CHEK

deCarbonising sHipping by Enabling Key technology symbiosis on real vessel concept designs

Decarbonizing Shipping

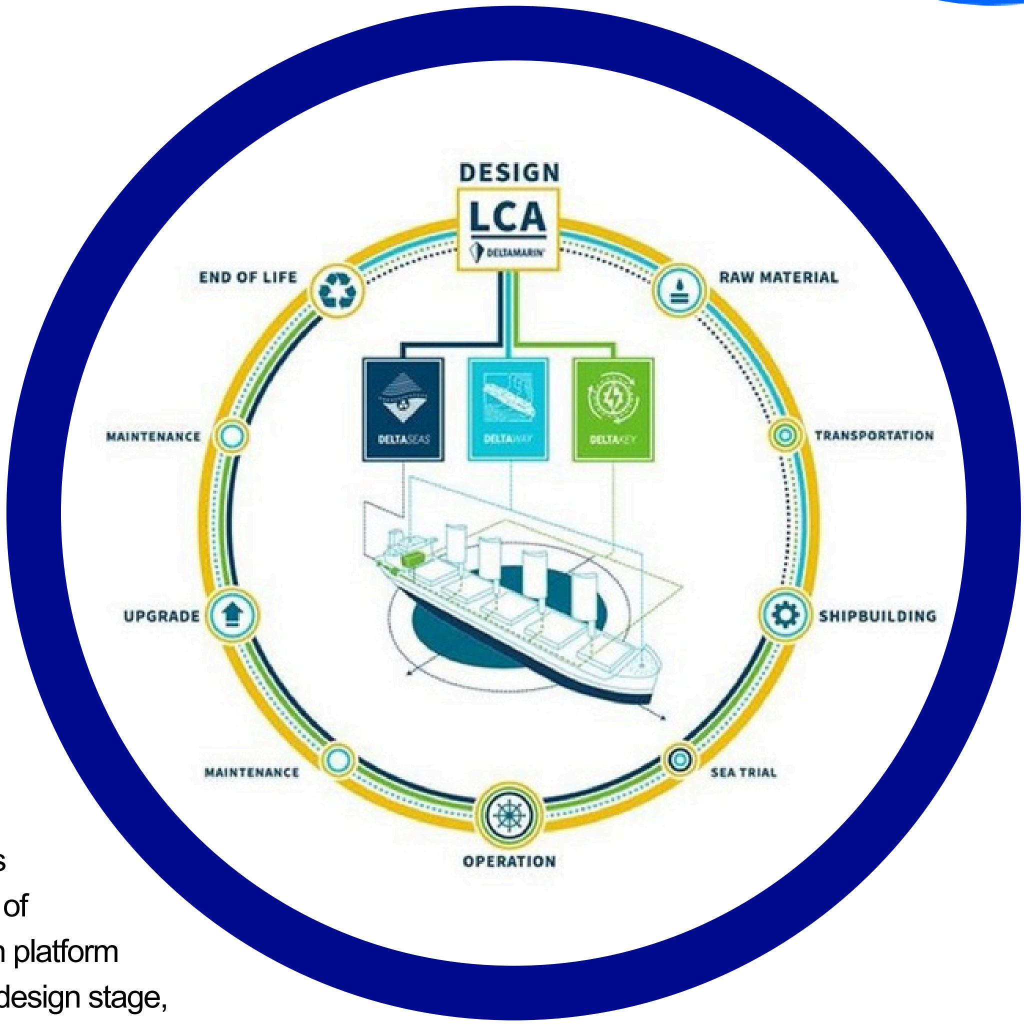
CHEK project aims to reach near net-zero emissions in shipping by redesigning vessels to combine innovative technologies working in symbiosis.

