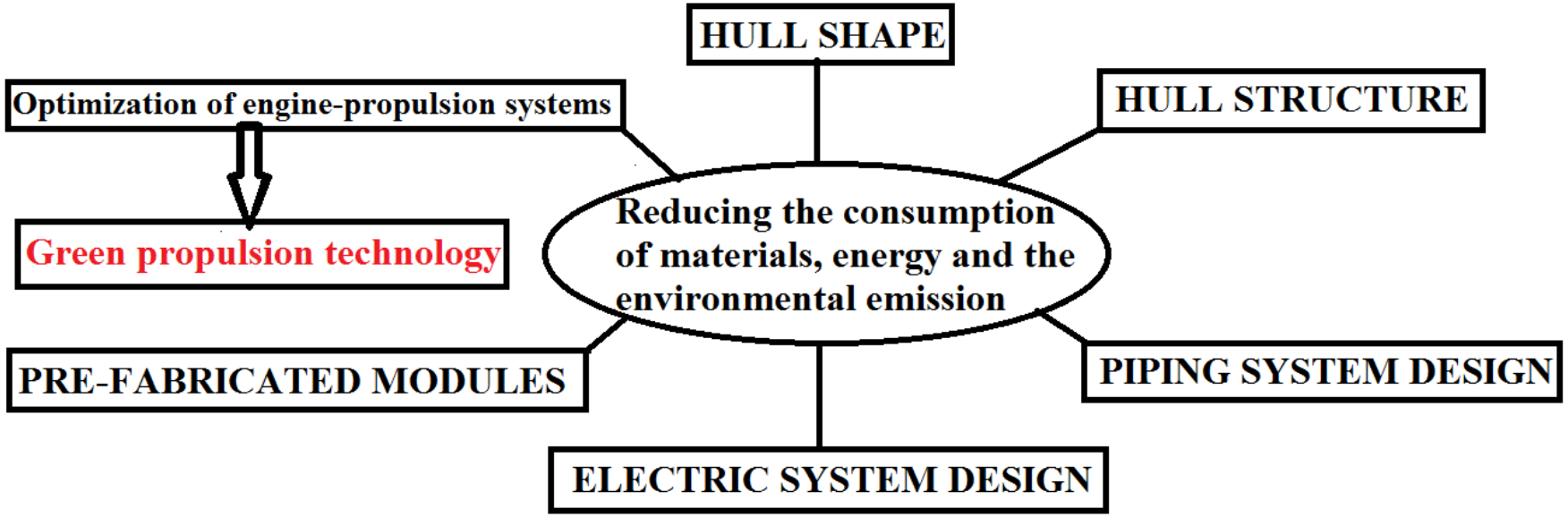


- **Chemical tanker waterway class Va:**
  - Engine system: 4-stroke medium speed marine diesel engine with average engine power 1350 kW
  - Propulsion system: diesel-electric
  - **Aft-peak part length = 18 m compose 16% of total length**
  - Navigate along the Rhine only



GREEN SHIP TECHNOLOGY

- **Main aspects:**
  - Reduction of the consumption of materials, energy and the environmental emission
  - Recycle & reuse the materials



- **Green propulsion technology:**
  - Dual-fuel engines
  - LNG-fuelled engines
  - Innovative propulsion system

- **Reduces harmful environmental emissions during vessel's operation along the inland waterways**

