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Virtual Mill:
New opportunities for plant design, training and maintenance with virtual models

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Innovating for sustainability

Sustainable solutions and new innovations are needed now in various industrial sectors. Global challenges can be solved through cooperation, abandoning environmentally unsustainable solutions, developing clean technologies, and utilizing the industrial circular economy. Sustainable technological and process innovations play a crucial role in the competitiveness of companies and smart investing. Tomorrow's clean and sustainable solutions require new know-how and the ability to create functional products, processes or, for example, hydrogen as an energy form to enable emission-free mobility.

In this magazine you can read about sustainable innovations with technology and circular economy, and about what kinds of opportunities digital technologies such as XR and Digital Twin offer for industrial operations. XR technology allows, for example, the user to move freely, familiarize themselves with processes and practice various maintenance activities. The maintenance, communication and change management of your production sites can also be made easier with mobile scanning. We are one of the leading organizations providing technical analysis services, and there are a couple of practical examples in this magazine of how computational fluid dynamics (CFD) can be used in the design of ships, e.g., in order to reduce hull resistance and decrease harm to the environment.

You have in your hands a magazine with a new look and a new corporate image that is gradually being rolled out in all encounters and channels. The aim of the makeover is to communicate our multidisciplinary approach to helping companies tackle the move towards an ecologically sustainable and successful future. Our purpose is to design solutions that increase the well-being of the environment as well as people, and our goal is to improve the competitiveness of our customers.

Hope you enjoy reading our magazine. Together we can create a sustainable and clean future!

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Virtual Mill:

New opportunities for plant design, training and maintenance with virtual models

Text: Jaakko Mattila, Jukka Timonen

Virtual models of production plants offer significant benefits at all stages of a plant's lifecycle. From the visualisation of a plant design to streamline the construction process to a digital twin serving alongside an operational plant, the immersive experience utilising a VR headset allow the user to dive into the environment created by the 3D model in a realistic way. VR is particularly well suited for training, as virtual training is safer and more cost-effective than training in the physical environment, while still offering a hands-on approach to learning.

Elomatic's Visualisation services have been involved in the development of the Valmet Virtual Mill concept which assists Valmet's customers in the presentation of a machine line, in design reviews as well as in various personnel training activities. Delivering a digital twin alongside a board and paper machine to the customer allows Valmet to offer a new range of digital services and innovations by complementing the Valmet Industrial Internet offering. The Virtual Mill is a digital twin of the entire factory in which the user can move freely, get acquainted with the processes and practise various maintenance operations using VR technology.

> **Where digitalisation creates data, virtualisation is able to bring the environment described by the digital data under examination as well using a 3D model.**

Virtualisation brings new opportunities to maintenance

In paper mills and other production plants, downtime is known to be an expensive affair. Maintenance must be on top of its game, which means quick response and efficient operation so that all maintenance operations can be completed on time. Digitalisation has been able to provide many tools with which efficient service and maintenance planning can be achieved. The collection and analysis of real-time data has succeeded in streamlining operations in many plants. Proactive maintenance and remote monitoring are activities that would not be profitable without the digital solutions enabling them.

These new possibilities can be further developed through virtual models. Where digitalisation creates data, virtualisation is able to bring the environment described by the digital data under examination as well using a 3D model. In this way, the environment described by the data can be presented to individuals in a visual way that promotes the internalisation of information. The virtual 3D model can be used, for example, to train maintenance in the implementation of a pre-planned measure. Alternatively, situations detected by remote monitoring can be communicated effectively to employees in the field who react to them. Solutions like the Virtual Mill, that use the same base 3D model, can be utilised for installation, commissioning or assembly training.

Virtual models streamline production plant design and construction

Time to market is also a key challenge in setting up new industrial production plants. Virtual solutions are useful and complementary to digital solutions against this challenge as well. Current 3D design models enable the creation of virtual environments already during the construction phase of the plant. Thus, training can begin before the production line is even up and running, which streamlines the start-up and commissioning of the plant once it is completed. Different perspectives can be considered already in the reviews during the design of the plant. For example, the locations of service hatches, the interchangeability of large parts, and the safety of maintenance procedures are easier to illustrate in a real-size virtual environment, and it can help prevent additional costly alterations during construction. 3D models can be used when discussing and planning for the placement and installation of different equipment to quickly build consensus. Feedback related to control rooms and other working environments in the

operational phase can be collected as these can be clearly visualised using virtual models. All of this streamlines the construction of production plants and speeds up their start-up.

Virtual models as a competitive advantage

VR, or virtual reality, offers many benefits for utilising 3D models. Immersive experiences utilising VR headsets allow the user to dive into the environment created by the 3D model in a realistic way. The 3D models can be exported to the customer's actual scanned environment, allowing the 3D model to be viewed in its relevant context. Or, if necessary, the environment can be removed, allowing the user to fully focus on the displayed material in a way that is memorable and easy to understand regardless of 3D perception.

Although VR technology is relatively new, its functionality has been strongly verified. The flexible, scalable and secure way of presenting technical entities using VR is also superior in terms of cost-effectiveness, and the same goes for training. This is especially true when the alternative is using a huge production plant tied to a physical location, which is preferably always operating at full capacity. It is also possible to access the virtual environment anytime and anywhere, without travel or COVID-19 restrictions.

VR is particularly well suited for training activities. Learning by doing and the effect of immersion on concentration speed up training compared to other forms of e-learning. In addition to its cost-effectiveness, training in a VR environment is also safe compared to the physical alternative. For example, working in ATEX environments can be practised virtually in which case the mistakes made are not fatal. These features provide huge benefits in training utilising VR technology.

When purchasing large and complex systems, VR enables the rapid internalisation of technical information, which helps the buyer in decision-making. Examining the equipment and familiarising themselves with the production principles of the production plants from the support processes to the maintenance measures before making a purchase decision help the customer understand exactly what they are purchasing. Content based on design models is reliable, and key functions can be visualised in more detail with animations. Properly constructed, the various contents serve to train the customer, operators and maintenance personnel.

Design models in the field using AR

AR, i.e., augmented reality, and VR are often presented side by side, but there are significant differences in their uses. In general, VR is best suited for off-site pre-planning measures. AR, in turn, allows 3D data to be imported directly into the operating environment, allowing the same 3D content to be used directly in the field. The information content may be exactly the same, but the creative utilisation of AR in the field creates completely new opportunities for utilising design models.

Information necessary for maintenance can be brought on-site in an AR-assisted manner at a scale of 1:1 to physical reality for just the right need and place in the form of manuals, 3D design models or signs. For example, a 3D animation of maintenance procedures can be brought as a full-size model to the exact location where the physical maintenance procedure is performed. In this way, the person performing the maintenance procedure can see on site the order in which the maintenance will be performed and what other factors should be taken into account during the maintenance.

When used in sales, AR can be used to place a product in the right place before the purchase decision is made and to ascertain the extent of the change or the whole of the procurement that has to be made. If the product or component is assigned to an old factory, AR can assist in the examination of the product's transport and assembly. Possible problems caused by the delivery of the product are easily detected, as are the changes to the current process. This helps with preparing for complications already at the purchase stage. By adding instructions on the installation procedures to the content, the installation can also be planned in detail on site in advance. When the AR model is shipped, the customer can also be provided with a mobile viewer which makes it easy and quick to view the lightly rotating 3D design model, drawings and operating and maintenance instructions to support interpretation.

The advantages of VR/AR methods are particularly emphasised when performing complex or expensive maintenance, where success is guaranteed and security risks eliminated.

"VR is particularly well suited for training activities. Learning by doing and the effect of immersion on concentration speed up training compared to other forms of e-learning.

The digital pipeline: From 3D models to digital twins

Solutions such as the Valmet Virtual Mill are created using precise and technical 3D models created by designers. 3D models are optimised through a partially automated process into simplified 3D models that are suitable for a variety of application development platforms. Even as such, the simplified design model is suitable for many uses in operational control, design, manufacture and installation, but it can also be embellished to achieve a photorealistic form. This creates the basis for a wide range of solutions in the form of images, animations and VR and AR applications. The security of the solutions is ensured by erasing the patented parts in the simplification phase to protect intellectual property in cases of misuse.

The earlier a simplified version of a design model is made, the more it can be utilised during the life cycle of the product. In concept design, VR is a great technology for collecting user feedback from various sites such as control rooms, cabs and lines. A simplified and fast-loading model that even operates via the internet can be used during design reviews to enable communication between different stakeholders. At the start of the installation, 3D models utilising AR technology can be implemented from the design models and used to place the machines and equipment in the installation environment first virtually. AR models can be used to carry out spatial examinations and to identify possible problem areas early during reviews. In this way, the locations of the structures, the examinations of the implementations and the challenges posed by the coordination of the design areas, for example, are detected in time, making the installation run more smoothly. All of these tools can be implemented from the 3D models produced from designs with Elomatic's effective Digital Pipeline process.