CHEK developed and demonstrated two bespoke vessel designs – a wind energy optimised bulk carrier and a hydrogen powered cruise ship – equipped with an interdisciplinary combination of innovative technologies working in symbiosis to reduce greenhouse gas emissions by 99% and achieve at least 50% energy savings. By developing a unique Future-Proof Vessel (FPV) Design Platform, CHEK ensures maximised symbiosis between the novel technologies proposed, considering the vessels' real operational profiles. The FPV platform also serves as a basis for replicating the CHEK approach for other vessel types, initiating new vessel designs and optimizing vessel operation to ensure efficiency and sustainability. To achieve real-world impact and the decarbonisation of the global shipping fleet, CHEK analysed framework conditions influencing long-distance shipping today, and conducted a foresight exercise to simulate the deployment of the CHEK innovations on the global shipping fleet.

This EU-funded project involved a consortium of 15 partners, including technology providers, ship owners, classification society, ship designer and academic institutions. In November 2023 the CHEK project was recognized by European Commission for its contribution towards a more sustainable maritime industry and was listed as one of its Research and innovation project success stories.

15	10M	3
Consortium partners	Euro budget	Years

Future Proof Vessel (FPV) design platform



Ship FPV design platform aims for holistic evaluation of ship energy and environmental efficiency. The platform consists of several digital layers, instead of one single tool. The FPV design platform is available for ship conceptual design stage, when the key decisions are made regarding ship life time costs or emissions. The layered approach allows the platform to be flexibly utilized for various retrofit analysis as well.

The dimensions in FPV design platform are the ship volume and structural layer (DeltaWay), ship propulsion model layer (DeltaSeas) including external forces such as weather and ship system level energy simulation layer (DeltaKey). The energy simulation layer enables assessing ship fuel consumption and emissions during operation.

For reaching the results in project CHEK, especially the DeltaSeas and DeltaKey were further developed, in order to better assess the impact of sails and the interconnections between the various drag reduction methods (air lubrication, ultrasound antifouling, and GATE RUDDER™). DeltaKey was also enhanced with absorbing external simulation models for ship machinery system. All the digital design layers also feed the latest dimension on the FPV design platform, life cycle analysis (LCA). “Design-based LCA” could give important insight in the future for vessel and fleet strategic development, adding on top of the operational stage the environmental impact of also ship building, the chosen fuel and ship upgrades and end-of-life stages.

Key results

In the heart of project CHEK is to save considerable amount of energy on the CHEK vessels with a symbiosis of “CHEK technologies” and design supporting them. Real operational data and commercial trade route and ship loading condition information was utilized from bulk carrier and cruise ship, for simulating and calculating the relative CO2 reductions and energy savings. Realistic operation profile is important as basis for simulating the technologies. The performance of some of the technologies is, for example, directly related to the speed of the vessel. Vessel speed influences on ship propulsion power and also waste heat production of ship machinery. The ultimate goal of 40-50% energy saving was defined as a comparison to a hypothetic “EEDI phase 2” compliant vessel. In practice, the simulation results of a CHEK case ship without the energy saving technologies and considerations were scaled with a factor related to the ship attained EEDI, compared to the phase 2 requirements.

The pictures below illustrates the simulation of CHEK technologies in bulk carrier and cruise vessel.

Bulk carrier (VLSFO as baseline fuel):

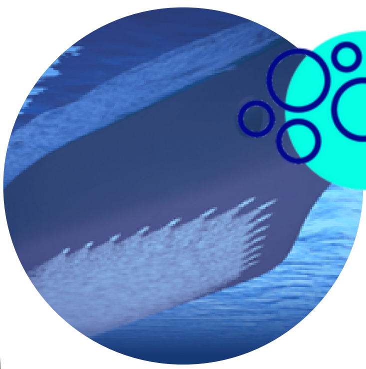
- Fuel flexible machinery consisting on 4-stroke engines (various combinations), CPP propeller, PTO/PTI and batteries for spinning reserve)
- WindWing sails
- Gate rudder
- Solar panels installed on the wings
- Liquid bio gas (LBG as fuel

Both cruise ship and bulk carrier:

- Ultrasound antifouling
- Air lubrication
- Waste heat recovery
- Shore power enabled in all ports

Cruise ship (HFO as baseline fuel):