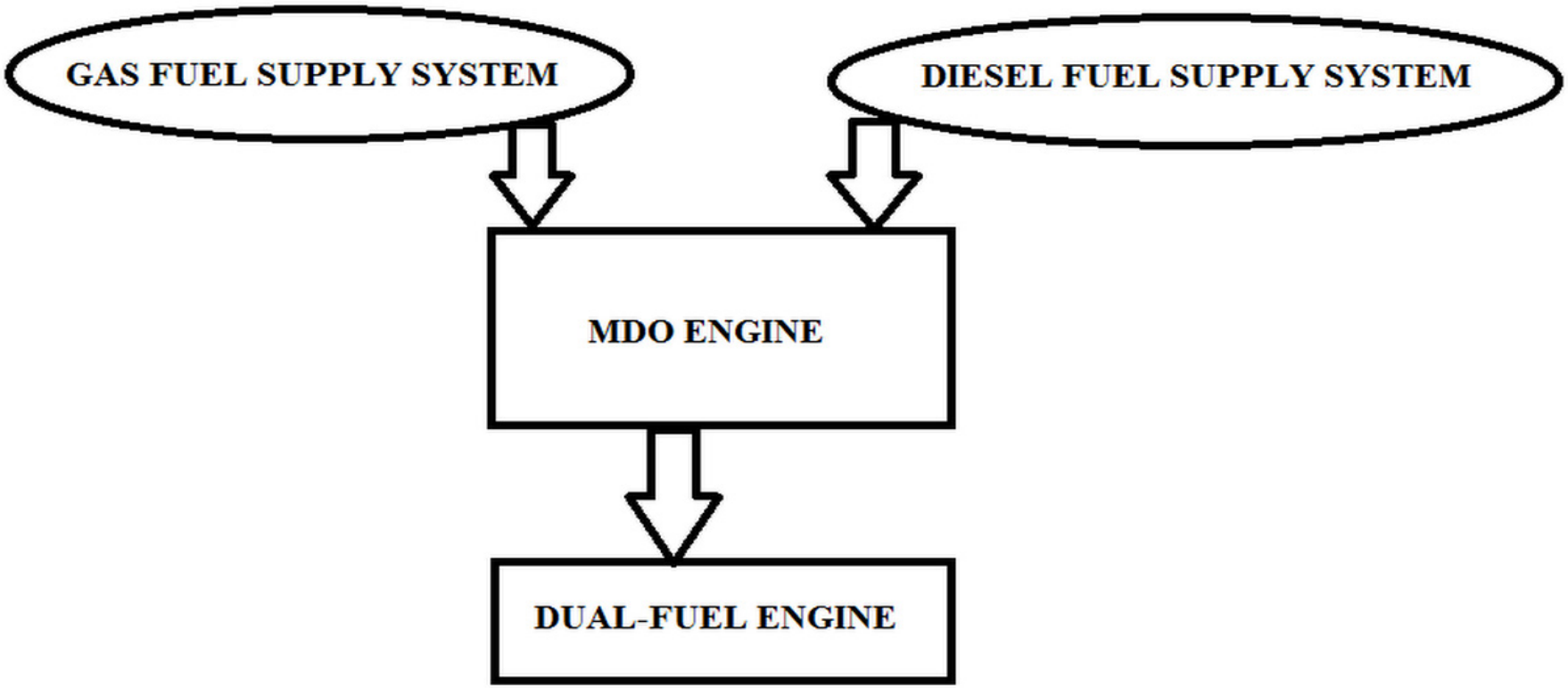
- **Improves economical and social benefits**
  - Reduction of fuel consumption in inland waterway vessels gives **economical benefits** for ship owners
  - **Clear environment** for huge number of population which lives close to inland waterways

Green Fuel for the Future – LNG

No.	Characteristics	MDO engine	LNG engine	Dual-fuel engine
1	Thermal efficiency	38%	**50%**	**Gas mode: 47%** Diesel mode: 38%
2	CO_2 emission reduction	NO	**25 – 30%**	**Gas mode: 30%** Diesel mode: NO
3	NO_x emission reduction	NO	**85%**	**Gas mode: 85%** Diesel mode: NO
4	SO_x emission reduction	NO	**100%**	**Gas mode: 100%** Diesel mode: NO
5	Particles emission reduction	NO	**100%**	**Gas mode: 100%** Diesel mode: NO
6	Fuel flexibility	NO	NO	**YES**

