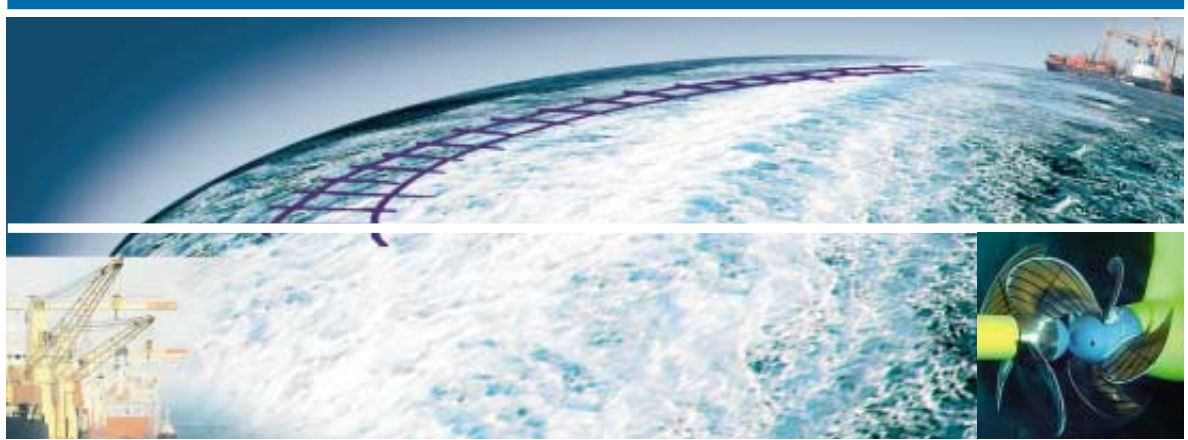


# The CRP Azipod<sup>®</sup> Propulsion Concept

The most economic way from crane to crane



# The CRP Azipod® Propulsion Concept

Pod-propulsion innovator ABB has proposed a system, in which a steerable Azipod unit is mounted immediately behind the standard propeller. Located on the same axis, but without any physical connection, the pod pulling propeller will contra-rotate in relation to the shaft-driven main propeller. This arrangement results in some 10% improvement in hydrodynamic propulsion efficiency.

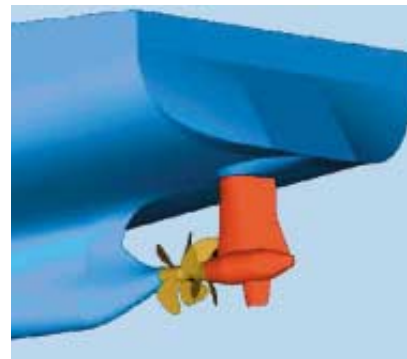
## The most efficient propulsion system

### The reasons for better hydrodynamic efficiency

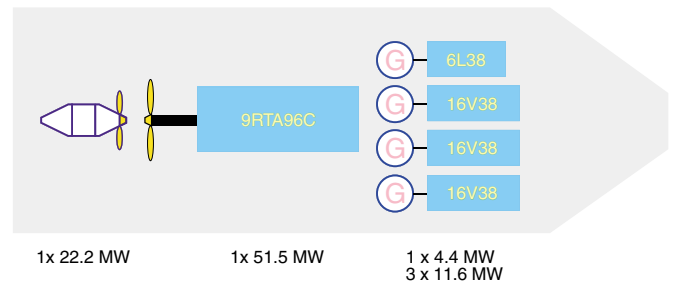
- The forward propeller rotation energy is utilized in the aft propeller.
- Propeller loading distribution is easy to select
- Single skeg is the smoothest hull form

### Technical features

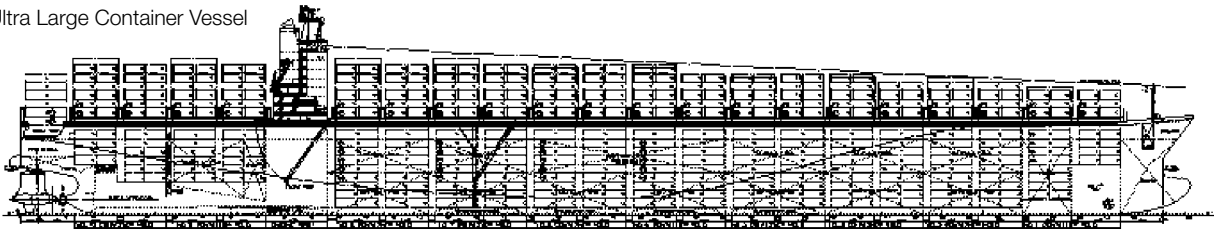
- Load ratio for the main propeller and Azipod propeller can be flexibly adjusted. The main propeller has a 60...70% load and the Azipod propeller a 40...30% load
- The Azipod propeller diameter is smaller than that of the main propeller to prevent a possible main propeller tip vortex cavitation from hitting the Azipod propeller in autopilot steering angles
- Propeller blade numbers are different to avoid blade resonance
- The Azipod propeller speed is higher than that of the main propeller to ensure maximum propeller efficiency on both propellers
- The Azipod turning angles are 100 degrees (another option is free 360° rotation)



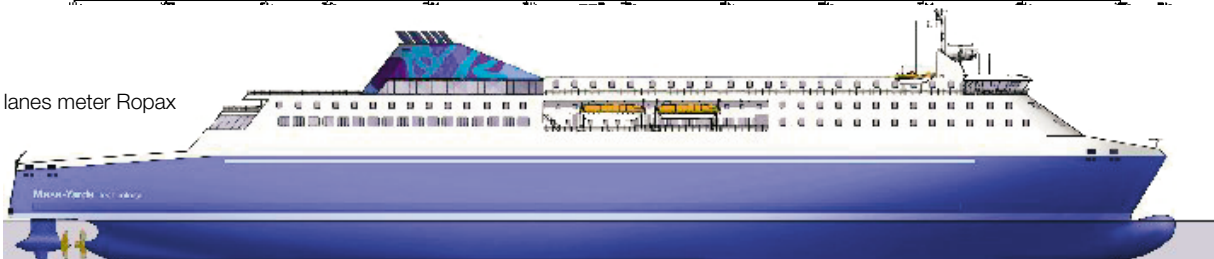
A steerable Azipod unit mounted behind the standard propeller