As mentioned, the potential for training and communication during design and start-up phases is great, but the same virtual 3D model also serves as a platform for digital twin data visualisation. Creating these tools does not require long development projects. They can be built one by one in a few hundred hours of work. Thus, the 3D design model, the production of which has consumed thousands of hours of meticulous engineering work, will continue its life after the design phase throughout the plant's lifecycle as its digital twin, serving an immense number of different stakeholders along the way. ◣

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XR Solution Manager, M.Sc. Information system sciences

Jaakko is a passionate XR visionary, building the roadblocks for future advancements. He is a kind-hearted innovator that drives change and manages technological development with his degree in digital business development. 3D assets are Jaakko's main raw ingredient and he works with his team to build useful applications for industry to transform training, collaboration and design. With years of experience in XR, Jaakko helps us enter the new era of immersive technologies and all they bring with them.

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Jukka has more than 15 years of experience in visualization and 5 years of experience in marketing. He has strong skills in 3D modeling and animation as well as video shooting and production. Productions in visualizations and training materials for large industrial companies has given Jukka a good understanding of mechanical machinery and equipment, including hydraulics. Jukka leads the Marketing and Sales of Elomatic Visualization Solutions. He joined the Elomatic ViSU team in November 2019 and works in the Tampere office.

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Elogrid first piloting

Text: Juha Tanttari

The Elogrid product (pat. Pend.) is developed and designed in Elomatic's technical analysis team together with the marine business unit. The purpose of the device is to contribute fuel savings in ships equipped with bow thruster tunnels, and increase thrust from the transverse propellers. The device is set in tunnel openings to prevent water entrance into the tunnels when the ship is steaming forward, and when maneuvering the Elogrid blades set in radial direction, it operates as stators decreasing swirl and increasing jet axial momentum.

Now the first delivery of Elogrids has been realized to Viking Line M/S Gabriella, and the first experiences and feedback from the ship are available. The delivery includes CFD (Computational Fluid Dynamic) calculations, dimensioning, design, production with the subcontractor, supervising of the installation and measurements with data analysis.

Dimensions and design

The Elogrid 3D model was produced based on ship drawings and laser scan documents from the client.

CFD models for analyzation of grid impacts were generated for the ship moving at a given speed range and maneuvering at a given thruster propeller rotational speed and pitch angle. The simulations for the Gabriella were conducted for comparison with and without Elogrids.

FEM calculations were conducted in order to detect the grid nominal frequency, stress and deformation in the worst possible load conditions.

The grid shape has been carefully designed based on local flow directions and hull form. The grid is curved in all directions, uniform with hull surface form at the openings. The flow simulation has been done including tunnels with and without grids.

The simulations proposed 2–2.5% fuel savings at the speed range of interest when sailing straight ahead, and thrust improvement was esti-

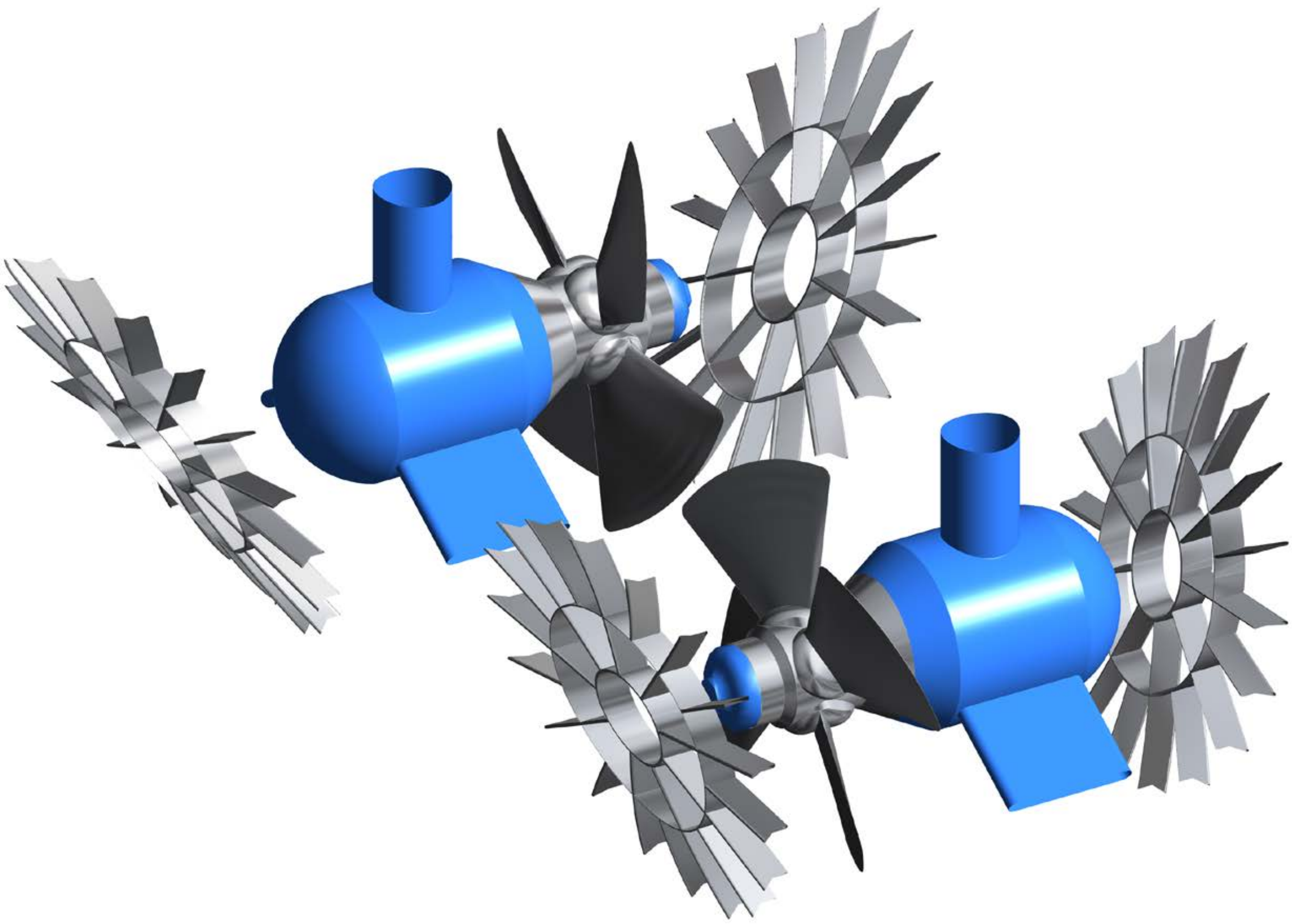

Figure 1: *Elogrid 3D model from tunnel inside devices without tunnel walls.*

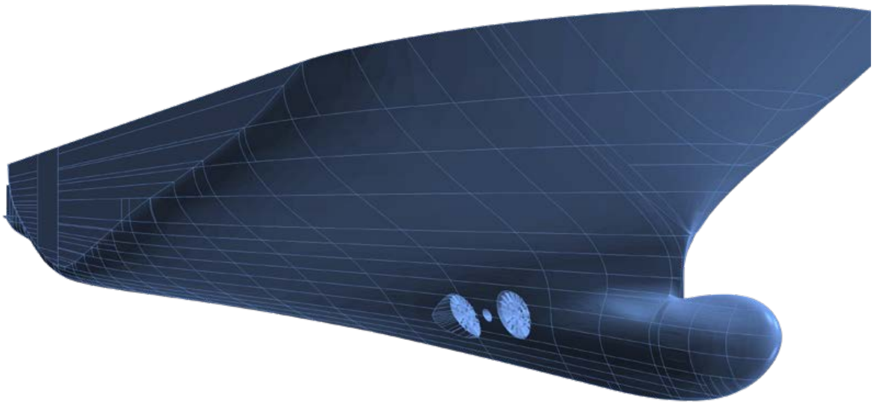

Figure 2: *Gabriella 3D model with Elogrids.*

mated to be between 1.6–3.6% with Elogrids installed. The actual savings are higher in typical conditions where wind or maneuvering is causing drift that leads to a higher flow rate through the tunnels.

The hydrodynamic pressure shown in **Figure 3** indicates the positions which contribute to pressure resistance from the ship movement. The grids prevent water passing through the tunnels and therefore the resistance from tunnels and grids together remain lower.

The velocity contours in **Figure 4** show a much higher amount of water circulation and flow through the tunnels without grids when sailing ahead. The propeller at 0° position is slightly blocking the flow allowing a higher flow rate from the pod side.

The thrust is summed from all components on which the propeller induced jet impacts. Highest thrust forces are detected from the propellers, but also the bevels at openings and the hull surface close to bevels contribute thrust on the suction side and possibly losses on the pressure side – depending on how they are designed.

The propeller bossing and strut generate losses that decrease the thrust as well as conventional grids, however the new Elogrid design can contribute thrust forces with stator impact and secondly improve the flow pattern into the propeller suction.

The grid stress and displacements remained on an acceptable level even in the tough ice load conditions shown in the figures. The nominal frequency is much higher than that contributed by fluid force vibrations, which means no risk of resonating should be expected.

The Elogrid drawings were made according to the 3D model for production and installation, slightly modified from fluid dynamics design, based on the ice load demands detected by structural analysis.

The grid material stainless steel is selected to ensure durability for the product at demanding conditions on tunnel openings.