Preference: dual-fuel engine technology with its fuel flexibility

Dual-fuel engine technology



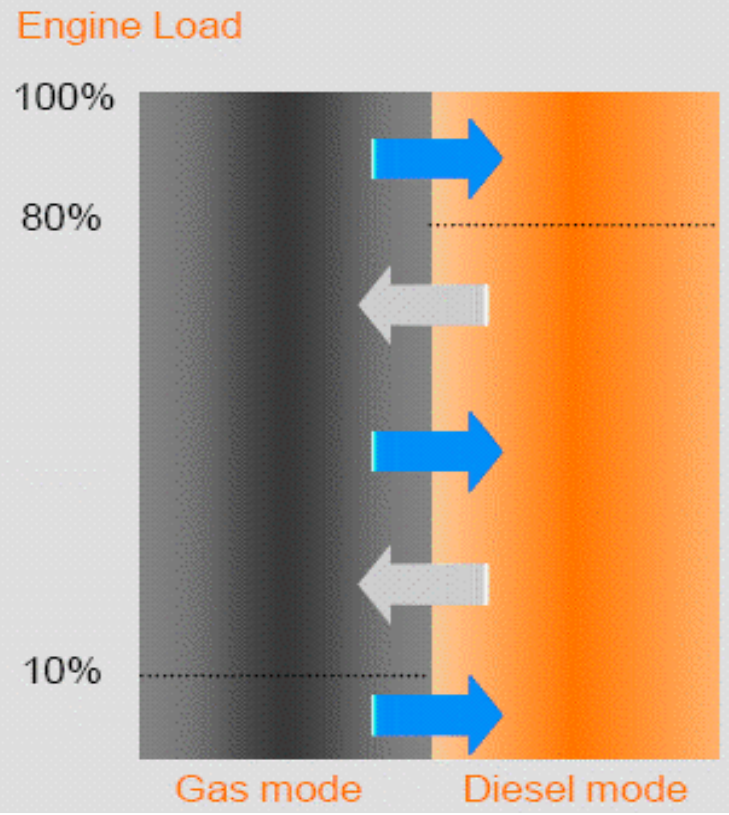
Dual-fuel engine technology

- **Characteristics:**
  - Dual-fuel diesel engines can be run in either gas mode or diesel mode
  - Fuel flexibility:

Gas mode
- Natural gas + MDO pilot
- Automatic and instant trip to diesel operation in alarm/emergency situation
- Transfer to diesel operation at any load on request

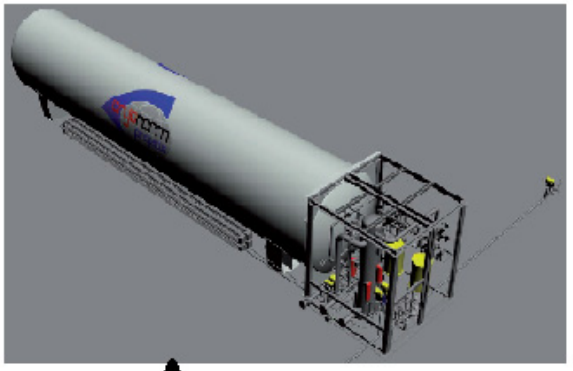
Diesel mode
- MDO/HFO/CRUDE + MDO pilot
- Operated as an ordinary diesel engine
- Transfer to gas operation at any load below 80%
- Pilot fuel injection in operation also during diesel mode operation