9000TEU Ultra Large Container Vessel



1600 trailer lanes meter Ropax



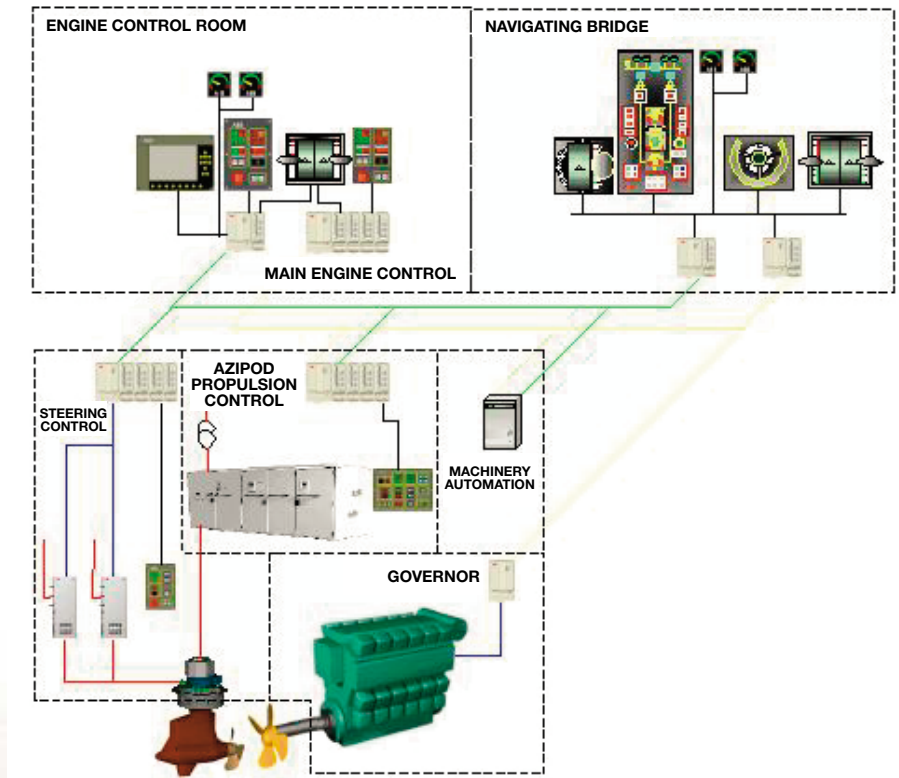
# The CRP Azipod® Control System

Control system topology is based on the integration of functionally independent main engine and Azipod unit control systems.

This arrangement provides maximum flexibility, allowing the CRP Azipod propulsion system to work with any type of main propulsion:

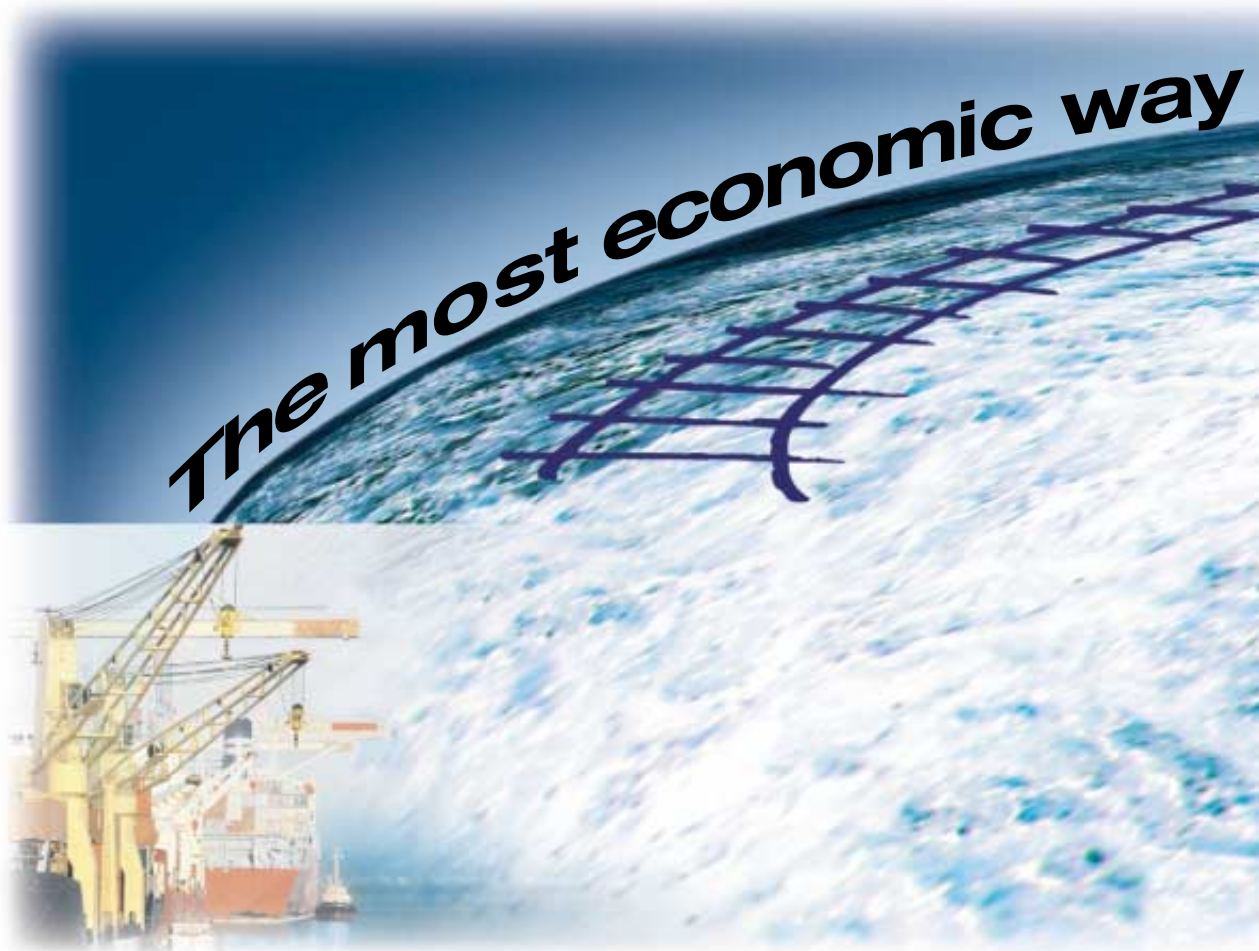
- *slow speed and medium speed engines*
- *electric drives*
- *fixed-pitch and controllable pitch propellers*

Mutual independence provides maximum redundancy in case of a major malfunction in one system and also enables independent operation of both systems in manoeuvring. In normal sea conditions, both propulsion systems respond to joint commands given from a selected control site. The Azipod system includes steering controls that meet IMO and classification society standard requirements. The system can also be used with DP, autopilot and speedpilot systems.