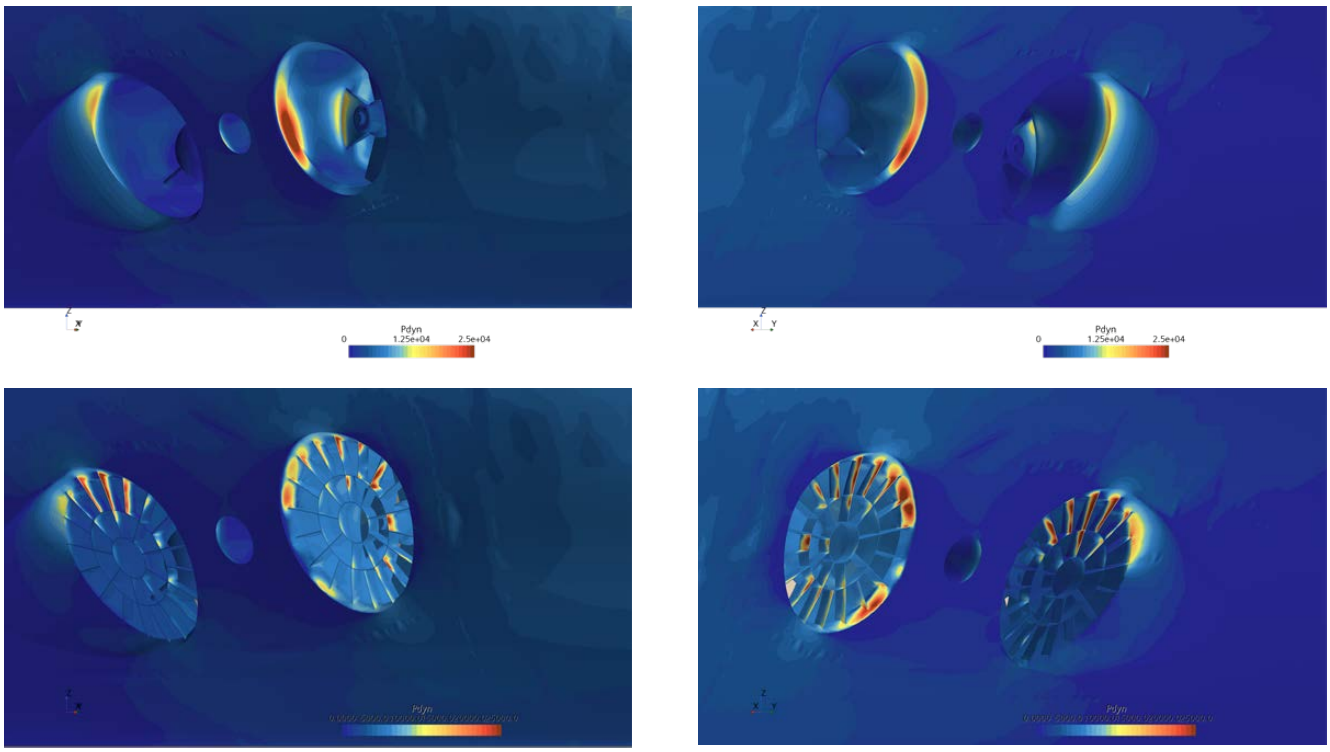

Figure 3: *Gabriella fore part hydrodynamic pressure.*

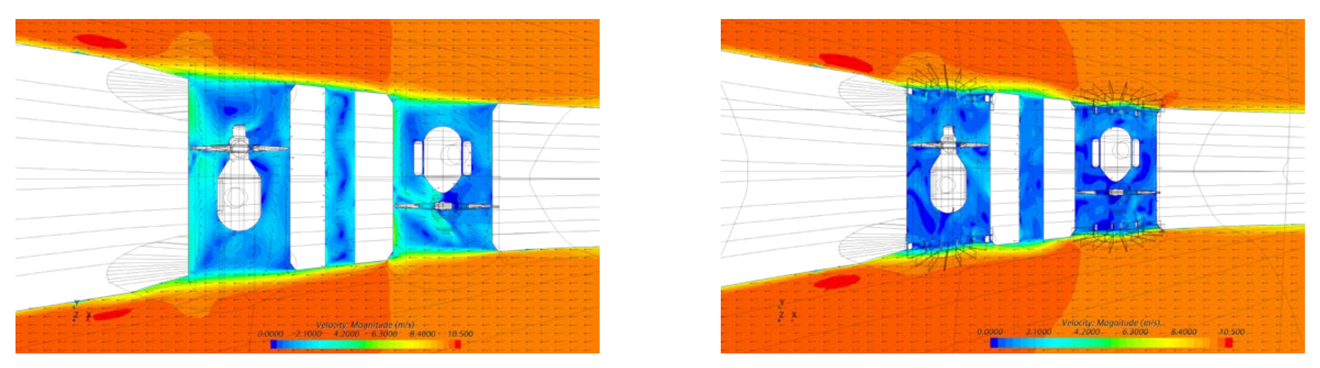

Figure 4: *Gabriella water passing through the tunnels.*

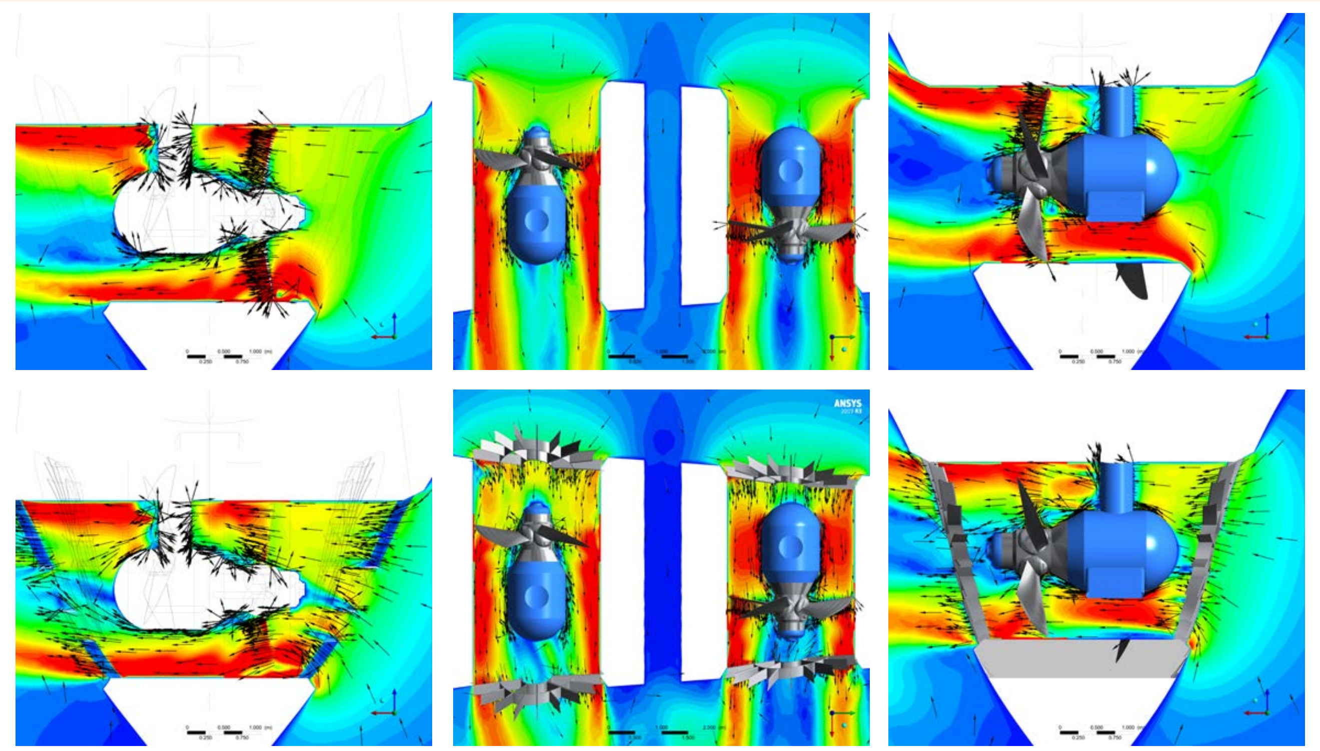

Figure 5: *Gabriella thruster propeller induced flow through the tunnels (top = no grids, from left: aftmost tunnel midplane, both propeller axis level, foremost tunnel midplane).*