- Hydrogen engine
- Waste to power
- 10MWh battery pack



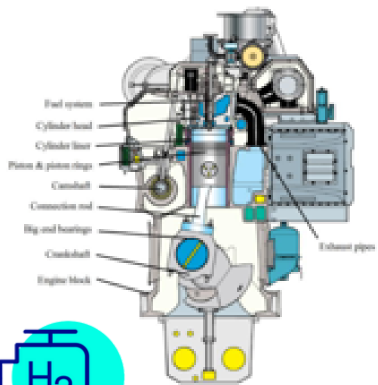


Image: Cargill

Bulk carrier

In the bulk carrier the pure energy savings achieved with the design-technology combination resulted in close to 50% savings, even when the "EEDI-phase 2 correction factor" would not be considered. The true technology symbiosis was witnessed by the design team in the final results. For instance, the vessel drag reduction technologies resulted in considerable lower ship propulsion power than in the base line ship case. This enabled studying hypothetical engine configurations with smaller main engine installed power installed. This flexible machinery provided best power plant efficiency overall contributing, thus, to further total energy savings.

When examining the ship operational CO2-equivalent emissions to air on a well-to-wake basis, utilizing liquid bio gas as ship main fuel would be able to reduce the emissions even below the baseline.

Image: Cargill

Bulker: Final achieved energy and emission reductions on average route relative to EEDI Phase II adjusted baseline performance	
EEDI Phase II Baseline, fuel energy consumption	95.67 GWh/year
Final 4-stroke configuration with all technologies combined (4s 6c combo LBG ELB Solar) fuel energy consumption	45.33 GWh/year
Achieved Energy savings	50.345 GWh/year
Relative energy savings, Final design vs EEDI Phase II baseline	**-52.6 %**
Project CHEK energy savings target	-40 %
EEDI Phase II Baseline, WtW $CO_{2\text{-eq}}$ emissions	31 821 t/year
Final 4-stroke configuration with all technologies combined (4s 6c combo LBG ELB Solar) WtW $CO_{2\text{-eq}}$ emissions	-1 934 t/year
Achieved WtW $CO_{2\text{-eq}}$ emissions reduction	33 756 t/year
Relative CO2 reduction, Final design vs EEDI Phase II baseline	**-106.1 %**
Project CHEK Emissions savings target	-99.0 %

Cruise vessel

For the cruise ship the share of CHEK technologies represented approximately 21% energy savings as a function of the selected operational profile representing a mediterranean cruise. The most interesting technical symbiosis was observed when the vessel energy system was simulated with hydrogen fuel. In this case the ship total energy saving, compared to operational baseline vessel without the EEDI scaling was lifted to 27.5%. Contributing factors were several, such as improved ship power plant efficiency. In addition to this, clean fuel such as hydrogen requires less heating for the ship processes. Therefore, the boiler fuel utilization was reduced and also additional waste heat was released from the ship. The waste heat recovery system could utilize this and lift further the ship efficiency.

Cruiser: Final achieved energy and emission reductions relative to EEDI Phase II adjusted baseline performance	
EEDI Phase II Baseline, fuel energy consumption	446.7 GWH/year
Hydrogen combo with el. Boiler in port, fuel energy consumption	235.2 GWh/year
Achieved Energy savings	211.5 GWh/year
Relative energy savings, Final design vs EEDI Phase II baseline	**-47.4 %**
Project CHEK energy savings target	-50 %
EEDI Phase II Baseline, CO_2 emissions	126 063 t/year
Hydrogen combo with el. Boiler in port, CO_2 emissions	250 t/year
Achieved CO2 emissions reduction	125 813 t/year
Relative CO2 reduction, Final design vs EEDI Phase II baseline	**-99.8 %**
Project CHEK Emissions savings target	-99.0 %

CHEK

Technologies

AIR LUBRICATION SYSTEM

- Harnessing the power of both air and oceans, the innovative Silverstream® System utilises a natural phenomenon known as Kelvin-Helmholtz instability. It shears air from air release units (ARUs) in the hull to create a uniform carpet of microbubbles that coats the full flat bottom of a vessel. As a result, the frictional resistance is decreased, reducing fuel consumption and associated emissions.
- https://www.silverstream-tech.com/

