

# Fuel Cell Systems in Maritime Applications

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Financial Support given by the EC

## Content

- Motivation
- Legal Background
- FC-systems for maritime applications
- Concepts for the use of FC on board
- Possible Market Potential
- Challenges for the implementation of FC in shipping
- Examples and Outlook on ongoing Projects
- Conclusion

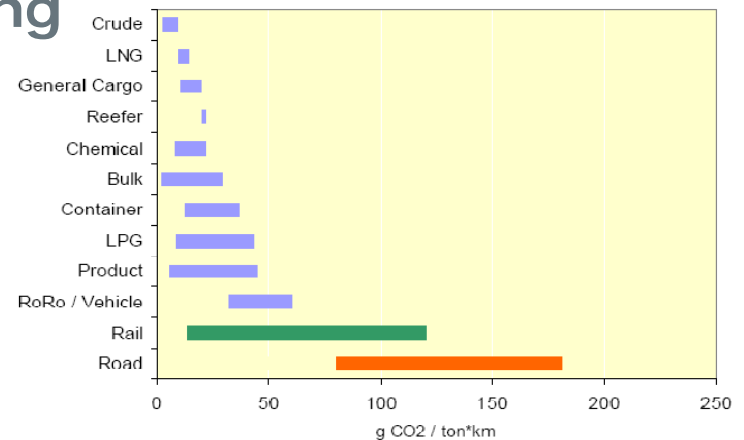
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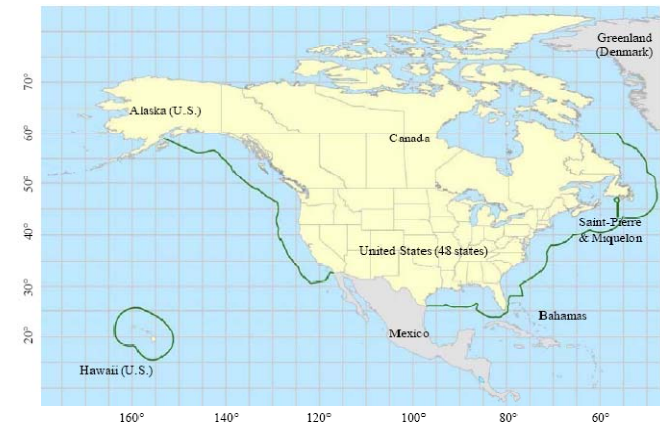
## Motivation - Emissions in Shipping

- Shipping is the most energy-efficient mode of transport.
- However, emissions to air are currently in the focus of society and of IMO
- A continuous reduction of NO<sub>x</sub>- and SO<sub>x</sub>-emissions was recently agreed
- A control and later reduction of maritime CO<sub>2</sub>-emissions is currently discussed
- New technologies are required to enable more environmentally friendly shipping

Range of typical CO<sub>2</sub> efficiencies for various cargo carriers



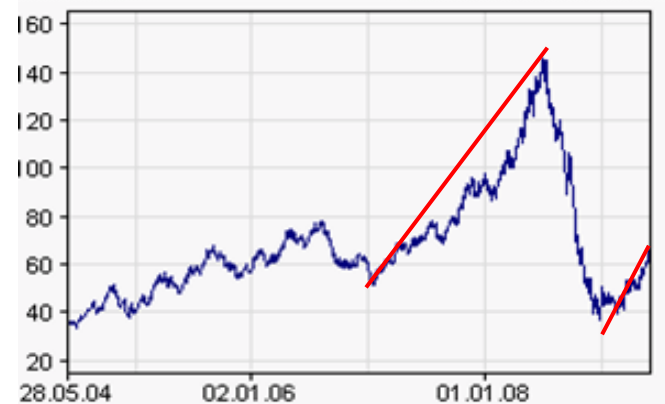
**Transport work (1/(t km): 14.4 (ship), 7.1 (truck), 6.2 (airplane)**  
**Source: MEPC 59/4/7**



## Motivation - Costs

- Harbour fees for vessel will be related to the produced ship emissions  
(e.g. Schweden / Norwegen, Rotterdam)  
additional costs / discount per BRZ
- High energy prices

CHART - Ölpreis (Brent)



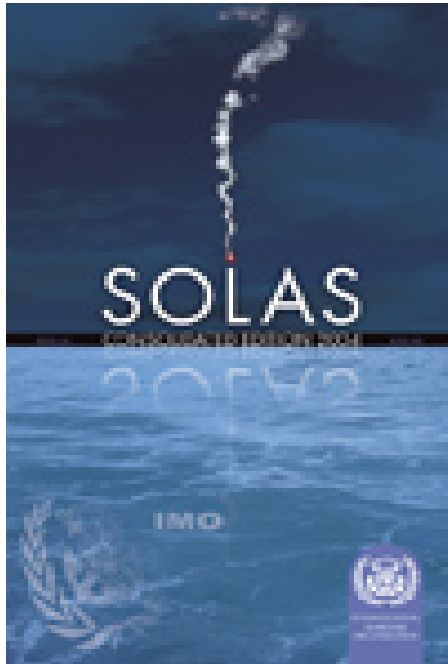
1.)