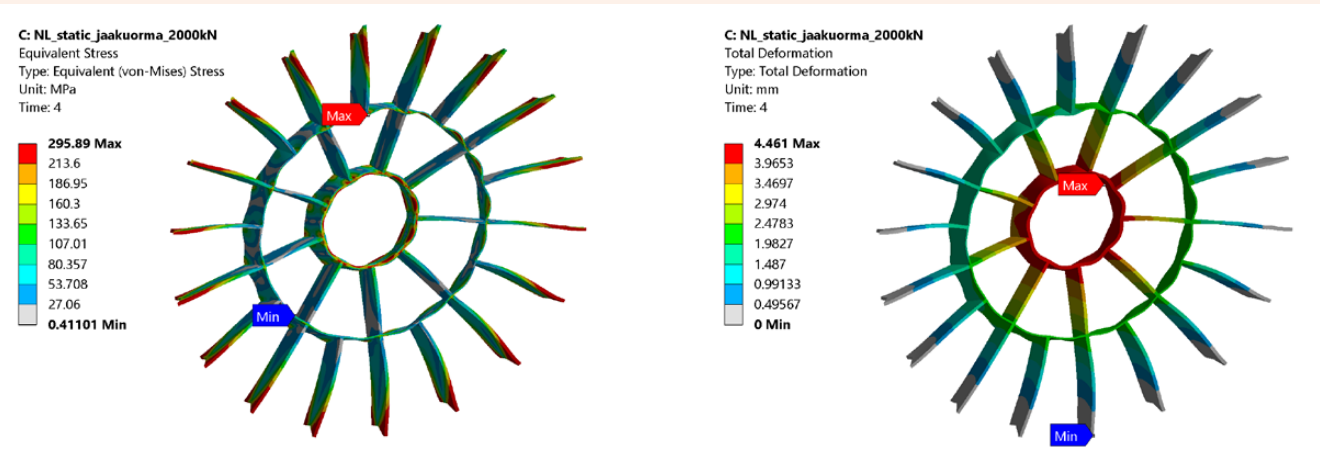

Figure 6: *Gabriella's Elogrids stress and displacements at ice load.*

Production and installation

VL Gabriella has two 2.4 m tunnels meaning four Elogrids should be manufactured to cover each of the openings. The devices are manufactured in Turku Finland by Synkronex, which specializes in high quality product manufacturing for marine vessels. The manufacturing procedure demands several weeks due to the complicated structure of the device. Each component to be welded into the Elogrids is different and should be treated in a certain way – tolerances for the assembly are quite tight to ensure the expected performances based on simulations.

The Gabriella drydocking was at Fayard Denmark. One of Elomatic's specialists was supervising the installation to ensure high quality and also that the complicated structure fit together.

The large scallop at the aftmost tunnel requires special attention – incorrect installation would easily contribute to elevated resistance.

The installation of grids was – thanks to the skillful professionals – successful; the immersion together with the right angle should all be correct to ensure the device fits the opening – and the welding should be made correctly to avoid deformations from high temperature and to ensure durable joints.

According to the collected data, thrust improvement with grids was 5–10% when values are compared at the same thruster shaft power rate. The difference is larger at lower power rates.

Measurements and data analysis

The Elogrids are supposed to reduce tunnels' additional resistance and at least not decrease the thrust forces from the tunnels. The actual impacts in performances were already analyzed with CFD in the design phase, but in this case we had an opportunity to have measurements onboard in ship scale as well.

The measurements were conducted in co-operation with Viking Line and Meyer Turku Shipyard. The Gabriella side thrust was measured before and after the installation of Elogrids in order to find the contributed impact.

The pull tests included separate and combined use of the thrusters with different pitch angles, which was varied between 50–100%.

The ship was aligned with the open dock to keep it more stable during the operation. Four groups were collecting measurement data at the same time while the tunnels were tested. One group on the quay detected force values from a dynamometer log, vibration data was detected right above the tunnels, noise data was registered in the buffet bar on deck 8 and the bridge group was controlling the procedure. All the ship data was collected in the onboard energy management system, Blueflow.

The main difference during the tests was wind speed, which was logged in Viking Line's operation data system Blueflow – and compensated for in force calculations.

All the force data from the dynamometer, wind values, propeller pitch and power consumption data from the Blueflow system, vibrations and noise data were collected and average values calculated for comparison of test cases.

According to the collected data, thrust improvement with grids was 5–10% when values are compared at the same thruster shaft power rate. The difference is larger at lower power rates.

Vibration and noise values were detected, and average values were compared. The vibration values were reduced by 12% on average, and noise level – which is mainly contributed to by vibrations – was reduced by 1.9dBA from 61 to 59dB(A) when both thrust-

Figure 7: *Elogrids installed on Gabriella bow thruster tunnels.*

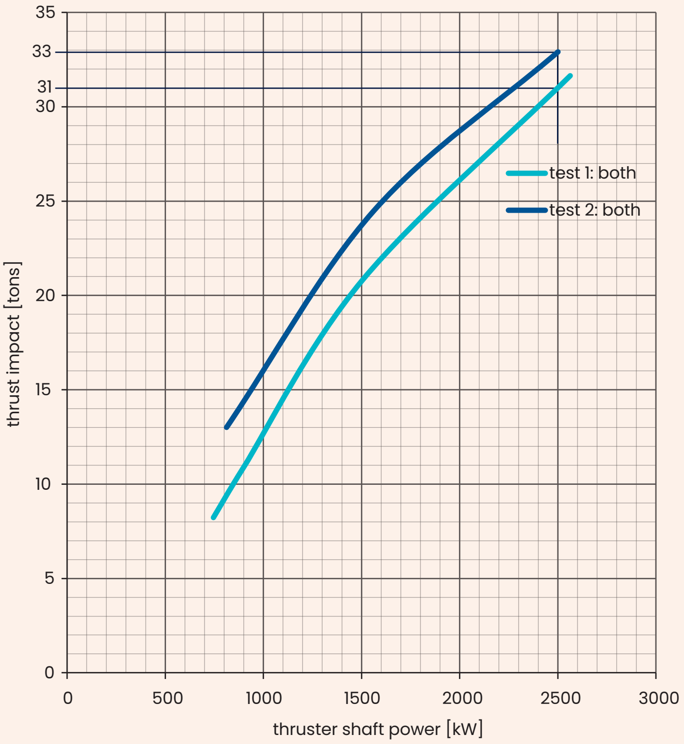

Figure 8: *Gabriella side thrust at VL quay (Test 1 = no grids, Test 2 = Elogrids installed).*

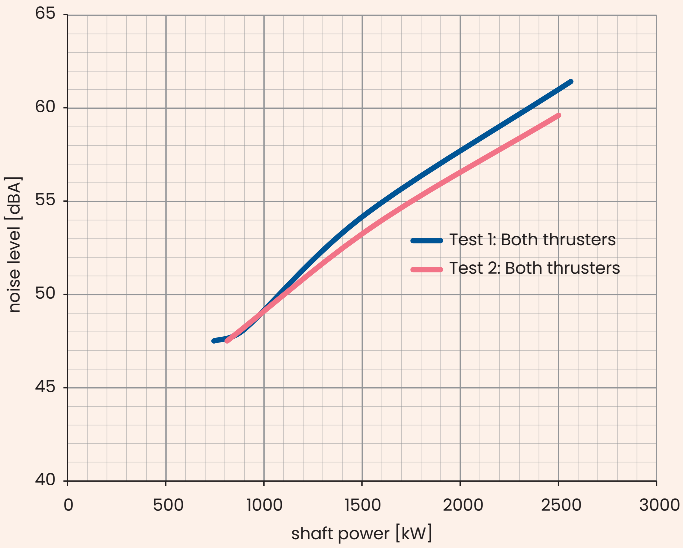

Figure 9: *Gabriella noise level in the deck 8 buffet during the pull tests.*

ers were in use. Fore tunnel noise was about the same with Elogrids, and the aft tunnel noise level was reduced. The fore tunnel is less noisy in general. The background noise was relatively low, meaning the measured noise was practically all from the thrusters.

Elogrids' impact on ship tunnel additional resistance is detected comparing Blueflow data from ship propeller pitch and speed versus speed over ground. The values are captured from journeys before and after drydocking of 2018 and 2021 to see the impact of drydocking separately.

Ship draught is detected separately from Napa loading condition sheets – slight differences are detected in draughts. On journeys after installation of Elogrids she has 8cm more draught.

The data was filtered removing high wind speed situations (>7m/s) and ship speed change periods from the filtered data.