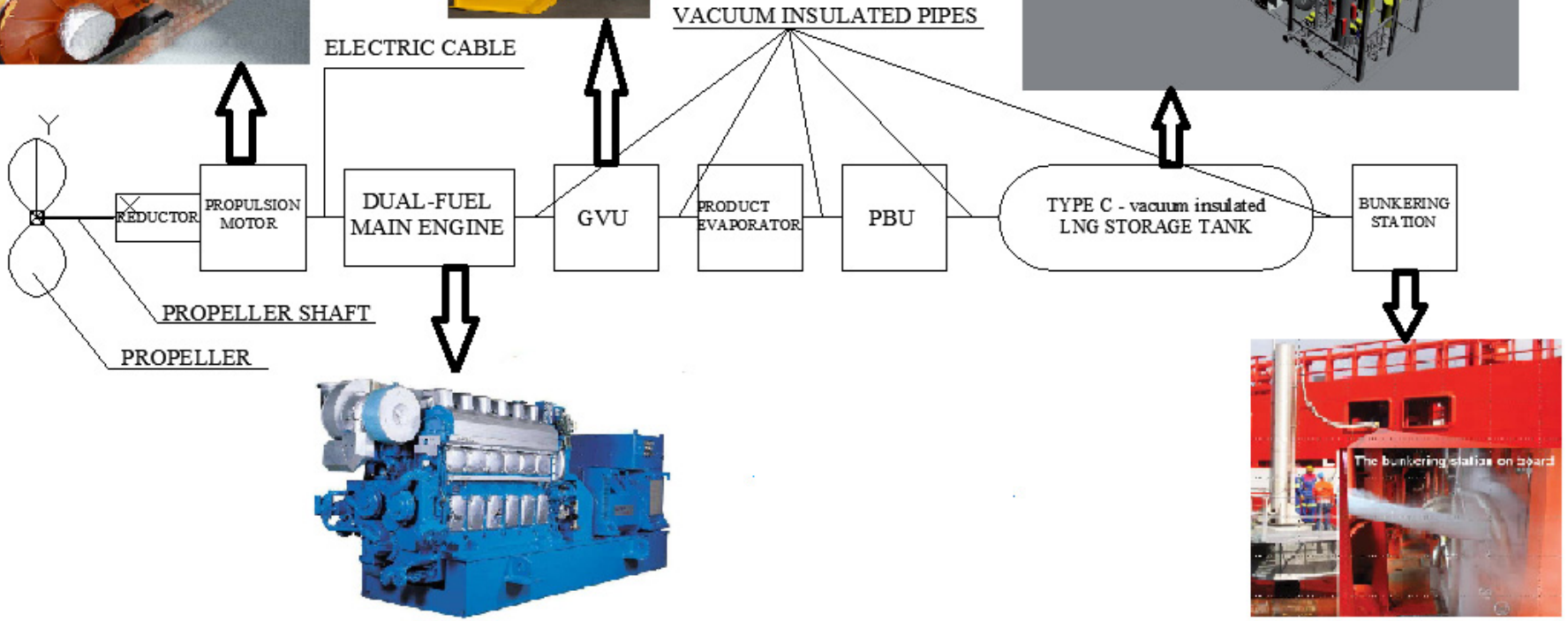
Transfer between modes without power interruption



Dual-fuel engine technology

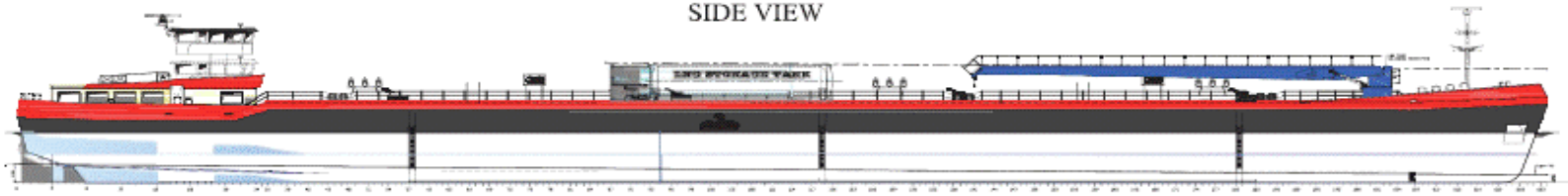
► Scheme



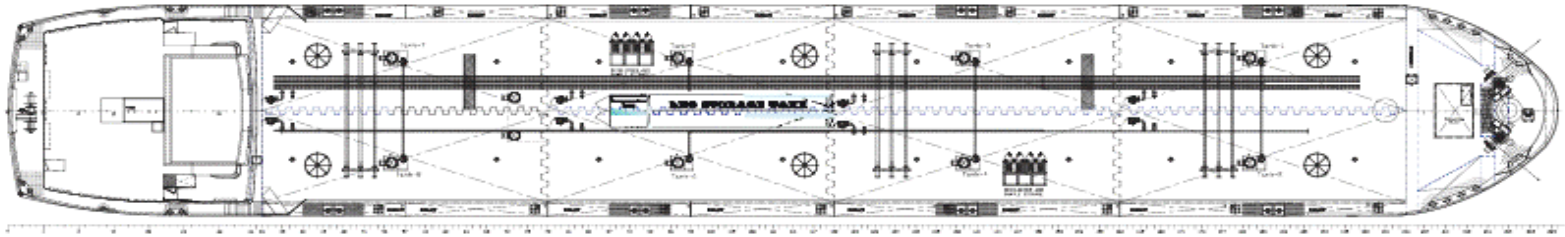


Europe's First LNG-fuelled Inland Vessel – "ARGONON"