Source: 1. [www.finanzen.net](http://www.finanzen.net), 2009-05-30

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## International background SOLAS



SOLAS, Part 1, Chapter II-2, Part B, Regulation 4,  
2.1 Limitations in the use of oils as fuel:

**„The following limitations shall apply to the use of oil as fuel:**

- .1 [...] no oil fuel with a flashpoint of less than 60 °C shall be used;**
- .2 in emergency generators, oil fuel with a flashpoint of not less than 43 °C may be used;“**

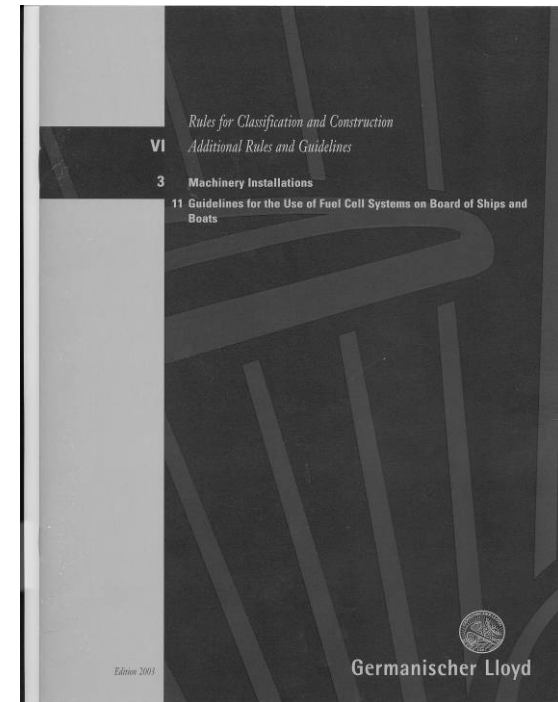
## International background IGF-Code

- **International Code of Safety for Gas-fuelled Engine Installations in Ships (IGF Code) under development**
  - first part of IGF-Codes comes into force 2010-07-01 as a guideline  
[MSC 283.(86); GL VI-3-1 - Guidelines for the Use of Gas as Fuel for Ships]  
(for methane CH<sub>4</sub>; ICE)
  - development of IMO regulation from 2009 for all kind of gases  
(till approx. 2014; if applicable for all kinds of fuels with a lower flashpoint; all kinds of energy converter)

## GL FC guideline (GL Rules for Classification and Construction VI – Part 3 – Chapter 11)

- Worldwide first Guideline for the Use of Fuel Cell Systems on Board of Ships and Boats issued in 2003

class notation FC-xxx



## Autorisation of FCS ALSTERWASSER

- According to BinSchUO and RheinSchUO no oil fuel with a flashpoint of less than 60 °C shall be used (similar to SOLAS)
- Exception for the FCS ALSTERWASSER by the German Federal Ministry of Transport, Building and Urban Development
- Approval of the ship hull by SUK (German ship inspection commission for inland navigational vessel) and Hamburg Port Authority (HPA)
- Approval by BGF (Governmental safety organisation for transport)
- Certification of the technical safety by GL
- SUK, HPA and BGF accept for the proof of the technical safety by a certificate of Germanischer Lloyd (recognised classification society). It was used as basis for the approval of the governmental organisations

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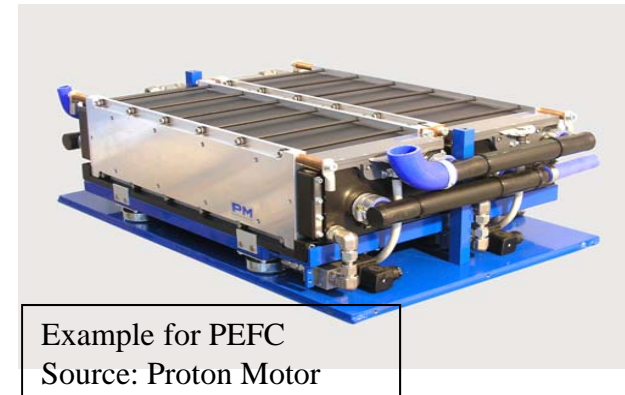
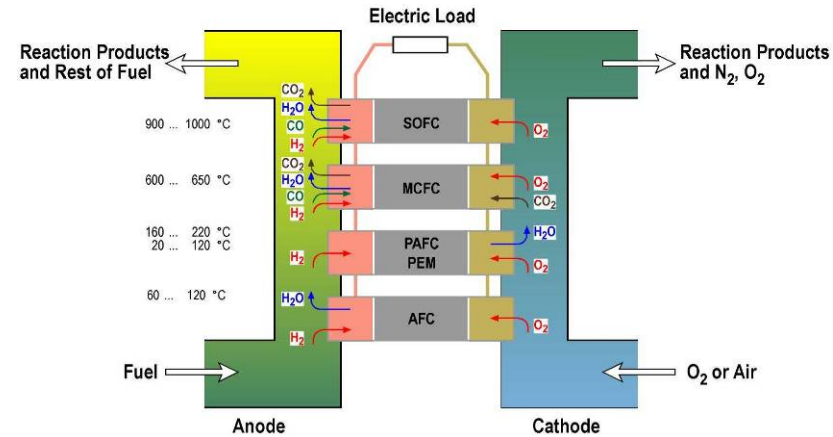
# Fuel Cell Systems – An overview

## Advantage of Fuel Cells

- Low emissions to air
- Low noise emissions
- High efficiency
- Low vibrations

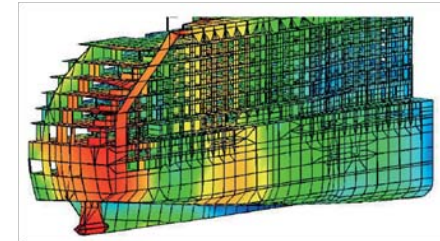
## Suitable Fuel Cell Types for maritime applications

- Polymer Electrolyte Fuel Cell (PEFC)
  - High development status
  - Dynamic load profile
- Molten Carbonate Fuel Cell (MCFC) and Solid Oxid Fuel Cells (SOFC)
  - High efficiency
  - Low demands for fuel and air quality
  - Exhaust temperature of 650°C - 1000°C for waste heat applications