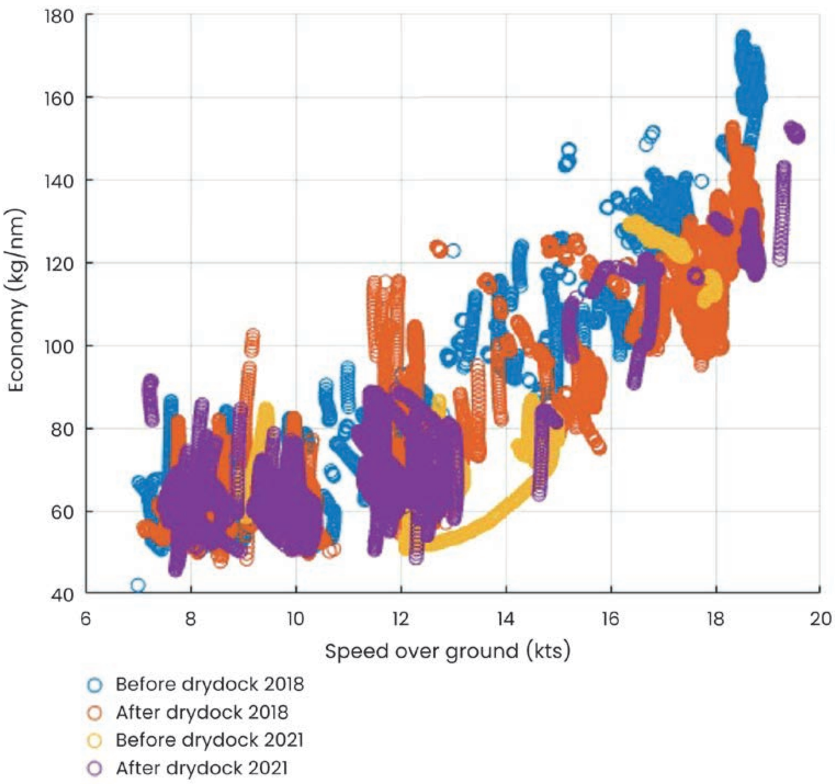

Figure 10: *Gabriella economy vs speed over ground.*

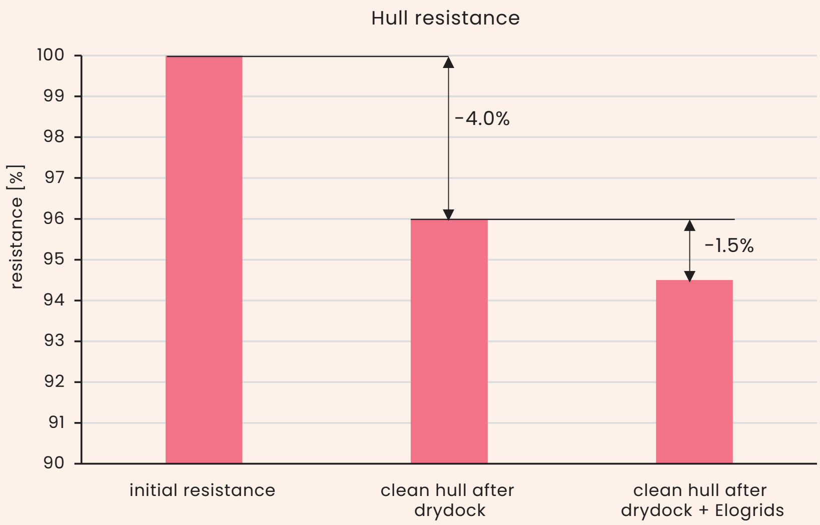

Figure 11: *Drydock impact to Gabriella hull resistance.*

Finally, after smoothing the ship speed over ground vs resistance data, we notice the hull service at dry docking contributed a 4% reduction in resistance, and installing Elogrids contributed an additional 1.5% reduction.

The accuracy of operational data improves when more data is collected – but during the time needed to collect data the hull surface is becoming less clean and that might affect the results. The number of variables during the ship journeys is enormous and therefore comparisons are challenging and time consuming.

Conclusions and feedback

The piloting of Elogrids was successful thanks to the professional group involved in the project, the product was delivered in the tight timeframe agreed, the quality of the product installed was high – and performances detected were as simulated and designed; development is needed in the delivery process in general to keep the expenses of the product as desired to satisfy the average payback times expected by ship owners.

Gabriella has been operating after the installation of Elogrids now for the whole time since May, after a long period in dock due to Covid limitations on ferry traffic. The experiences from these have been good in general, according to Gabriella's Captain:

"After the installation of Elogrids I really feel the difference in lower vibrations on deck already during the testing. The maneuverability of the vessel is clearly improved compared to original. I would have not expected to notice such a significant effect. The personnel I have met from Elomatic have all been true professionals." - **Captain Tomas Karlgren** of Viking Line

The fuel saving potential and other benefits seen in Gabriella has led VL to invest in Elogrids for the next drydocking vessel, and the design for the device has already been started. ◣

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- Captain Tomas Karlgren of Viking Line

Pathways to sustainable innovations

Text: Rami Raute, Pekka Koivukunnas

Throughout the industrial history of mankind, we have created new innovations based on the techno-economic point of view or paradigm. In the early seventies, Club of Rome published a report called The Limits to Growth. Since then, it has been common knowledge in our societies and among industry and world leaders, that we have to find more sustainable ways of developing industrial innovations to guarantee a comfortable life for humans and other lifeforms on this planet, which as far as we know, is the only one able to support the kind of life we live today.

In this article, we describe some pathways to sustainable innovations and provide background for sustainable thinking in general.

The planetary boundaries of industrialization

The techno-economic paradigm has been one of the key drivers of industrial revolution which has been at the center of mankind's actions for approximately 200 years. The model known as **Kondratiev waves** connects key industrial innovations and economic cycles together. These innovations have propelled economic wealth throughout the industrialized centuries.

The purpose of the Kondratiev wave model is not to depict environmental impacts. It was developed to represent the economic sustainability of western economies. It is worth taking into consideration, that most of the best industrial innovations remain in use for long periods of time once they have been adopted on a large scale (e.g., combustion engine, coal-based electricity, natural gas-based fertilizers etc.) However, looking at the wave model today and connecting the environmental impact information of key industrial technologies, we can see that the environment has paid a price for our development.

Later studies, that have connected human technological impacts to earth's lifeforms and the systems that support them, have created **the planetary boundaries model**. Studies into the planetary boundaries model, such as those conducted at Stockholm

University's Resilience Center, show that human industrial actions are key reasons for environmental problems.

In light of this, it is clear that we should aim to make new innovations sustainable or at least more sustainable in relation to the planetary boundaries, and this should be the guiding principle of strategic thinking.

Sustainable revolution

What is sustainability"? Wikipedia defines it as follows: *"Sustainability is the capacity to endure in a relatively ongoing way across various domains of life. In the 21st century, it refers generally to the capacity for Earth's biosphere and human civilization to co-exist. Sustainability has also been described as "meeting the needs of the present generation without compromising the ability of future generations to meet their needs" (Brundtland, 1987). For many, sustainability is defined through the interconnected domains of environment, economy and society. Sustainable development, for example, is often discussed through the domains of culture, tehnology, economics and politics."*

The definition of sustainability through the interconnected domains of the environment, economy and society is sometimes taken to mean that these three are of equal importance. In this article, we question this. The problem here is the same as with the techno-economic paradigm. It seems to decrease role of the environment or place it in a minor role in our decisions, while in reality its role is substantially bigger than that of the other two. We believe that the next wave of change, after the industrial revolution, will be a sustainable revolution.

Pathways to sustainability

When setting strategic targets to new innovations we have concluded that innovations have to be sustainable from the point of view of the environment now or in the near future, and this has to be a key target in development in accordance with, for example, the Paris agreement.

Currently, when it comes to sustainability, most companies choose to take no actions and make no changes in product design, even if sustainable materials are available. This is due to higher costs or other strategic reasons within the business. We believe that this is short-sighted.

As innovators, we used a method of brainstorming solutions based on simple phases or principles. Based on the idea that sustainability is the key driver of technology and product development, we created the following pathways towards sustainability:

- **Pathway 1/10. Wait for sustainable materials or create them.** Wait until material, part and component suppliers have sustainable materials available and start using them. Or start developing them yourself.
- **Pathway 2/10. Aim for a *more* sustainable product.** Start actions immediately and do everything possible right now. Use more sustainable materials, even if fully sustainable materials are not yet available, adapt product design to accommodate more sustainable materials.
- **Pathway 3/10. Aim for a fully sustainable product.** Start developing a fully sustainable product, even if it leads to radical changes in product structure, performance etc.
- **Pathway 4/10. Look at the bigger picture.** Accept unsustainable products in cases where the product helps to decrease the total emissions of some bigger system it is a part of.
- **Pathway 5/10. Discontinue unsustainable products.** Stop producing unsustainable products.
- **Pathway 6/10. Favor handcrafting.** Return to old technology, which often automatically leads to more sustainable production, for example, using manual powered tools instead of fossil fuel powered machines etc.
- **Pathway 7/10. Reduce and recycle.** Use only recycled or side stream materials and reuse aborted components
- **Pathway 8/10. Produce more durable products.** Extend product lifetime to transgenerational.