# The CRP Azipod® Propulsion Benefits

The CRP Azipod propulsion concept provides you with superior propulsion efficiency at a better price.



**The most economic way**

## Operational

- *Improved manoeuvring in ports and channels*
- *Less need for tug assistance in ports*
- *Vessel operation at lower speeds*
- *Environmentally-friendly propulsion, less emissions*
- *Superior safety in extraordinary situations such as crashstop, emergency manoeuvring and heavy weather*

## Technical

- *High propulsion efficiency*
- *Low total installed engine power*
- *Two independent propulsion systems provide a high degree of redundancy*
- *No need for stern thrusters or rudders*
- *Lower excitation forces on the hull from propulsor combination*
- *Versatile prime mover utilization*
- *Flexible general arrangement possible*
- *Easy-to-adjust required propulsion power steps*
- *Replaces conventional rudder*
- *Reduced levels of exhaust emission from the optimally loaded power plant*

# from crane to crane



## **Economical**

- *High propulsion efficiency provides better fuel economy*
- *Shipbuilding costs are reasonable as there is less installed engine power*
- *Better slot time keeping in harbors, as the manoeuvring is easier and less tug assistance is needed*
- *Increased container capacity (both space and weight)*

# The Model Test Results

Extensive model tests have been carried out to determine the most efficient propulsion system for Ultra Large Container Ships (ULCS), Ropax vessels, LNG carriers and tankers.

The Ropax model tests were carried out in cooperation with Kvaerner Masa Yards technology and the ULCS tests in cooperation with Samsung Heavy Industries to ensure that the best shipbuilding knowledge was available and figures were reliable, for comparing to model tests of existing reference ships.

CRP Azipod® propulsion was compared with the following

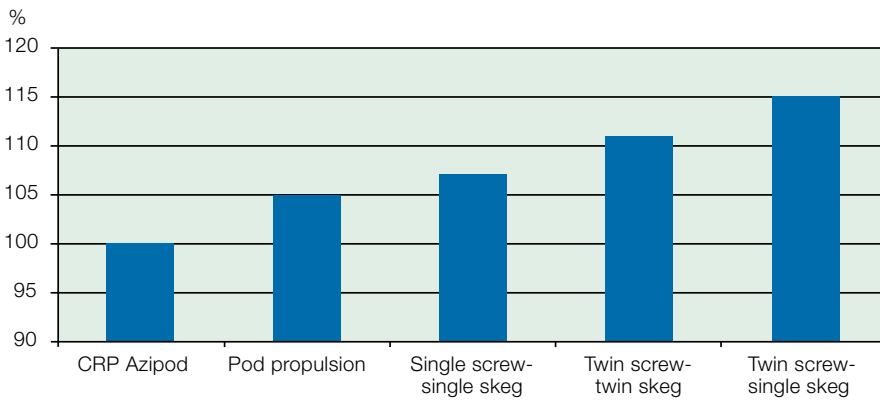
propulsion systems:

- twin screw (open shafts)
- twin screw (twin skeg)
- single screw
- twin pods

The following tests were made for all propulsion alternatives:

- resistance tests
- self-propulsion tests
- open water test for pod and propellers
- cavitation tests (Ropax)

Ropax ferry vessel data		Ultra large container ship (ULCS) data	
Length pp	176 m	Length pp	332 m
Breadth	25 m	Breadth	45.3 m
Draft	6.4 m	Draft, design	13.0 m
Service speed	27.5 kn	Service speed	25.5 kn
Passengers	700	Containers	9000TEU
Trailer lanes	1.600 m		



## Required propeller power

The model tests showed that the CRP Azipod had the best hydrodynamic efficiency. The columns indicate how much more propeller power is needed for the same speed.



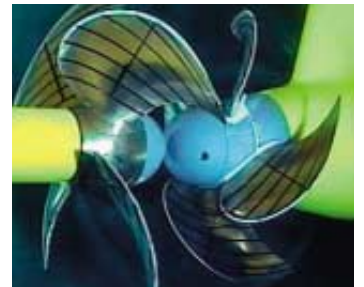
ULCS single screw - single skeg.



ULCS twin screw - twin skeg.



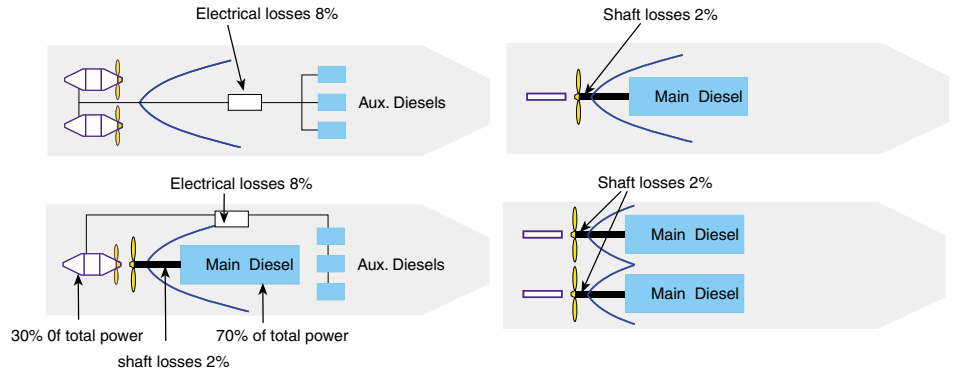
ULCS CRP Azipod.



CRP Azipod in cavitation tests.