CRUISE ITINERARY OPTIMISATION

- Novel architecture consisting of multiple software modules designed to create sustainable itineraries, compatible with current business and technical processes
- In silico testing
- https://www.msccruises.com/int

FUEL FLEXIBLE GAS ENGINE

- 4 stroke engines capable of running on LNG, bio-methane and e-methane in addition to conventional fuel oils. Provides flexibility to achieve emissions savings today via use of LNG, plus additional savings in the future as availability of low carbon methane bunker become more readily available.
- https://www.wartsila.com/

GATE RUDDER

- Innovative new rudder design that offers reduced drag compared to convention rudder designs; whilst also improving the propeller efficiency. Also predicted to offer additional savings when combined with the wing sails.
- https://www.wartsila.com/

HYBRID PROPULSION

- Enhancing the operation of the power plant by allowing individual engines to operate at a more optimal load point without compromising availability
- Operation on battery alone for a limited distance
- In silico testing
- https://www.wartsila.com/

H2 ENGINE

- Potential to reach net zero GHG emissions by effectively showcasing the technical feasibility of hydrogen as a fuel using a full scale research engine
- https://www.wartsila.com/

SCALABLE POWER TRAIN

- Maximising the benefit from weather-dependent propulsion assistance by introducing an inherently redundant, flexible and scalable power train operating with maximum efficiency and smallest GHG emissions in all conditions
- Increasing cargo capacity by 2% thanks to a more compact power train
- In lab engine testing and power train simulation
- https://www.wartsila.com/

ULTRASOUND ANTIFOULING

- Replacement for conventional toxic antifoul paints that utilizes ultrasound transducers attached to the inner surface of the hull, and to niche areas prone to biofouling.
- https://hasytec.com/

WASTE HEAT RECOVERY

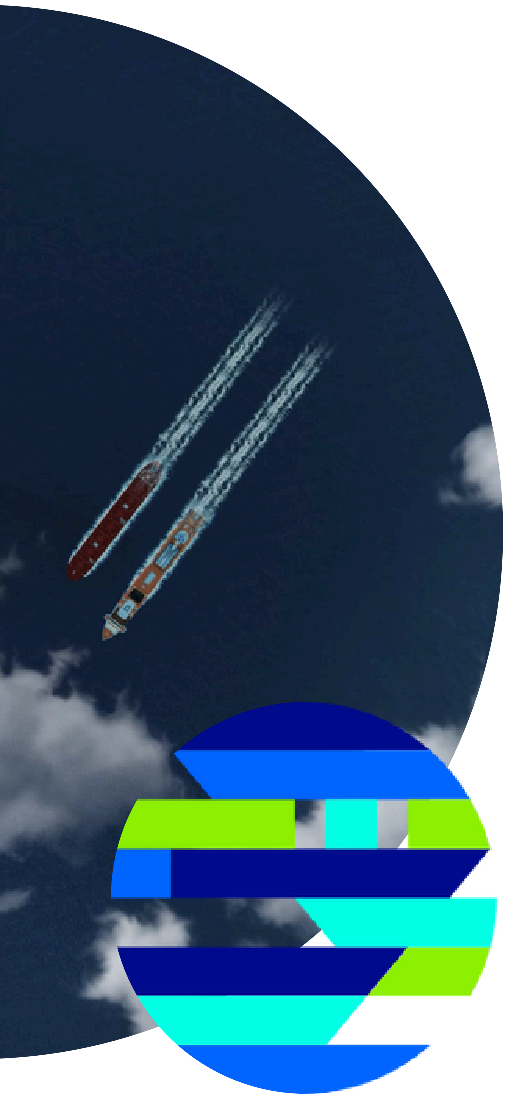
- Waste heat recovery systems reduce fuel consumption and emissions by converting low-temperature waste heat from the ship's main engines cooling water system and other waste heat source into usable electric power for the ship's electrical demand, reducing the load on the ship's generators.
- In lab testing
- https://climeon.com/