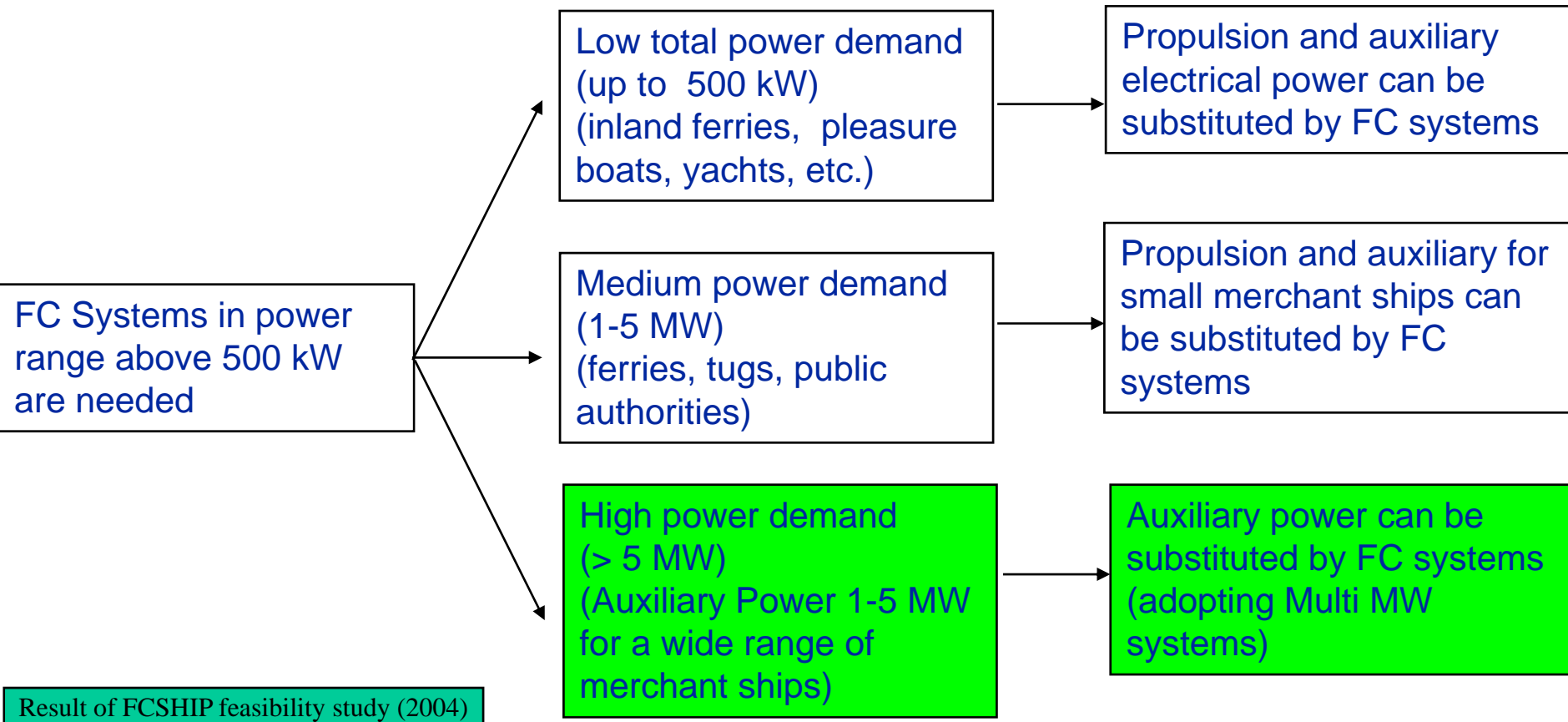


## Demands of maritime operating conditions

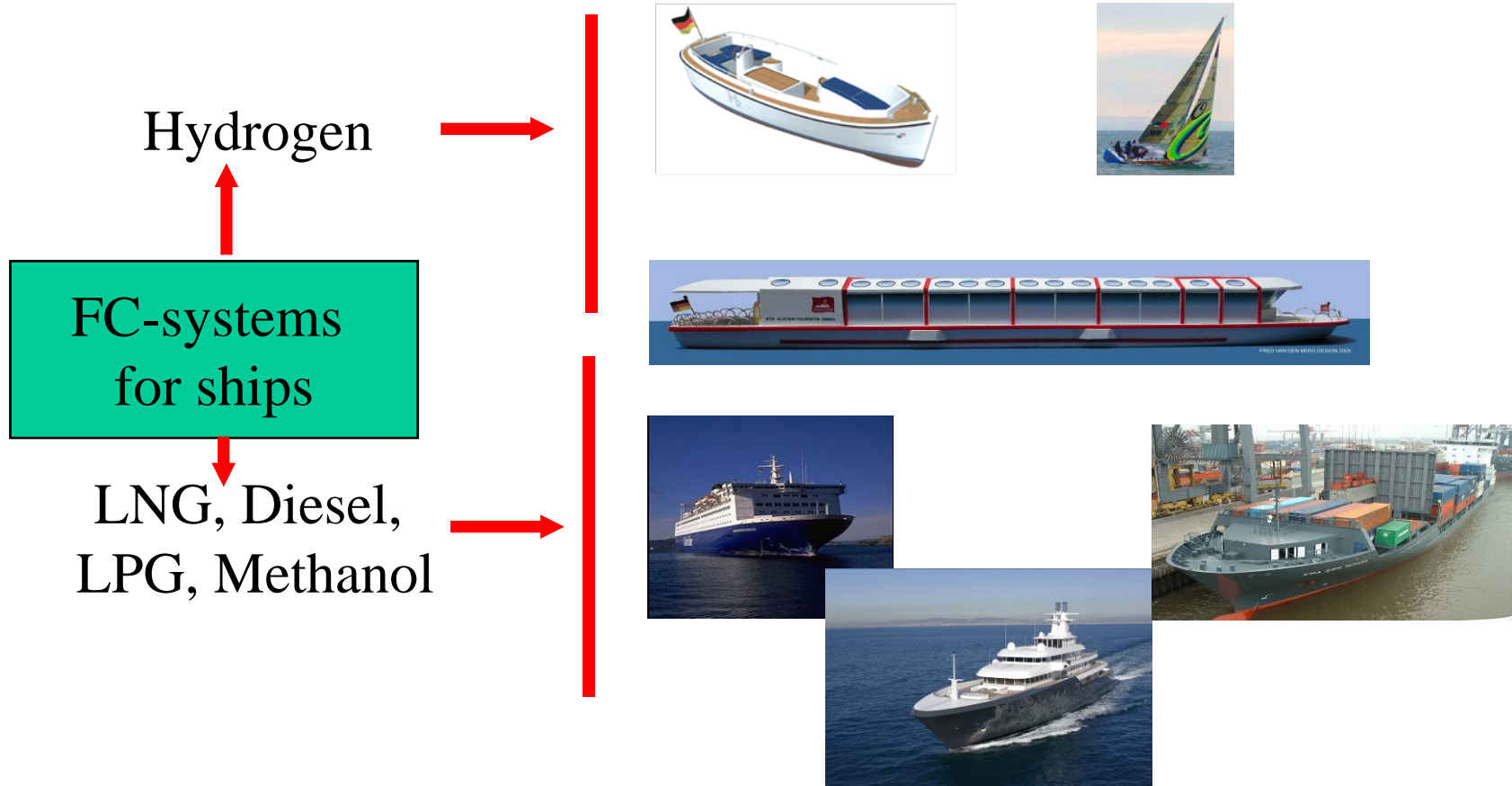
- Inclination and acceleration
- Vibrations
- Additional air components: salt, oil, humidity till 60%
- Full load capacity and efficiency till 45 °C
- Full response for electrical equipment till 55 °C