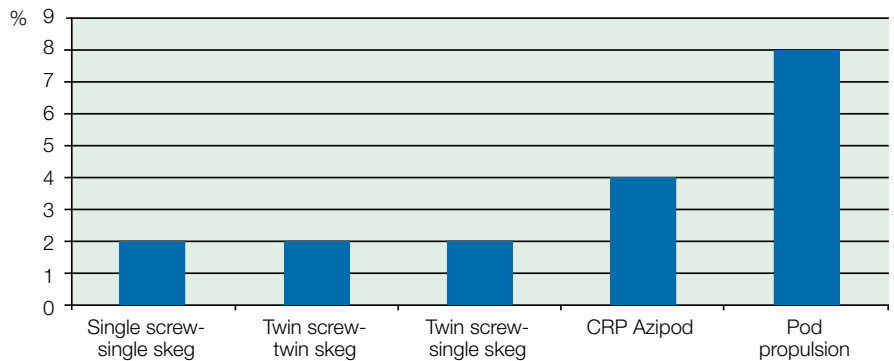
# Transmission Losses

When total propulsion efficiency is determined, the entire power chain from prime mover to propeller has to be considered. The used transmission losses in different propulsion systems are indicated in the following chart.



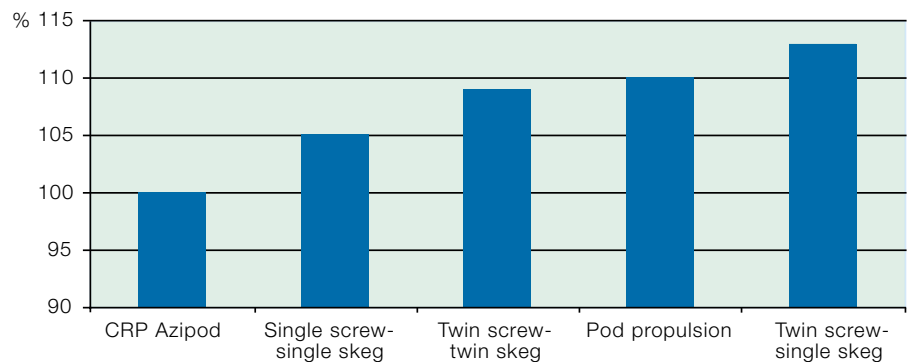
## Transmission losses

The figures indicate that the CRP solution has reasonable transmission losses compared with the 100% mechanical propulsion solution and significantly less than full electric propulsion solution.



## Required propulsion power

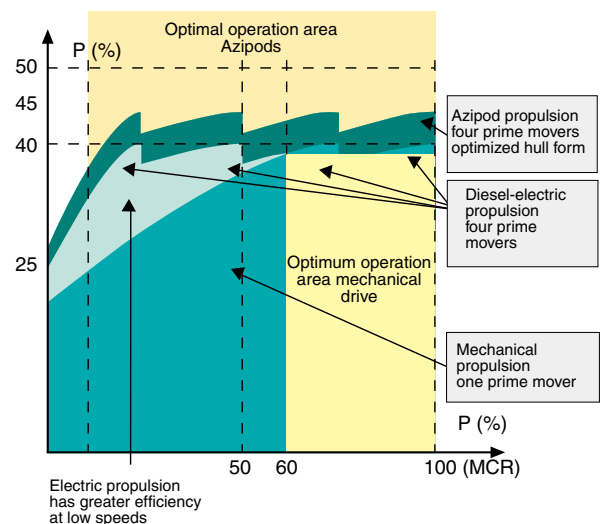
The total propulsion efficiency can be calculated, if transmission losses and hydrodynamic efficiencies are known. The columns indicate how much propulsion power is needed for the same speed.



## The effect of vessel speed on total propulsion efficiency

The above total propulsion efficiency figures apply if the vessel operates at service speed. If the speed is lower, electric propulsion (both CRP Azipod® propulsion and pod propulsion) improves the total propulsion efficiency compared with diesel mechanical solutions. The improvement comes from the benefit of the power plant principle.

The power plant principle means that the vessel's electrical and propulsion power networks are combined, instead of having separate electrical load and mechanical propulsion power networks. This gives the opportunity to select the number of diesel generators running to respond to propulsion and other ship power consumption. When the need for electrical power is smaller, some diesel generator set are disconnected and the running engines can always run at a constant speed and close to optimum efficiency. The following drawing indicates diesel engine efficiencies for different loads.



# Comparison of Propulsion Configuration

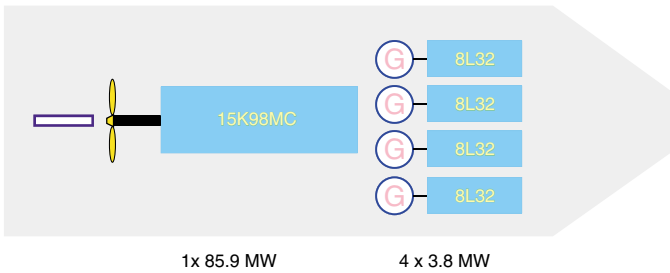
## 12000 TEU ULCS Example 20% Sea Margin

To better understand how propulsion efficiency influences installed engine power, the machinery in an ultra large container vessel can be used as an example. The vessel's maximum electrical load is approximately 13 MW and consists of service load, reefer load and thruster

load. In the CRP Azipod® solution, the pod electrical load of 22 MW is also taken into account. There is no additional reserve engine in the auxiliary power plant, which is one way to study the vessel's machinery. If one more engine is added to each propulsion solution to provide a higher

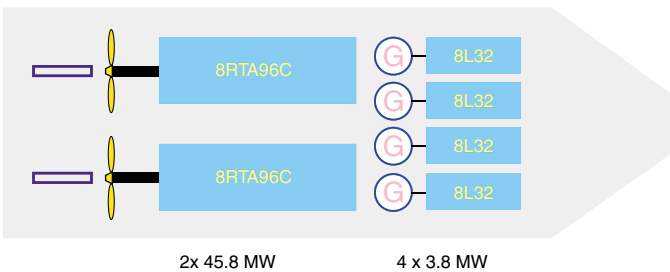
degree of redundancy, the result will still be fairly similar. In all propulsion alternatives, a 20% sea margin and an MCR of 90% are included. Service speed is 25.0 knots.