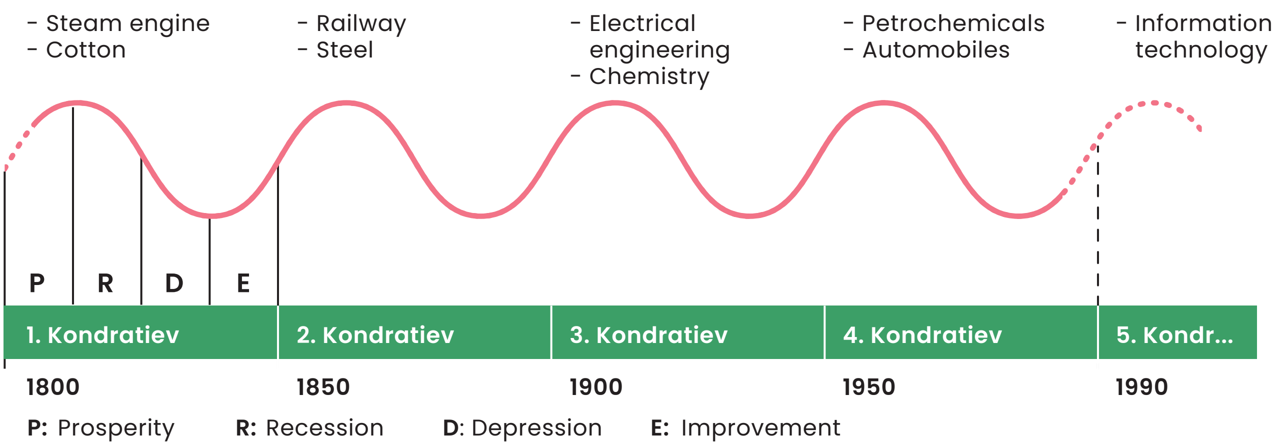

Figure 1: *Kondratiev waves.*

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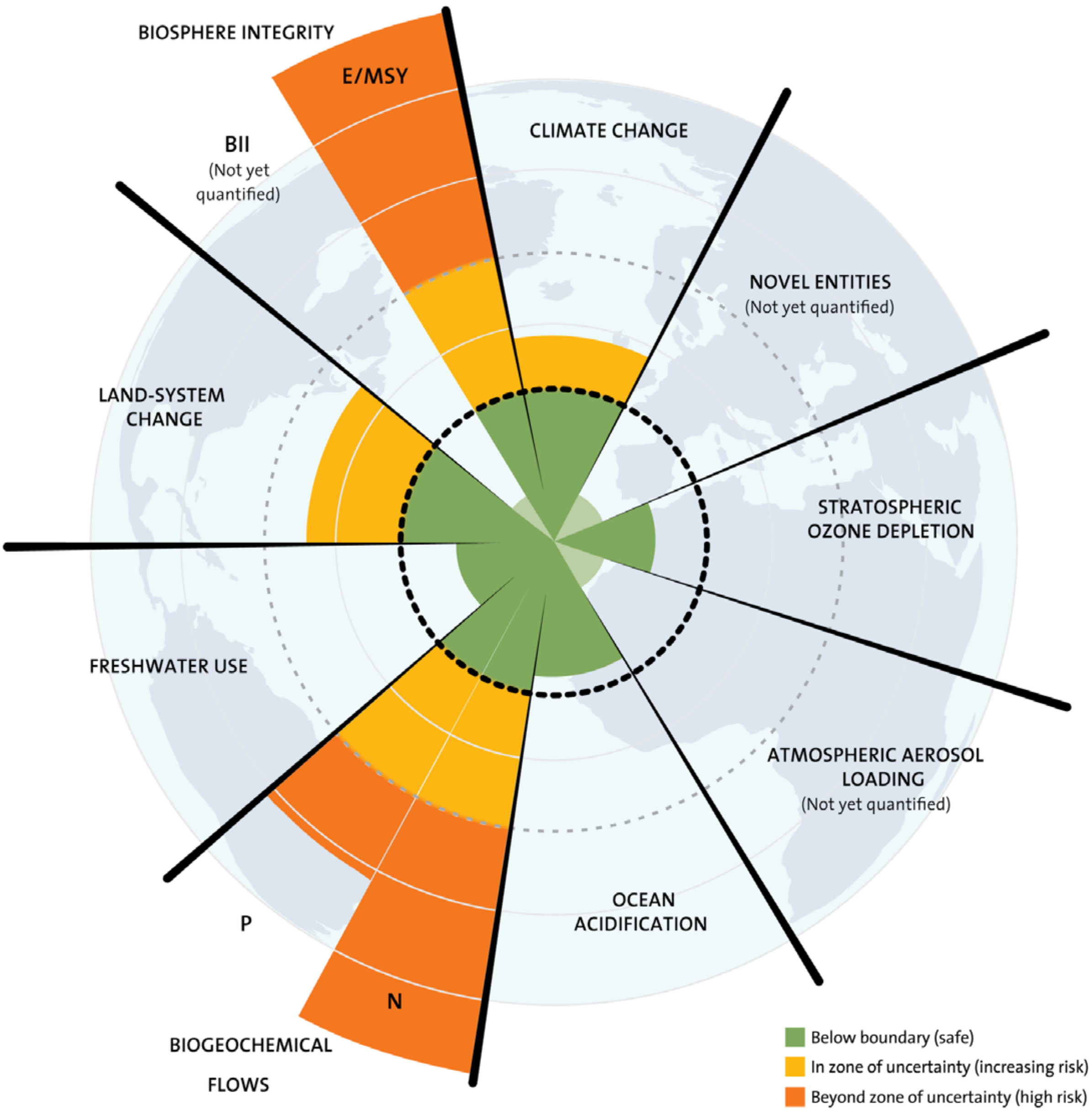


Figure 2: *The planetary boundaries model. Source: J. Lokrantz/Azote based on Steffen et al. 2015.*

Use of windmill blades (Pathway 7)

Thousands of used windmill blades are piling up in landfills annually, and no proper way for recycling them has been created so far. It is not difficult to see that those blades could easily be converted into wing sails. Use as a sail is less demanding for the blades, so they could still have a long service life ahead and produce vast amounts of renewable energy, replacing the use of fossil fuel. This type of wing sails could be used as auxiliary propulsion devices in various ships (tens of thousands of compatible ones exist) right away, compensating partially for the use of fossil fuel. Countless piles of old windmill blades exist out there. There is no reason why this couldn't be done today.

Accepting unsustainability (Pathway 4)

This should be taken to mean that partial unsustainability is accepted, or unsustainability is allowed for a limited period of time. The principle is described in Buckminster Fuller's Operation *Manual for Spaceship Earth* (1969). Fuller wrote that daily consumption should be based on renewables, and fossil fuel should be reserved for the exclusive function of getting new life supporting machinery built. One interpretation of Fuller's ideas is, that he understood that the constant use of fossil fuel and non-renewable materials connected to pollution will inevitably lead to an ecological bankruptcy.

Creating the ideal product based on sustainable goals (Pathway 3)

According to the concept of ideality, an ideal [technical] system is one, where the function of the system gets fulfilled without the system itself. For example, holographic stickers are used as an antitheft device on product packages. Such a sticker consists of multiple polymer and metal materials and needs a specific machine for applying it on the package. The very same function can be fulfilled by embossing an optical grating directly on the package material itself. No material whatsoever is added to the system, and still the function is performed, actually better than by using stickers.

- **Pathway 9/10. Control your emissions.** Minimize emissions and compensate for any remaining emissions.
- **Pathway 10/10. Aim for a *more than* sustainable product.** Create a more than sustainable, carbon negative product, a carbon sink. Is this principle applicable to other emission types than carbon?

Even at first glance, some of these pathways are clearly more sustainable than others. We chose a few of them for closer inspection based on which ones might prove most fruitful.

We looked at the pathways from the point of view of future generations in world where sustainable development is already underway and tried to introduce some ways these pathways might be used as design principles.

The meaning of paths

As you see, these principles have been combined in many ways and not used in their pure form. Or even explained only in theory. Is there a reason why these principles are rarely used? We have seen that complexity, and complex technical devices, is a product of the industrial revolution and one of the key elements that should be changed. Simple solutions may lay in the far history of the industrial age when complexity was not easily achieved and unfunctional products were rarely created. It may have to be accepted that some modern standards have to be decreased or replaced completely to get on a sustainable path.

Our solution to get human technologies to a sustainable path is quite simple. We have to keep increasing the level of sustainability of our products and technologies until they are fully sustainable. First from the point of view of the environment, and later on a wider scale taking into consideration the environment, society and economy.

We all have a role in sustainable development

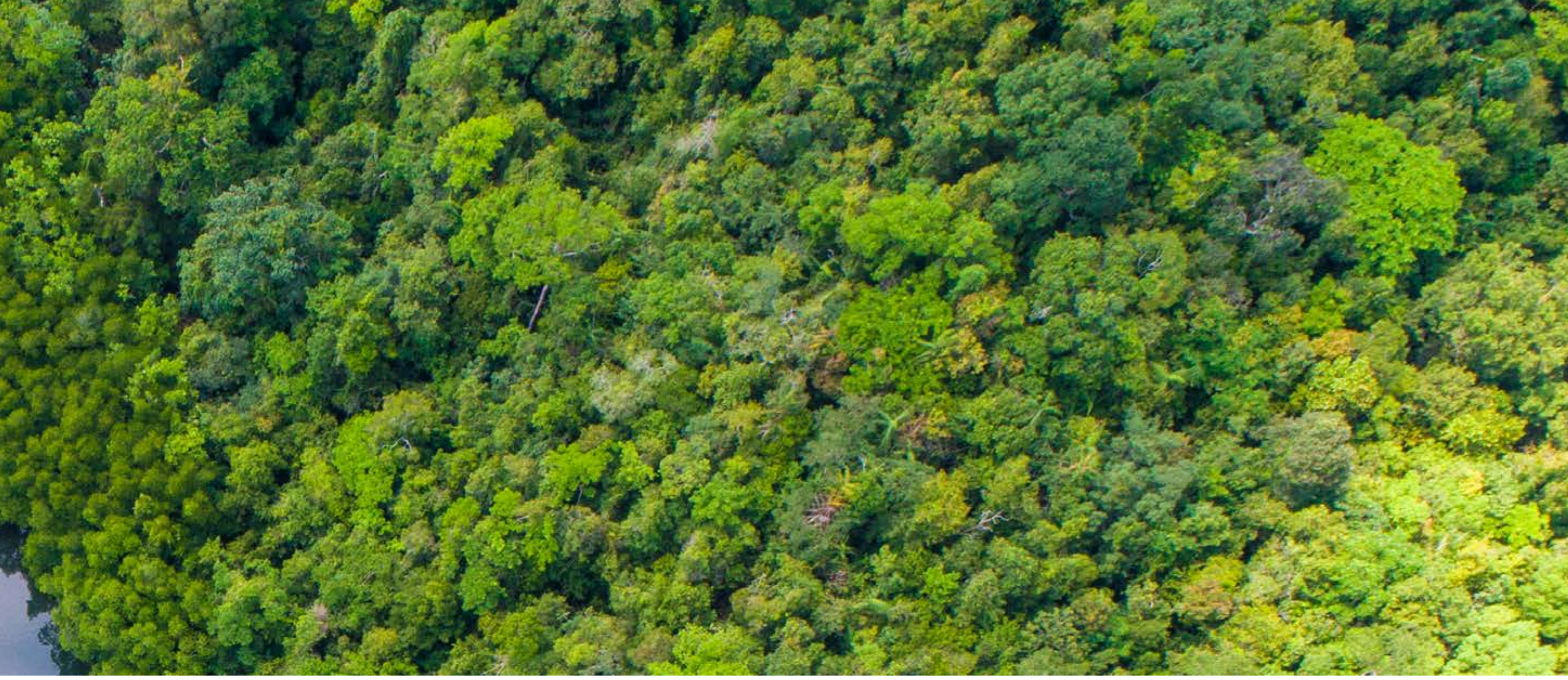
In this article, we have introduced ways and methods that lead to the path of sustainable development. The keys to the future are in our hands when we are making decisions about future products and technologies.