## Which FC Systems are Needed for Commercial Shipping?



# Which fuel for which application?



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## Concepts for the use of FC on board

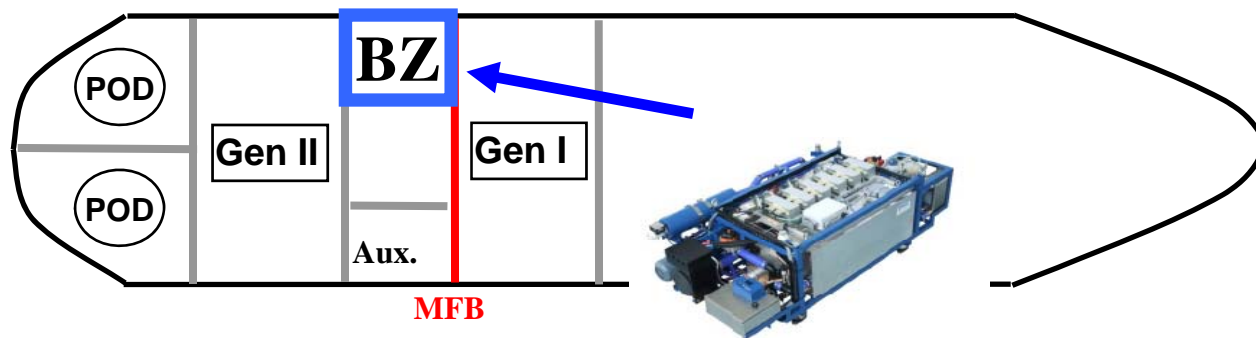
1. Supply of basic load in parallel to further diesel generators
2. Supply of the total auxiliary power as a FC-battery-hybrid-system
3. Propulsion and auxiliary power provided by a FC-battery-hybrid-system

## Concepts for the use of FC on board

- supply of basic load in parallel -

- Example cruise ship -

- the auxiliary power of a cruise vessel can be partly supplied by fuel cell systems already today ( $P = 2 \text{ MW}$ )
- fuel cell systems can partly supply the auxiliary power for the safe and autarkic power supply of single ship sections (Safe Return to Port)



## Concepts for the use of FC on board

- auxiliary power supply by FC-hybrid -

- example RoPax-ferry -

**Length, Breadth**      **166.3, 28.4 m**  
**Service speed**        **21 kn**  
**Passenger, Cars**        **1444, 750**