## 20% Sea Margin and 90% MCR



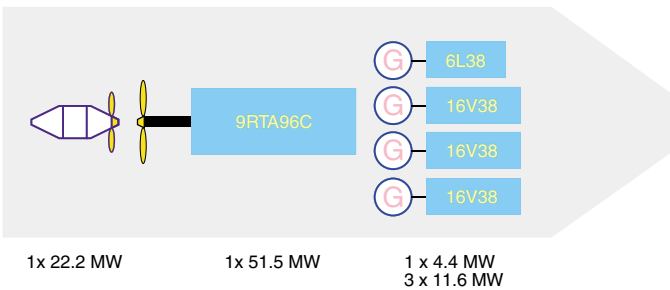
### Single propulsion

Main engine power: 85.9 MW  
 Aux. engine power: 15.2 MW  
 Total installed power: **101.1MW**



### Twin propulsion

Main engine power: 91.6 MW  
 Aux. engine power: 15.2 MW  
 Total installed power: **106.8 MW**



### CRP Azipod propulsion

Main engine power: 51.5 MW  
 Aux. engine power: 39.2 MW  
 Total installed power: **90.7 MW**

## 20% Sea Margin and 90% MCR

	CRP Azipod	Single screw	Twin screw
Total installed engine power	90.7 MW	101.1 MW	106.8 MW
Difference	100%	11%	18%
Price difference	REF.	+ 2.2 MUSD	+ 3.4 MUSD

The example clearly shows the benefit of the CRP Azipod in ULCS. As the difference is greater than 10% compared with any other propulsion system, there is potential for major savings in operating and building costs. An engine power cost of USD 210/kW is used.



## 12000 TEU ULCS Example 30% Sea Margin

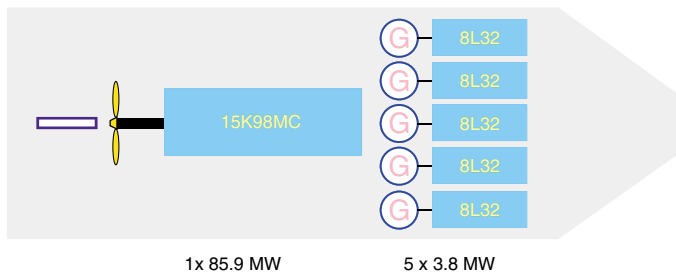
Another example shows how the total installed engine power will change with different input values. If more margin is required in operation, the same ship will have more installed engine power. In main propulsion engines in single and twin screw options there was just enough

power available for 30 % sea margin. In the CRP Azipod® solution the Azipod power is reduced and one additional cylinder is added to main engine. Azipod power is now 20.6 MW. There is also a great flexibility in choosing auxiliary engine types in the CRP Azipod solution

and now other engine types are selected.

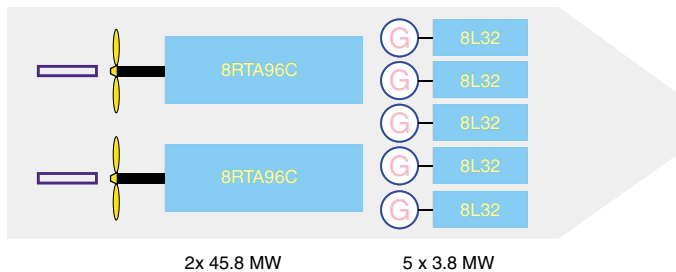
The example clearly indicates that the CRP Azipod system has always the lowest total installed engine power, irrespective of the operation margin.

### 30% Sea Margin and 90%MCR



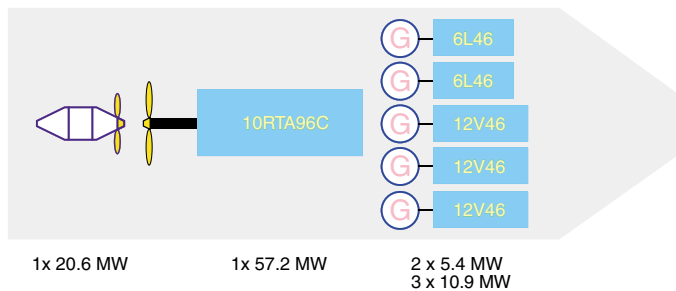
#### Single propulsion

Main engine power: 85.9 MW  
 Aux. engine power: 19.0 MW  
 Total installed power: **104.9 MW**



#### Twin propulsion

Main engine power: 91.6 MW  
 Aux. engine power: 19.0 MW  
 Total installed power: **110.6 MW**



#### CRP Azipod propulsion

Main engine power: 57.2 MW  
 Aux. engine power: 43.5 MW  
 Total installed power: **100.7 MW**

### 30% Sea Margin and 90% MCR

	CRP Azipod	Single screw	Twin screw
Total installed engine power	100.7 MW	104.9 MW	110.6 MW
Difference	100%	4%	10%
Price difference	REF.	+ 0.9 MUSD	+ 2.1 MUSD

# Machinery Comparison

## Savings in operational costs

In ULCS, selected machinery depends on the required propulsion and service power. In the CRP Azipod® system, power split between a slow speed engine and the Azipod unit also has an effect on machinery. Model tests demonstrate an 11.4% benefit in propulsion power requirement, which brings the installed diesel engine power on board to a minimum. Due to the CRP system benefits in hydrodynamic efficiency, considerable savings in operation costs including fuel, lubrication oil and maintenance can be achieved.

The basis for the operation cost comparison is the 12000 TEU vessel size. Three different propulsion systems have been considered: CRP, twin screw - twin

skeg and single screw *Note 1* systems.

Operation at lower speeds has not been included in the calculation. Due to the power plant principle utilized by the CRP Azipod system these operation modes will be even more advantageous for the CRP concept than full-speed operation because the power plant engines can be loaded close to optimal loading. This means further savings in fuel consumption, which could have significant impact on total operation costs because on some routes full speed may be applied for only 50% of the total voyage time.

Total annual operation cost savings gained using the CRP Azipod system compared to the twin screw system are

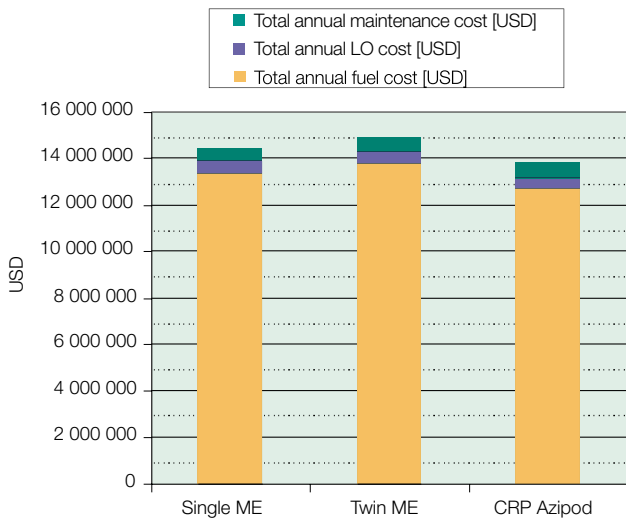
7% (MUSD 1.1), and 3% (MUSD 0.54) compared to the single screw system.