SIDE VIEW



TOP VIEW



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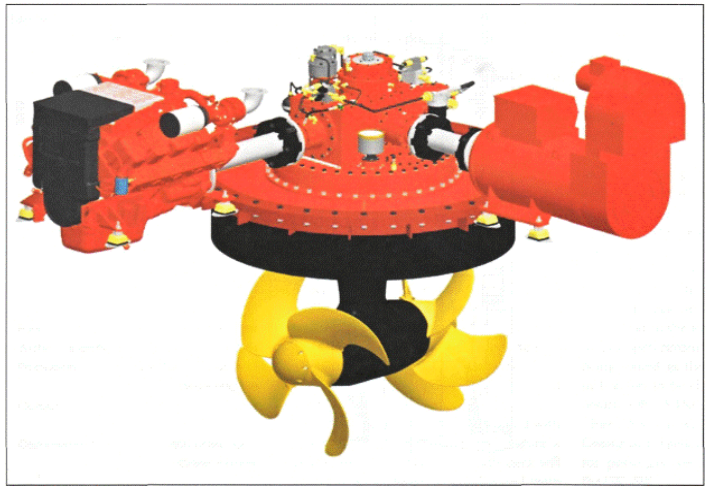
ARGONON – LNG-fuelled inland tanker

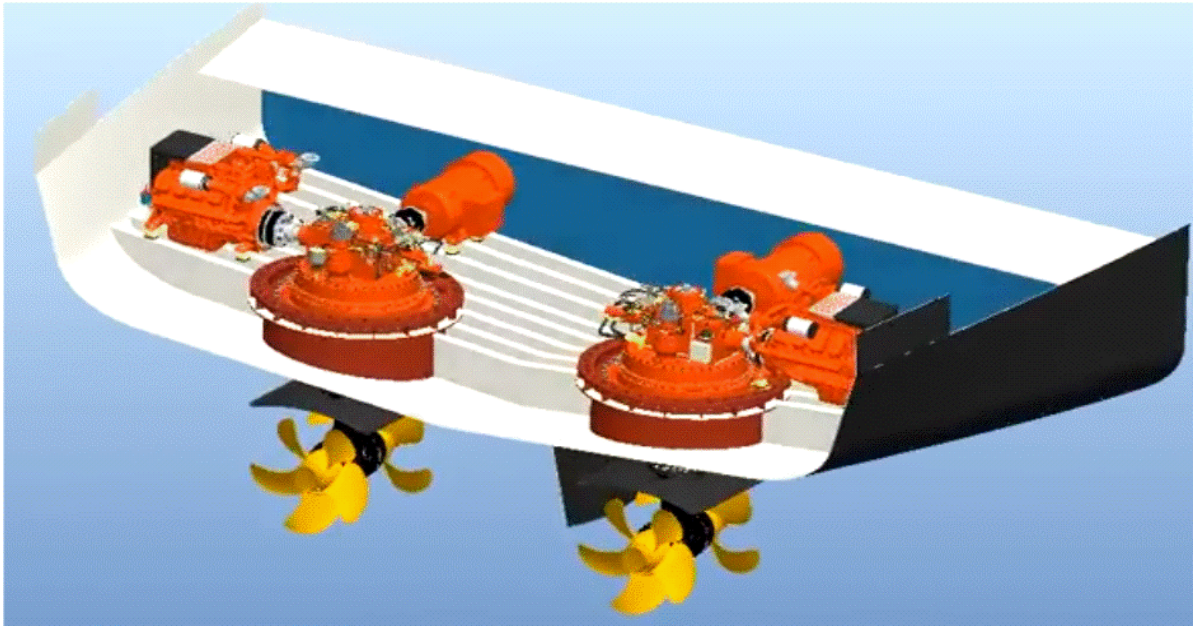
►Main specifications of "ARGONON"