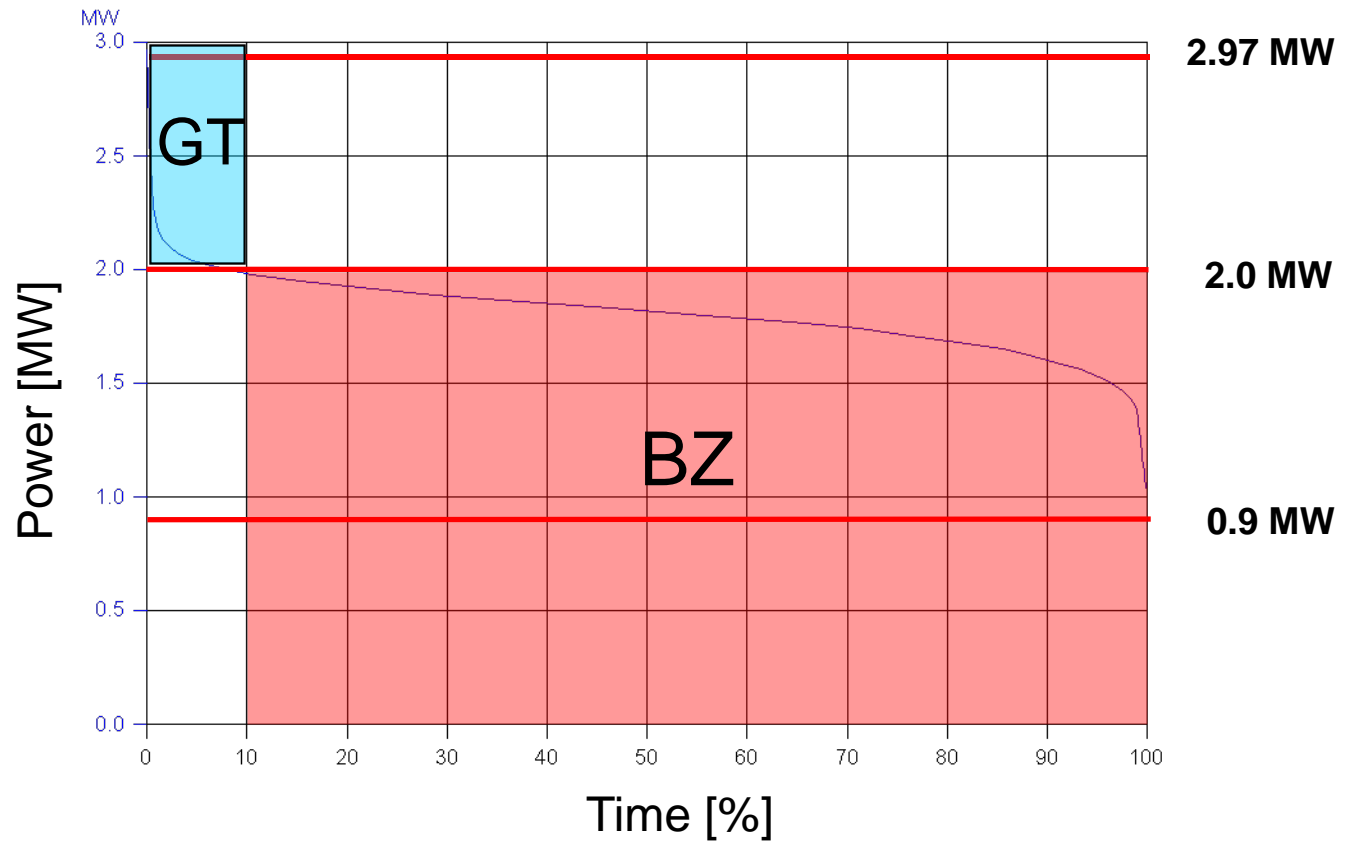
	No.	Motor Type	Power [MW]	Total [MW]
ME	1	Wärtsilä Sulzer ZA40V12	6600	19,8
	2	Wärtsilä Sulzer ZA40V12	6600	
	3	Wärtsilä Sulzer ZA40L6	3300	
	4	Wärtsilä Sulzer ZA40L6	3300	
AE	1	Wärtsilä Vasa	1770	5,9
	2	Wärtsilä Vasa	1770	
	3	Wärtsilä Vasa	1180	
	4	Wärtsilä Vasa	1180	



# Concepts for the use of FC on board

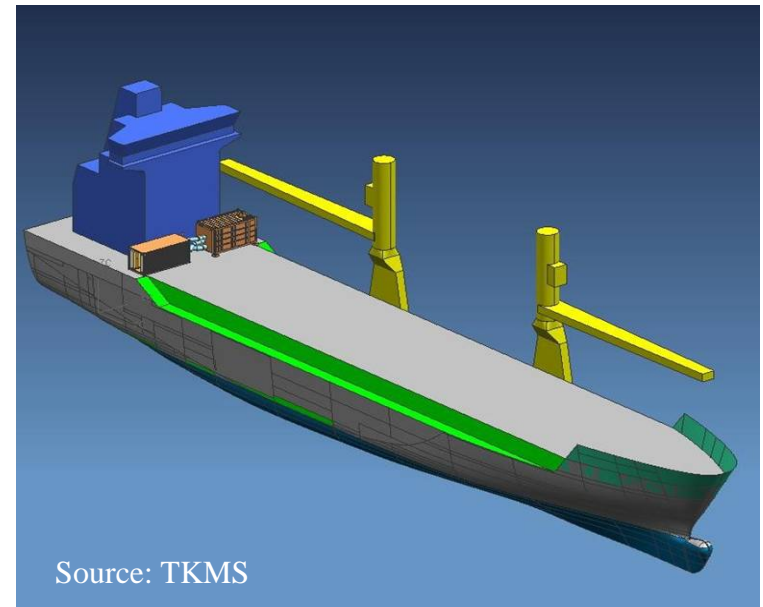
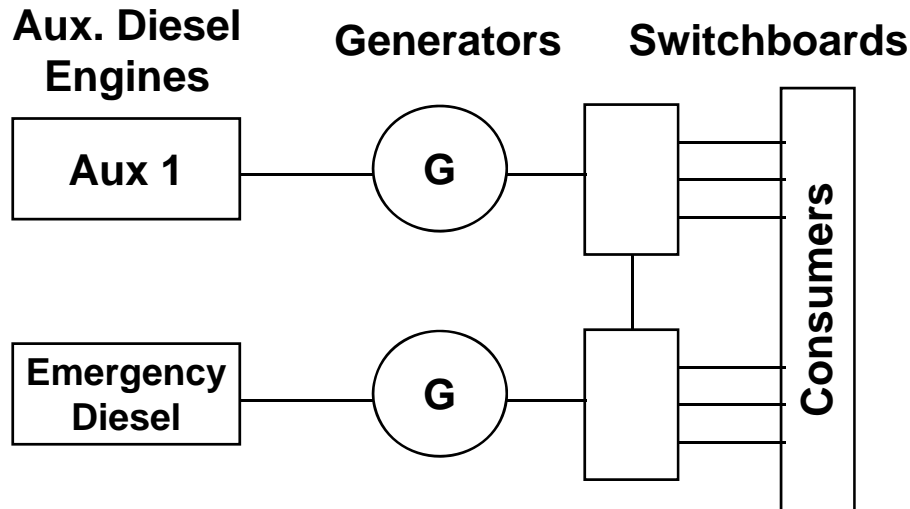
## - auxiliary power supply by FC-hybrid -

power duration characteristic of the diesel generators from „Kronprinz Harald“ (one week)