Annual operational savings (MUSD 1.1) compared to the twin screw system are discounted using a 10% interest rate to obtain the NPV of the savings.

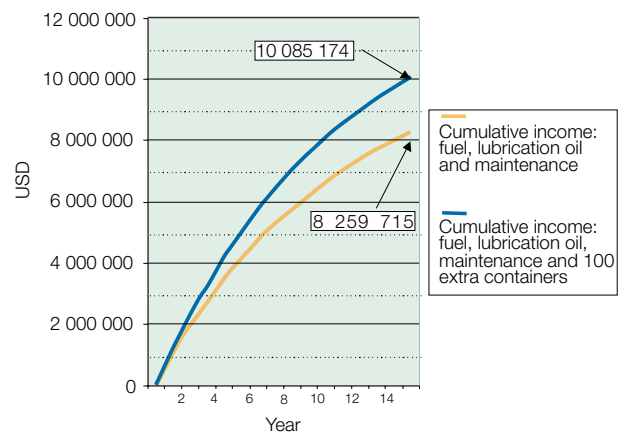
Accumulated income over a 15-year period is approximately MUSD 8.2.

Revenue from increased container capacity can also be taken into account. With the following conservative assumptions:

USD 200 net income per container, 100 extra containers per voyage, 12 voyages per year, total accumulated savings over a 15-year period increase by MUSD 1.8 to more than MUSD 10.0.



Operation cost calculation results for 12000 TEU vessel: total annual cost of fuel, lubrication oil and diesel engine maintenance.



CRP system operational benefit for 12000 TEU vessel: cumulative operational savings over a 15-year period compared with the twin screw system.

## Operation cost calculation data and results for 12000 TEU vessel including fuel, lubrication oil and maintenance costs.

Main Engine Data	CRP	Twin ME	Single ME <sup>Note 1</sup>
Main engine(s)	1 x Sulzer 10RTA96C	2 x Sulzer 8RTA96C	1 x 15K98MC
Main engine MCR [kW]	57 200	91 520	85 800
Sea margin [%]	30 %	30 %	30 %
Main engine loading	90 %	87 %	90 %
Azipod unit power [kW]	20 550	-	-
Power Split, ME and Azipod	71 %/29 %	-	-
Auxiliary Engine Data			
Auxiliary engines	3 * 12V46A / 2 * 6L46A	5 * 8L32	5 * 8L32
Total installed aux. engine power [kW]	43 440	18 000	18 000
No. of aux engines in normal operation	4	4	4
Total installed engine power [kW]	100 640	109 520	103 800
	100 %	109 %	103 %
Auxiliary and service load			
Service load [kW]	1 500	2 500	2 000
Bow thruster load [kW]	0 <sup>Note 2</sup>	4 400	4 400
Reefer load [kW]	8 000	8 000	8 000
Losses			
Shaftline losses [%]	2 %	2 %	2 %
Electric losses for propulsion [%]	8 %	-	-
Electric losses for service and auxiliary [%]	4 %	4 %	4 %
Operation cost calculation data			
Annual operating hours [h]	6 000	6 000	6 000
Main engine SFOC [g/kWh]	167	167	167
Aux. engine SFOC [g/kWh]	172	183	183
HFO price [USD/t]	150	150	150
LCV (Lower Calorific Value) [kJ/kg]	42 700	42 700	42 700
LO price main engine [USD/t]	1 000	1 000	1 000
LO price pod and auxiliary engine [USD/t]	1 000	1 000	1 000
SFOC LO ME [g/kWh]	1,10	1,10	1,10
SFOC LO Aux. engine [g/kWh]	0,60	0,60	0,60
Specific maintenance cost ME [USD/MWh]	0,66	0,69	0,59
Specific maintenance cost aux. engine [USD/MWh]	2,00	2,40	2,40
Fuel Cost			
Main engine, annual fuel consumption [t]	51 379	79 778	77 444
Annual fuel consumption pod [t]	23 051	-	-
Annual fuel consumption auxiliary [t]	10 213	12 009	11 438
Total annual fuel consumption [t]	84 642	91 787	88 881
Total annual fuel cost [USD]	12 696 360	13 768 054	13 332 186
Relative difference	100 %	108 %	105 %
Difference in USD	0	1 071 693	635 826
Lub. oil costs			
Main engine, annual LO consumption [t]	339	526	511
Aux engines, annual LO consumption pod [t]	80	-	-
Aux engines, annual LO consumption auxiliary [t]	36	39	38
Total annual LO consumption [t]	455	565	548
Total annual LO cost [USD]	454 865	565 487	548 220
Relative difference	100 %	124 %	121 %
Difference in USD	0	110 622	93 356
Maintenance Costs			
Main engine, annual maintenance cost [USD]	226 512	378 893	303 732
Auxiliary engines, annual maintenance cost [USD]	456 120	207 360	207 360
Total annual maintenance costs [USD]	682 632	586 253	511 092
Relative difference	100 %	86 %	75 %
Difference in USD	0	-96 379	-171 540
Total operation cost			
Total fuel, LO and maintenance cost [USD]	13 833 857	14 919 793	14 391 498
Relative difference	100 %	108 %	104 %
Difference in USD	0	1 085 936	557 641

Note 1. The single screw may be a hypothetical option, as today there is no manufacturing capabilities to build such a large-diameter propeller. Tip vortex cavitation also poses a problem.

Note 2. Bow thruster power can be neglected in the CRP system dimensioning.