WASTE TO POWER

- Convert waste into usable energy via waste heat recovery or through direct combustion of generated gases offering a significant environmental improvement to conventional incineration.
- Feasibility study
- https://www.wartsila.com/

WING SAILS

- High tech multi element rigid sails that use the wind to propel the ship.
- https://www.bartechnologies.uk/



Framework conditions

Focusing on CHEK ships and technologies, all framework conditions were mapped out. These framework conditions were regulatory landscape, port infrastructure, cost of alternative fuels, shipping's business models and emission estimation methods to empower crew onboard. Each condition brought learnings and highlighted some challenges along the way. These were:

- Regulatory landscape is changing rapidly; and ship design, new technologies and ship operation should be agile to meet these current and upcoming regulations.
- Lack of infrastructure is a barrier for alternative fuels and energy saving technologies therefore more funding should be available.
- New business models should be taken up by marine industry to incentivise fair adoption of alternative fuels and energy saving technologies.
- Crew competency and training are vital for the safe and efficient adoption of alternative fuels and energy saving technologies.

Global fleet development

The global fleet development was mapped out to understand the trends in 2030 and 2050 from the perspective of types of ships, types of alternative fuels and energy saving technologies. With these in mind, further elaboration took place to establish a methodology to scale these learnings from CHEK ships and technologies to global fleet towards 2050. Highlights were:

- Well-to-Wake GHG emissions projection from the shipping industry with and without CHEK's technologies results demonstrate that technologies working in synergy play a significant role in reducing GHG emissions (approximately a 38% reduction in GHG emissions can be achieved with the use of CHEK technologies, compared to the EEDI Phase II adjusted baseline). Additionally, it is apparent that total GHG emissions are projected to decrease in the future. This reduction can be attributed to the ongoing energy transition towards more sustainable fuels in the maritime industry. The total Tank-to-Wake GHG emissions from international shipping with the CHEK technologies also significantly reduce the Tank-to-Wake emissions.
- It is expected that sustainable fuels will be more expensive in the future. Therefore, energy saving technologies will most probably be desirable to all industry stakeholders looking to invest in new technologies, as they have the potential to reduce operational expenditure costs over the service life cycle.

Dissemination

Throughout the project, the activities and results of CHEK have been effectively communicated and disseminated across various channels, even capturing global media interest. Key dissemination activities include:

- Nine workshops: Four workshops with shipyards, three workshops with maritime academies, one workshop with European Commission, and one workshop with ECSA (European Community of Shipowner Association)
- Four E-lessons: Wind wing technology, Digital twin for vessel design, Safety of hydrogen engine, and Business model for maritime industry
- Participated in multiple conferences, seminars and exhibitions during the project
- Emissions simulator on CHEK's website www.projectchek.eu

Looking to the future

To align with the IMO's GHG Strategy, a combination of zero emission energy sources and efficiency improvements will be required across the industry. The CHEK Bulker and Cruise designs provide a blueprint for combining multiple efficiency technologies, together with low and zero emissions energy sources; using a wholistic approach where the interaction between the different technologies is considered from the outset.

In a similar way to the technologies, shipping stakeholders will need to work together rather than in isolation if we are to achieve these goals. CHEK has also considered this by investigating new business models that facilitate collaboration on efficiency; by quantifying infrastructure impacts; and more.

The solutions found in the CHEK work well together in these two cases, with the set routes. Having said that it needs to be highlighted that there is unfortunately no silver bullet. For different shipping segment, region and/or route other solutions might give a better economic-environmental feasibility. Just to name regular short sea passenger traffic, which we can already see being electrified. Similarly deep sea shipping using renewable hydrogen does not have the best feasibility due to lower energy density compare to for example renewable ammonia. The feasibility of energy saving devices, and especially dimensioning of them, is also shipping segment and route dependent.

At the end of the day, the regulation set forth "polluter pays" will steer towards the technology agnostic solution which has the lowest Total Cost of Ownership, including the capital and operational costs of green shipping for each segment and region.

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