Sustainability will be integrated into every decision that we make in the future, and you can start with small details or with deeper strategic thinking depending on your role.

Decisions that let nature recover and recapture human based carbon emissions and traces of human land use might even be free and happen without human involvement in some areas if we allow it. In other places, human intervention is needed in order to facilitate regeneration.

The wildest dreams of technological solutions to tackle climate change and revolutionize our daily life, such as inhabiting Mars, are interesting and exciting. But they beg the question whether they will be available readily enough to make a difference and tackle problems on a wider scale. Maybe the better solution would be to create pathway solutions that improve products and technologies and take us one step closer to achieving sustainability.

While many new technologies genuinely do work to create a cleaner, more sustainable future, we cannot let ourselves be so intoxicated with our unwavering believe in technology, that we close our eyes to the fact that more sustainable choices must be made now. What could you do to make your product more sustainable? And what's stopping you? ◣



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Design for circular economy a solution for increased sustainability? (Pathway 1)

Päivi Kivikytö-Reponen & Marjaana Karhu, VTT

Keeping materials in use, retaining their value as high as possible, and avoiding material degradation and waste, are the key strategies of circular economy. However, currently, the average lifetime of many devices is relatively low, as the rapid technological development of devices leads to outdated solutions in a few years' time. Still, e.g., the use of digital applications and digital devices continues to grow due to increasing amounts of content in digital format.

Furthermore, many materials used for digitalization and the required devices are challenging, such as critical, conflict and hazardous materials. Due to overcoming these challenges of electrical and electronics sector, the importance of design for circular economy is currently acknowledged. **For example, from a sustainability perspective, the design phase may determine as much as 80% of the environmental impact of a product.** (European Commission, 2014). Typically, circular design strategies cover 'narrowing', 'slowing' and 'closing' the material loops. These are the strategies that can be the bases of business models in material, product and service design.

First of all, **the materials should fit to circular systems**, and therefore, it is essential to take into consideration and understand the whole lifecycle of the materials. **It is sometimes forgotten that circular systems require both circular materials and circular products, therefore both circular material design and circular product design are important steps.** *However,* there seems to be more literature about circular product design than circular material design concepts. The key product design concepts and terms of the 'design for circular economy' of have been reviewed by Hollander et al. (Hollander 2017) stating circular product design encompasses both design for product integrity and design for recycling. Product integrity covers longer lifetime strategies such as design for emotinal and physical durability, design for maintenance and upgrading and design for repair, design for refurbishment and design for remanufacturing (Hollander 2017).


NavVis
V98micro

iReality3D: Mobile scanning – digitizing industry

Text: Niko Kuosmanen, Samu Sundberg

The service solution iReality3D produced with mobile scanning boosts the maintenance, communication, security and modification management of your production sites in an agile way. The visual digital twin solution is available to you wherever you are, as long as you have an internet connection.

The benefits of laser scanning in generating initial data for modification planning have been undeniable for years. As technologies evolve, grey-scale scanning is becoming a thing of the past and the visual presentation of data is becoming increasingly important. Today, collecting 360° HDR panoramic photos during colour laser scanning is commonplace, and there are already many good solutions for using the data.

The challenge in many user environments is the sensible handling, sharing and huge file sizes of collected data. In large projects, there can be up to several terabytes of laser-scanned material, and the simultaneous processing of such a large amount of material between several parties in real time is very challenging. Materials are often accessed from external hard drives that are under the control of

> **SLAM technology enables fast and accurate 3D data collection and is particularly well suited for mapping complex spaces.**

specific users, and the sharing of materials between different parties in a project is not always smooth.

Data sharing and user management can now be solved with a cloud-based SaaS service, **Elomatic iReality3D**, which takes into account several different uses and user needs.

The comprehensive service is based on mobile on-site scanning and processing the material into a ready-to-use cloud service application. User rights and different user categories for various parties are created in the secure service according to need. Users do not have to download or manage heavy files on their own computers, as the material is directly available via the cloud service through a web browser.

The scanning material traditionally collected with plant scanners is mainly used as initial data for modification planning. The more agile mobile scanning and service platform enable a wider range of uses during the completion and use of the site. It is also possible to include material produced with other scanning methods, such as plant scanning or drone mapping, in the service.

SLAM

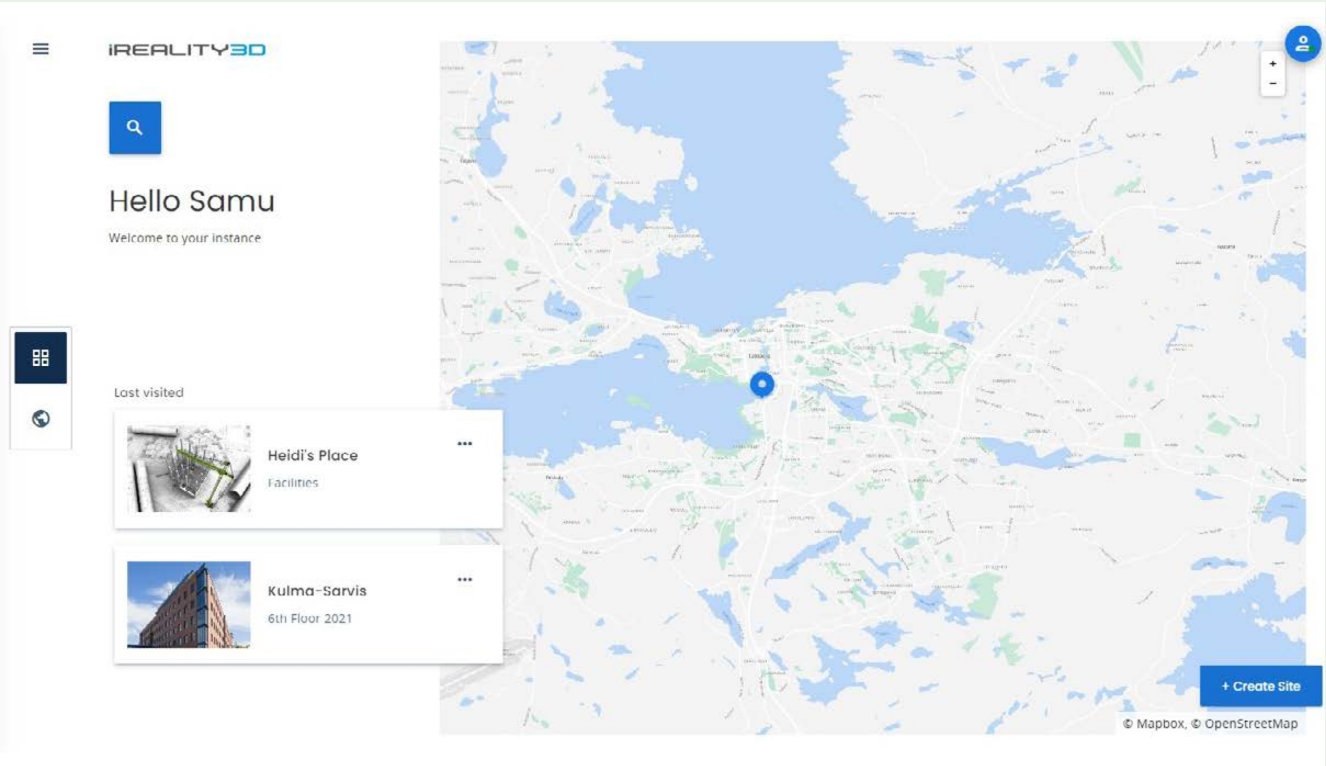
The mobile scanning solutions utilise SLAM (Simultaneous Localisation and Mapping)-based technology, which was originally developed in the robotics industry and used in self-propelled vehicles. In SLAM technology, the algorithms continuously utilise information from sensors that scan the environment to determine the location of the device and map the environment.

SLAM technology enables fast and accurate 3D data collection and is particularly well suited for mapping complex spaces. SLAM technology works particularly well in spaces with a wide variety of shapes and environmental features. Many measurement algorithms can become confused in fully open spaces where there are not enough identifiable objects or they are identical or too similar. A long, open tunnel, aisle, or an empty car park with dozens of symmetrical pillars can present slight challenges, which, however, are always solvable.