The calculation result may vary depending on

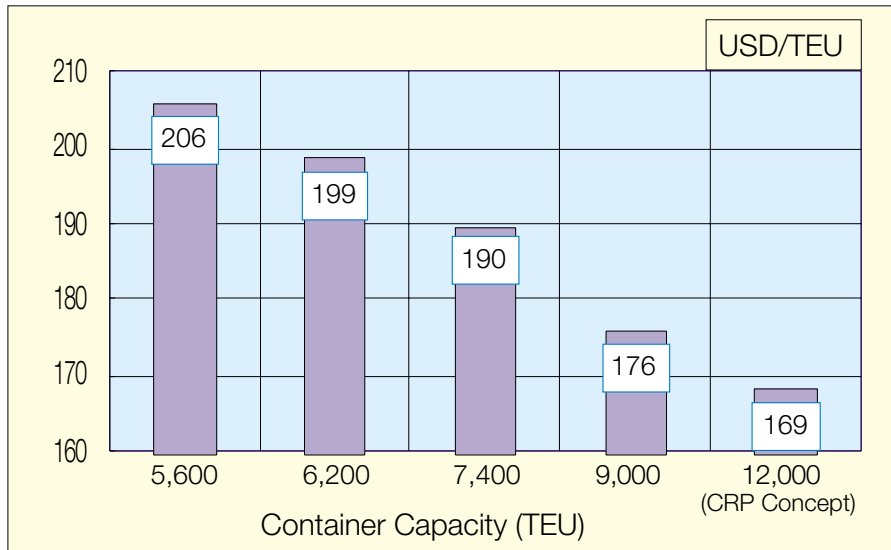
- Sea margin
- MCR values
- Diesel engine types
- Prices used

However, the result of the CRP Azipod<sup>®</sup> solution being most economical remains the same with other input values. Please contact ABB to calculate the result for your project.

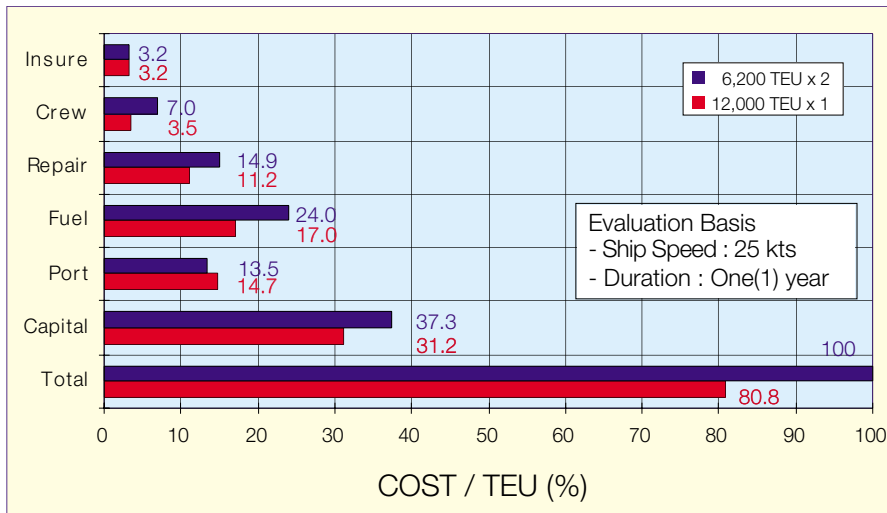
# Economical Studies

The scale economies have been the driving force behind larger container vessels. The Samsung and ABB studies show how that CRP Azipod® solution gives clear benefit in ultra large container vessels. The study was carried out on a 12000 TEU container vessel, but the result can be scaled down or upwards to smaller or bigger vessels as well.

## Operating cost comparison



The economy studies show that the CRP Azipod concept gives the lowest required freight rate. The other propulsion studied in 12000 TEU range, result in only limited unit cost reductions. All cost of insurance, crew, repair, fuel, port and capital are taken into account.



Comparison of the 12000 TEU (CRP Concept) to two 6200 TEU container vessels indicates that a bigger ship will yield more for the ship operator.

## Other issues to consider:

### Slot time keeping

The CRP Azipod® “Power Rudder” enhances manoeuvring in port and thus increases the slot time reserve. Subsequent delivery costs are approximately **500 USD / TEU**. The value depends on the route and destination harbor.

### Tug fees

Enhanced manoeuvring capability, even in harsh weather conditions, reduces the need for tug boat assistance, by on average one unit per visit. In fair weather conditions the need for tugs may be completely eliminated. Assuming the costs for one tug boat to USD 5000 the annual savings may be estimated to **USD 375.000**.

### Time saving benefits

Time saving in the harbor and coast areas is a possible utilize on transit time when operate the ship with lower speed and power on open seas. The saved time is due to faster manoeuvring and less tug assistance.

Let's take an assumption that during harbor visits the total time saving is one hour when there is no need to use tugs and two hours when the tugs are normally needed.

Route: Rotterdam - Marsaxlokk - Singapore - Hong Kong

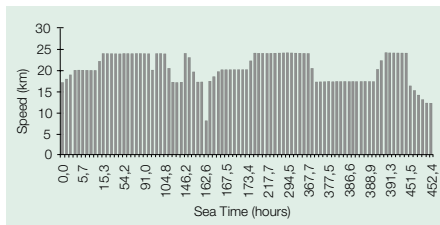
Harbour visits: 4 x 2 h = 8 hours / 456 h (19 days) Suez Canal: 2 hours faster

**Totally: 10 hours saving**

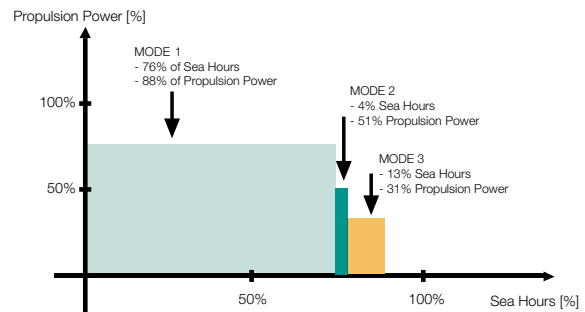
Normal average service speed 22,15 kn  $\frac{446 \text{ h (CRP Azipod)}}{456 \text{ h (Conventional)}} \times 22,15 \text{ kn} = 21,65 \text{ kn}$   
**Annual fuel cost saving USD 750 000**

### Operation profile considerations

Operation profiles may vary a lot depending on studied voyage. When example voyage between Rotterdam-Marsaxlokk-Singapore-Hong Kong is studied in more detail, three main operation speeds can be found: 24, 20 and 17 knots. Time used for each of the speeds is approximately 76%, 4% and 13% of the total voyage time, respectively. Rest of the time is spent accelerating or decelerating.