No.	Parameters	Specifications
1	Ship type	Type C inland waterway tanker
2	Hull	Double-hull, Y-shape
3	Length (m)	110
4	Breadth (m)	16.40
5	Height (m)	6.20
6	Draft (m)	4.95
7	Deadweight (t)	6100
8	Displacement (t)	7600
9	LNG tank	40 m^3 Type C tank (IMO IGC-code)
10	Cargo volume	6400 m^3
11	Main engine	2 x Caterpillar 3512DF dual-fuel engines
12	Propulsion system	Diesel electric with single propeller + nozzle on tunnel
13	Operation range	1600 km without refuelling along the Rhine (between Rotterdam and Basel)

Innovative Propulsion System – Veth Hybrid Drive

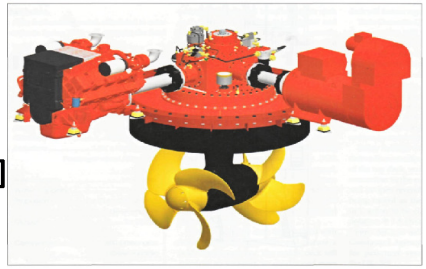
- **Project “Semper Fi”**
- **Characteristics:**
  - Higher propulsive efficiency
  - Greater manoevrability
  - More power can be transmitted with smaller propeller
  - Compact propulsion system
  - More layout flexibility for ship designers
  - Low noise and vibration characteristics





Future design (proposed)

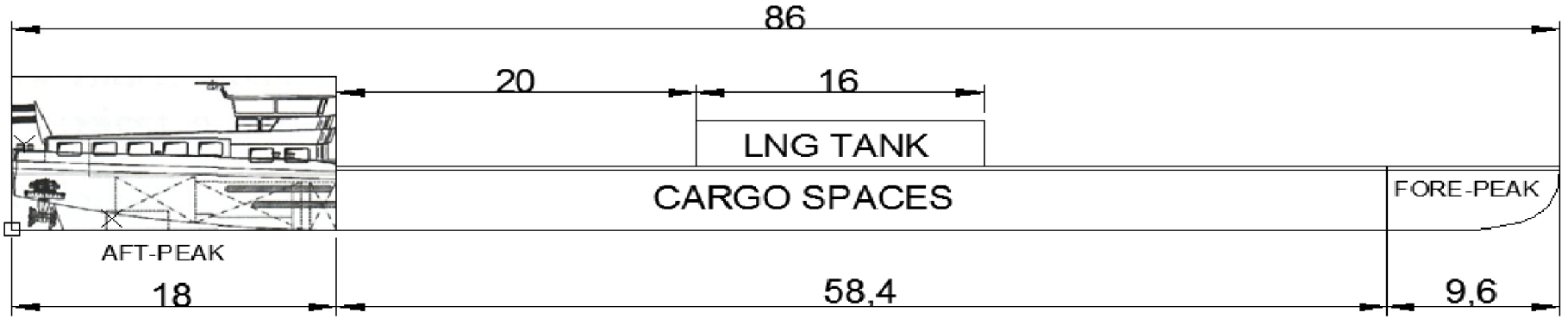
INLAND CHEMICAL TANKER CLASS IV "STAVORDIA"