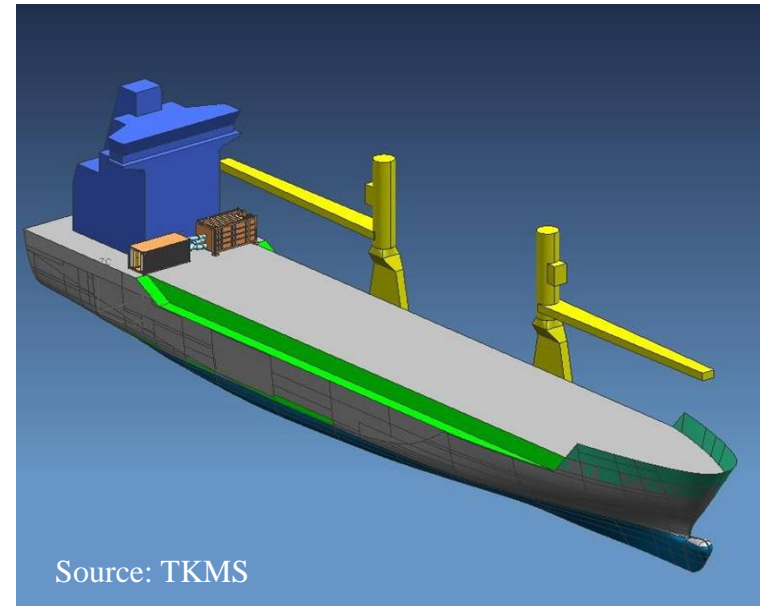
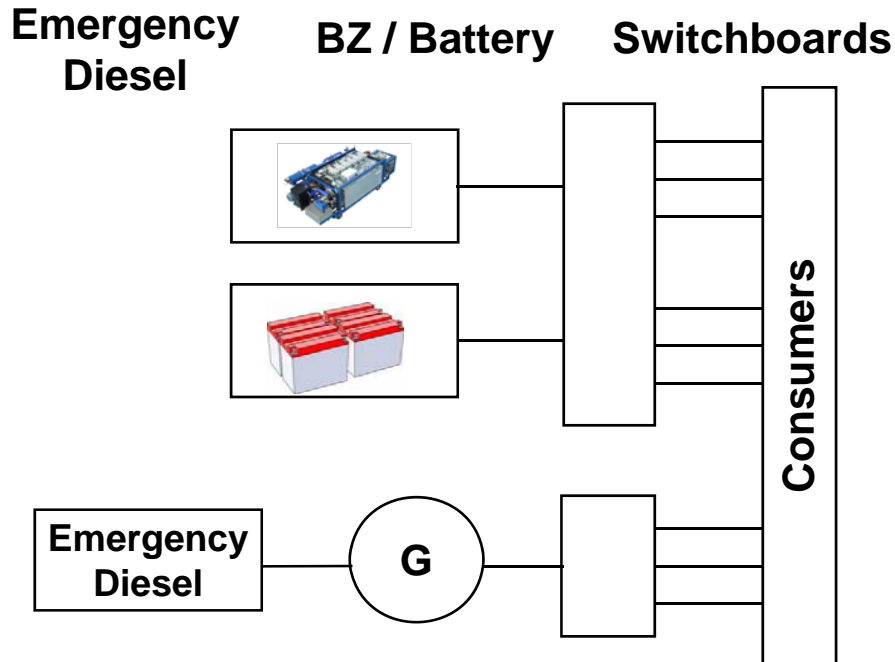
## Concepts for the use of FC on board

- auxiliary power supply by FC-hybrid -
- Example multi purpose vessel -



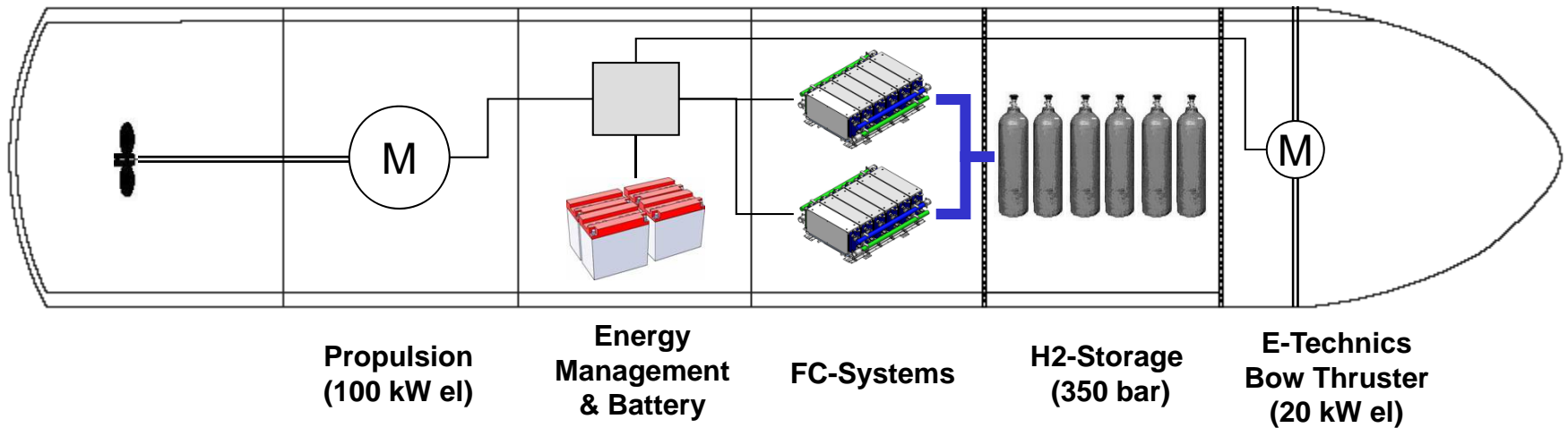
## Concepts for the use of FC on board

- auxiliary power supply by FC-hybrid -
- Example multi purpose vessel -



# Concepts for the use of FC on board

- direct propulsion of small vessel -



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## Is there a market for maritime Fuel Cell Applications?