Maximum speed during a voyage between Rotterdam-Marsaxlokk-Singapore-Hong Kong. (Source: Malacca Max [2] Container Shipping Network Economy, Niko Wijnolst et al.)



Propulsion power and sea hours during a voyage between Rotterdam-Marsaxlokk-Singapore-Hong Kong. Calculated relative fuel and lubrication oil consumption in three different operation modes during one voyage are

	CRP	Twin-Screw	Single-Screw
Mode 1	100 %	109 %	106 %
Mode 2	100 %	110 %	107 %
Mode 3	100 %	112 %	108 %

Calculated relative fuel and lubrication oil consumption in three different operation modes during one voyage are:

It can be seen that the power plant principle used with the CRP system in these three operation modes is even more advantageous for the CRP system than full-speed operation. Total savings obtained during one voyage in fuel and lubrication oil using the CRP Azipod system are USD 70.500 compared with the twin screw and USD 44.200 compared with the single screw.

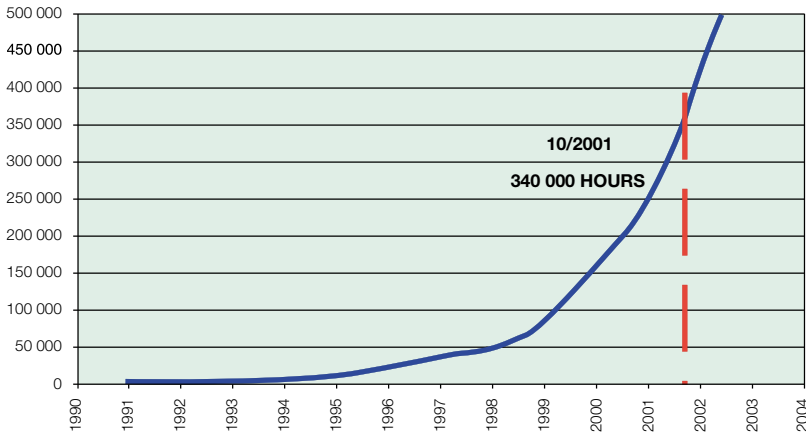
Machinery data and prices used in the calculation are the same as on page 11.

# Azipod® Products

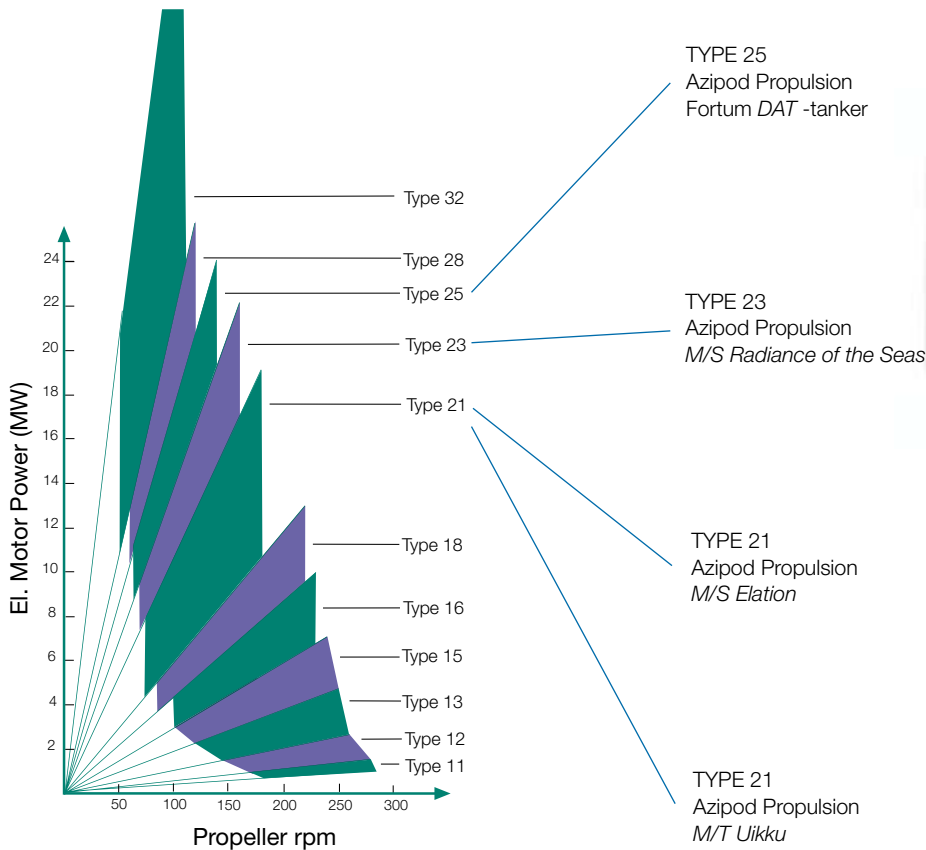
The Azipod power range reaches levels of approximately 30 MW, depending on the selected rpm. Higher power levels are also possible, but these need to be evaluated separately.

The owner and operators can rely on Azipod products as our availability value is 99,62%. The total off-hire time is only 1.296 hours, and ABB has more than 10 years experience in podded propulsion. More than 100 units are ordered, and more than 50 units are in operation.

**Operating hours**



2 x 20 MW Azipod® units installed on *Radiance of the Seas*



TYPE 25  
Azipod Propulsion  
Fortum *DAT* -tanker



TYPE 23  
Azipod Propulsion  
*M/S Radiance of the Seas*



TYPE 21  
Azipod Propulsion  
*M/S Elation*



TYPE 21  
Azipod Propulsion  
*M/T Uikku*

# ... will make future concepts and markets...

Model test results clearly indicate that CRP Azipod® propulsion is the most economic propulsion system. In large power applications it is a serious alternative in RoPax, ULCS, LNG carriers and tankers. Its high total propulsion efficiency makes the initial cost of the system attractive and because its operating costs are much lower than conventional propulsion systems, its selection is fully justified.

It is clear that CRP Azipod is a propulsion system that is going to change the marine world. Conventional 'passive' rudders will be replaced by 'active' rudders on several vessel types, for more economic and safe ship operation.



[www.abb.com/marine](http://www.abb.com/marine)

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Cruise & Ferries:**

**ABB Oy**

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**Center of Excellence  
Oil & Gas Related Vessels:**

**ABB AS**

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