DIESEL-ELECTRIC PROPULSION SYSTEM

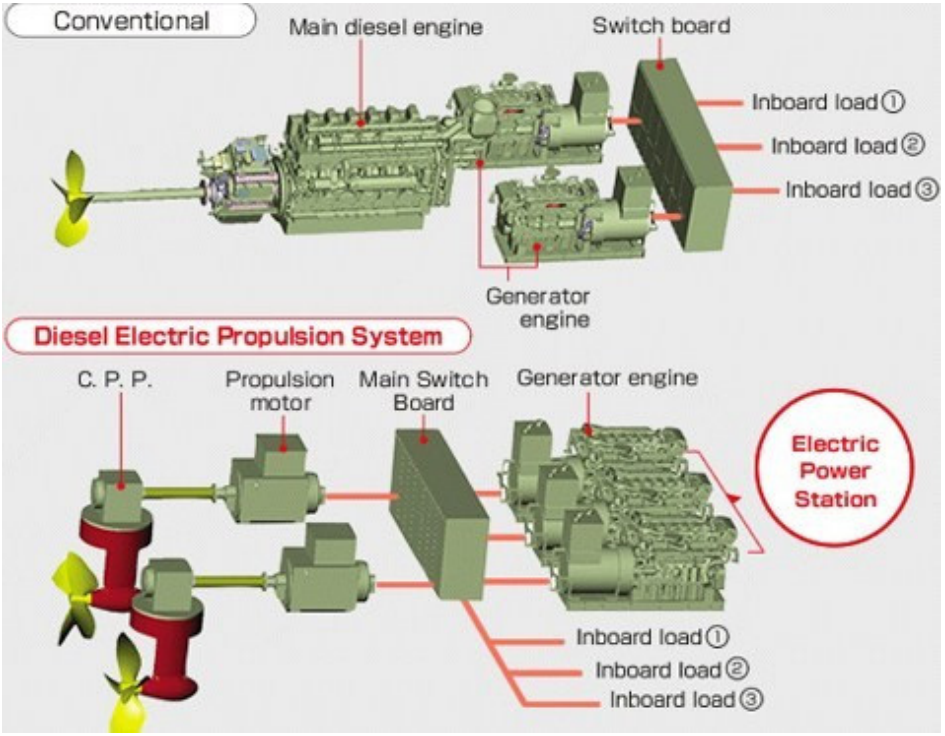
DUAL-FUEL ENGINE TECHNOLOGY

FUTURE DESIGN



Combination - WHY?

- **Veth Hybrid Drive:**
  - COMPACT
  - Higher propulsive efficiency
  - Greater manoeuvrability
- **Diesel-electric propulsion system:**
  - Layout flexibility
  - Low noise and vibration levels
- **Dual-fuel engine technology:**
  - Low environmental emissions
  - Fuel flexibility



Future design (proposed)

► Dimensional comparison

No.	Parameters	"ARGONON"	"STAVORDIA"	"Semper Fi"	"Future design"
1	Ship type	Type C tanker class Va	Type C tanker class IV	Inland container vessel	Type C tanker class IV
2	Aft-peak length (m)	18	18	18	18
3	Length (m)	110	86	110	86
4	Breadth (m)	16.40	11.40	11.40	11.40
5	Height (m)	6.20	4.75	-	4.75
6	Draft (m)	4.95	3.20	3.70	3.20
7	Deadweight (t)	6100	1800	3160	1800
8	Displacement (t)	7600	2250	3950	2250
9	LNG tank	40 m^3 Type C tank (IMO IGC-code)	NO	NO	40 m^3 Type C tank (IMO IGC-code)
10	Cargo volume (m^3)	6400	2280	3450	2280
11	Total engine power (kW)	2 x 1115 = 2230	1104	2 x 330 = 660	1056
12	Propulsion system	Diesel electric single propeller on tunnel	Fixed-pitch propeller on tunnel	Diesel-electric with 2 x Veth Hybrid Drive	Diesel-electric with 1 x Veth Hybrid Drive

Future design: possible to realize

SUMMARY

- The growth of inland shipping sector in recent years is induced by its capacious advantage and economical benefits
- The design of inland vessels is strongly defined and classified according to the waterways restrictions
- The preference fuel of the future in inland navigation is LNG through dual-fuel technology
- December 2011: tanker “ARGONON” – first dual-fuel vessel on the Rhine
- Proposed future design: the combination of 3 technical innovation is a feasible way to improve technical and operational performance
- New design: giving reason for the ship owner to incorporate new innovation into its fleet

EMship Advanced Design

Thank you for your attention!

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