- Worldwide approx. 100.000 ocean going ships
- Numerical domination
  - Tanker
  - Multi Cargo Vessels
  - Ferries and Passenger Vessels
  - Container Vessels
- First market
  - RoRo-Vessels (SECA-Requirements)
  - Cruise Ships (Noise and Emission reduction for passengers)
  - Mega Yachts (independence caused by low emissions)

## First markets

- needed FC systems per anno of the specific market shares RoRo-Vessel, Cruise Ship and Mega Yacht  
(substitution of 2 MW, 2 MW, 1 MW; 500 kW modules; ship numbers based on order receipts in 2008; refit rate 1%, 5%, 5%)

World fleet 2008			Newbulidings / a			FC replacement	Ships with FC in total	Required FC Modules			
Mega Yachts	RoRo-Vessel	Cruise Ship	Mega Yachts	RoRo-Vessel	Cruise Ship			Mega Yachts	RoRo-Vessel	Cruise Ship	total
170	2489	284	7	46	9	2%	1	0	4	0	4
170	2489	284	7	46	9	5%	6	2	16	4	22
170	2489	284	7	46	9	10%	10	2	28	8	28
170	2489	284	7	46	9	15%	16	4	44	12	60

→ this ship types only represent 3 % of the world merchant fleet !

## Further market potential

- further market potential can be shortly expected for the following ship types:
  - Inland Navigational Vessel
  - Coasters
  - Offshore Vessel
  - Container-Feeder
  - Military Vessel
  - Research Vessel
  - Authority Vessel
  - Fishery Vessel

## Further market potential

- world merchant fleet 2008

Schiffstyp/Type of Vessel	Anz./No.	1.000 GT	%-share
Öltanker/Oil Tanker	2.105	163.692	19,7
Produktentanker/Product Tanker	4.954	31.667	3,8
Chemikalien-/Flüssigtanker Chemical/Other Liquids Tanker	4.374	42.983	5,2
Gastanker/Liquefied Gas Tanker	1.455	41.044	4,9
Massengutschiffe/Bulk Carrier	7.744	231.964	27,9
Stückgutfrachter General/Specialized Cargo Ships	17.228	59.316	7,1
Containerschiffe/Container Ships	4.641	139.563	16,8
Kühlschiffe/Refrigerated Cargo	1.210	5.989	0,7
Ro-Ro-Schiffe/Ro-Ro-Cargo	2.489	41.635	5,0
Fähr-/Passagierschiffe Ferries/Passenger Ships	6.744	33.235	4,0
Fischereifahrzeuge Fishing Vessels	23.616	11.319	1,4
Offshorefahrzeuge/Offshore Vessels	5.273	16.267	1,6
Andere/All Other Types	17.908	12.033	1,4
<b>Total</b>	<b>99.741</b>	<b>830.704</b>	<b>100,0</b>

**approx. 100.000 vessel !!**

## Further market potential

- Order receipts 2008

Schiffstyp Type of Vessel	2007			2008		
	Anz. No.	1.000 GT %	1.000 CGT %	Anz. No.	1.000 GT %	1.000 CGT %
Rohöltanker Crude oil tanker	136	11,487 7,0%	4.096 4,8%	194	21.469 24,9%	6.759 15,7%
Gastanker Gas Tanker	80	3,668 2,2%	2,948 3,5%	62	1,268 1,5%	1,153 2,7%
Chemikalien- und Produktentanker Chemical and product Tanker	805	14,166 8,6%	9,822 11,5%	297	4,672 5,4%	3,229 7,5%
Massengutschiffe (einschl. komb. Massengutschiffe) Bulk carrier (incl. combined carrier)	1.737	81,812 49,6%	34,248 40,2%	834	38,311 44,4%	15,990 37,2%
Containerschiffe Container ships	587	37,727 22,9%	19,478 22,8%	166	9,912 11,5%	5,274 12,3%
Stückgutfrachter General cargo vessels	609	11,263 7,0%	8,172 9,6%	539	7,538 8,7%	5,902 13,7%
Fähren und Passagierschiffe Ferries and passenger vessels	108	2,334 1,4%	2,602 3,1%	51	727 0,8%	838 2,0%
Fischereifahrzeuge Fishing vessels	40	42 0,0%	1,17 0,1%	26	17 0,0%	55 0,1%
Sonstige Miscellaneous	749	2,336 1,4%	3,793 4,4%	759	2,377 2,8%	3,751 8,7%
<b>Total</b>	<b>4.851</b>	<b>164.833</b> 100,0%	<b>85.277</b> 100,0%	<b>2.928</b>	<b>86.292</b> 100,0%	<b>42.953</b> 100,0%

approx. 3.000 new vessel per year!!

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## Challenges for the implementation of FC in shipping

- delivery capacities, -times
- maintenance intervals, -times
- service network, spare part logistic
  - Service network comp. to engine manufacturer
- repair times
  - change of components
  - terms of guaranty in line with the industry standard
- investment-, maintenance costs

## Challenges for the implementation of FC in shipping

- **lifetime**  
comp. main maintenance intervals of diesel generators operated under full load  
operation time of approx. 8000 h/a
- **reliability**
- **availability**  
short repair times, short maintenance times,  
99% availability complies with 88 h downtime per year (24/7 operation)  
(or correlating redundancy)
- **availability of fuels**  
a sufficient fuel supply must be ensured for the specific application

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## Examples

- Pleasure boats

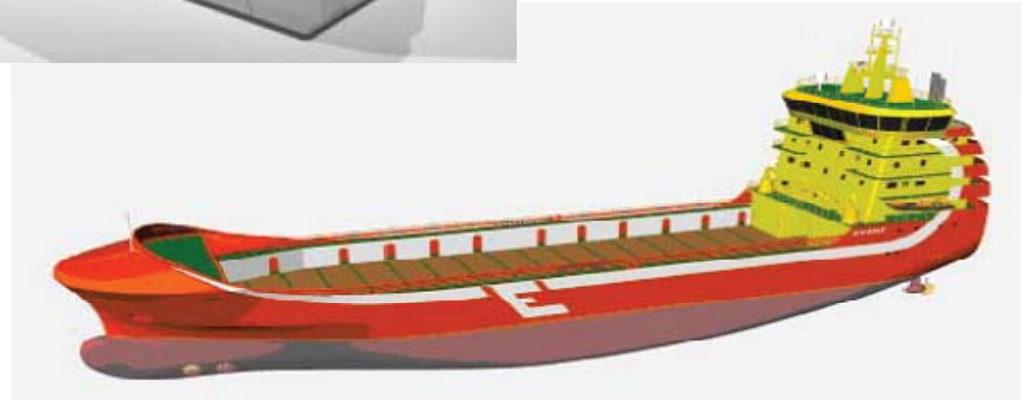
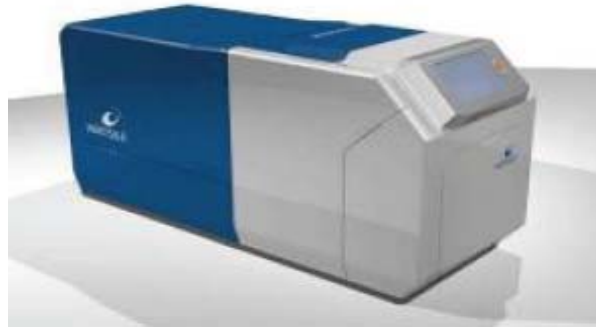


- Commercial vessel



## Further International Projects

- MethAPU  
20-250 kW SOFC  
methanol
- FellowSHIP  
320 kW MCFC  
natural gas



## Just started: Lighthouse Project e4Ships

- National promoted Lighthouse Project consisting of 3 Projects:
  - SchIBZ
    - Development of an maritime MCFC-System and test on board of a multi cargo vessel
  - PaXell
    - Integration and Testing of MCFC-System on board of a cruise vessel
    - Self-contained energy supply of a ship section with 2 Modules in a second phase
  - Toplaterne
    - Ecological, technical and economical rating of the demo projects
    - Development of Proposals for the Code-Development

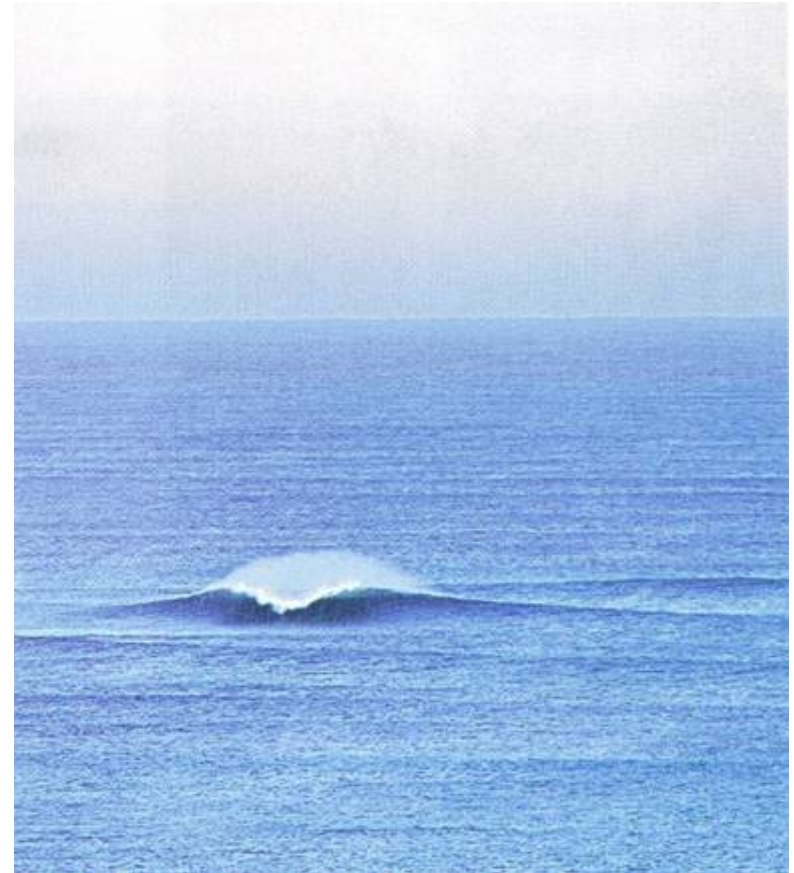


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## Summary

- Fuel cell systems for maritime applications are becoming attractive for their low emission potential and their high energy efficiency
- Shipping has a high market potential for fuel cell systems
- Fuel cells will be already used in niche markets of the maritime industry
- FCS ALSTERWASSER proves the feasibility of fuel cell systems on board of ships
- GL continues to actively drive development of new propulsion systems together with clients



Thank you for your attention!