Accuracy

Mobile laser scans are bound to local or general coordinates using known points measured with a tachymeter or coordinate points based on satellite

Software as a service (SaaS) cloud solution provides easy access for users world-wide requiring only an internet connection.



measurements measured with a GNSS device. The use of these control points also ensures overall accuracy, so that errors do not recur and the data is not twisted or stretched incorrectly. Depending on the conditions, the accuracy of the point cloud produced by mobile scanning using control points is about 8–15mm. Correspondingly, mobile measuring has more error factors than a plant scanning performed with a fixed tripod, due to which the exact same accuracy cannot be achieved. However, there is a place for more traditional plant scanning, too.

The trump card of mobile scanning is the speed of the measurement event. The measurement speed achieved with mobile scanning is up to tenfold compared to that of traditional plant scanning. During scanning, 360° photos are also taken at the desired shooting frequency. Thanks to SLAM technology, an automated process places the 360° photos in their correct places, creating flawless maps for easy navigation. Thus, mobile scanning often outperforms more traditional 360° photography with its agility and automation, even if there is no need for 3D data.

Features

In the interface, the user navigates in either 360° photo views or a 3D point cloud, assisted by floor map views and layer selectors. With the measuring tool, it is easy to measure distances, shapes and areas. In the application, POIs (Points Of Interest) can be created and categorised in feature groups to facilitate search functions. External information, such as images, videos, documents or even real-time data from IoT environments, can be linked to each POI. The application can be used on mobile devices, and route guidance is available. The user is able to download the 3D point cloud of the desired area directly from the service for use in third-party point cloud applications for modification planning or manufacturing analysis. The user management function allows to create different levels of user rights from administrator to content producer or viewer.

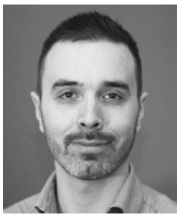
Why

Since mobile scanning is a fairly quick procedure, it usually does not interfere with production. After the scanning, virtual factory visits are possible from anywhere at anytime, and they can be arranged for any desired party without anyone having to travel. The application can be used to organise user training for new employees or tours for various visitor groups in good conditions and in an comprehensible and safe way. The application can be used for installation phase audits, safety assessments or planning for future maintenance activities without an on-site visit. It can also be used to easily present, for example, production premises for sale with their dimensions or as a marketing and presentation application for new properties. Situational awareness is improved and the risk of misunderstandings is reduced, time is saved and travel expenses are reduced.

Industrial sites are always a safety risk for workers and, in particular, visitors, which is why the method is particularly well suited to sites where it is especially difficult to arrange safe visiting conditions and permits.

As mobile scanning is a rather agile measurement event, the method is also suitable for repeated measurements, e.g. for recording different intermediate stages of construction. In this way, things that are hidden during the construction process can be documented for future needs.

Thanks to the development of sensor technologies and agile server solutions, various scanning technologies have become more common and methods are being used more effectively to serve modification planning as well as the management of the site throughout its lifecycle all the way to training, security, communication and marketing. ◣



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Niko Kuosmanen has worked on measurement solutions since 2007, at Elomatic since 2019. In addition to work, Niko is also completing a master's degree in the field. Over the years, Niko has accumulated solid experience in engineering measurements, production plant measurements, ship measurements and infrastructure and construction projects. At Elomatic, Niko works as an expert in laser scanning and is responsible for the mobile scanning service.

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/// CASE STUDY

Ship simulation in rough seas

Text: Teppo Aro

Visualization of Superfast III in irregular waves.

Background

The Elomatic technical analysis team has been developing and testing the methods for ship hydrodynamics simulation in rough seas.

The ships sail most of the time in wave conditions which differ from the specified promised speed test conditions. The calm sea conditions are closer to reality for very big ships, as typical wave conditions and their impact remain relatively small. However, for a ship scale with a length of 100m and under, the wave impact on ship behavior becomes more essential. To design ships of that length and meet real conditions with as high performance as possible, the computational dynamics should be used as much as for calm sea conditions.

Nowadays the ship hull form is usually optimized with Computational Fluid Dynamics (CFD) in calm water simulations. CFD optimization allow a huge number of alternatives to be simulated and tested during the process. These results are then factored into the other requirements to meet optimal solution for the ship design.

Estimating hull performance is an important part of the ship hull design process for any vessel type. It influences all design disciplines, so figuring out the main hull shape early on in the concept design stage is crucial. Ship design is highly interconnected, so changes in space reservations for ship functions can cause changes to hull main particulars, which in turn affect to the power requirements and so on.

Once the hull shape is optimized with CFD and other design work has been started, model tests are performed for the hull. Usually these contain all of the necessary tests to fully evaluate the hull. Hull performances are tested in calm water as well as in some of the most demanding sea conditions to check that the ship has met the requirements for motion, slamming and rolling. Based on these results, in practice only a few minor adjustments are available for hull modifications, as late changes to the design increase the cost and delay the schedule easily.

Development project

The development project included several stages starting from the literature study and test cases with simplified geometry, ending with a comparison of model scale measurements and simulations in rough sea conditions. In between, different sizes of vessels were tested and simulated in demanding circumstances to find the vessel size impact on the simulation results or behavior of the simulation models.

Floatable steel island

Elomatic's innovation for a floatable island was chosen for the initial simulations. The island is located in shallow water with a fixed position, allowing a good starting point for rough seas calculations.

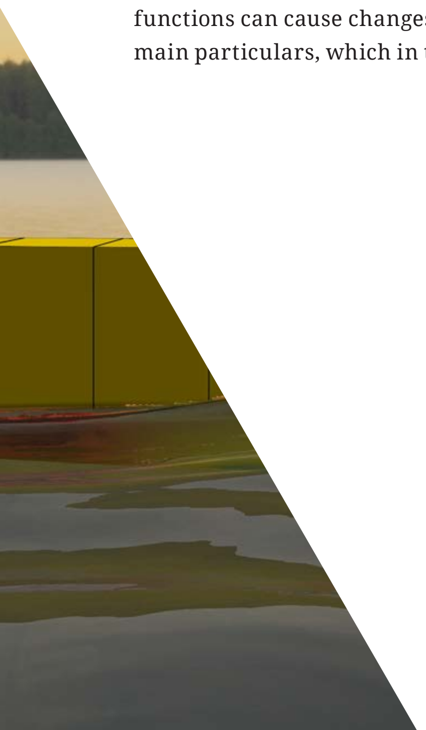
The simulation model was selected to serve our development work done for the islands, to get wave loads in realistic sea conditions.

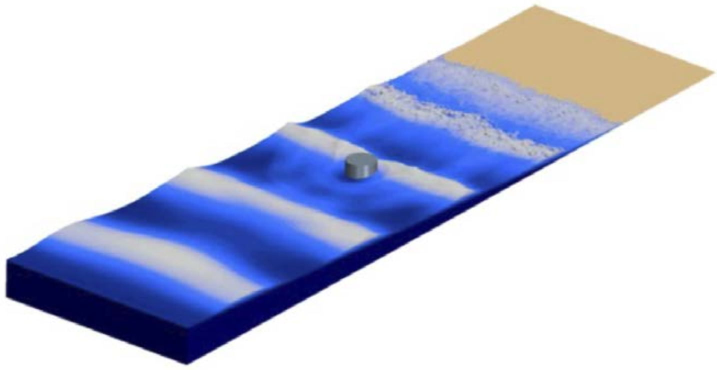
Our calculation team's main target was getting the simulation process to work decently and of course to get realistic wave conditions simulated and structure loads analyzed for the island in this case.

The visualizations derived from the simulation results match expectation well, supporting the impression that the model should be working as intended. The details detected in the animation made in post-processing show even small splashing observed in the figure captured from the animation. The island drag forces generated by the waves were in good agreement with literature values for a cylindrical obstacle. These are quite rough estimates, but they do show that the results are in the ballpark of what is expected.

Model scale measurements vs full scale simulations and sea trial

Simulations were carried out for a 200-meter-long sea faring vessel. The vessel chosen is Superfast III (she has a sister ship, Superfast IV) which is a Ro-Pax-type vessel completed in 1998 in a Turku shipyard. A full hull model and Napa models were available for the simulation model, and MARIN's model test reports for maneuvering,





Waves hitting the floatable steel island.

seakeeping and calm water were available to use for comparison as well as the observations from the sea trial (Published in Meyer Turku's hydrodynamics training course 2016/ R. Hämäläinen). The vessel was simulated in both regular and irregular waves, with fore waves in both cases and two oblique directions in the regular waves.

The vessel has a wave-damping afterbody, which was a new type of design during its production. This meant that the model testing did not have a close match for a reference vessel, which in turn lead to an overly conservative estimate for the vessel's top speed. In sea trials and in use the vessel managed about 2 knots higher top speed than predicted by model tests, but the motions and stability were within the predictions.

Several different wave lengths were simulated in regular wave cases, with a few different methods. Modeling self-propulsion with an actuator disc was found to be most suitable way for accurate results considering the computational resources needed. The simulation results with actuator disc were very well aligned with the model tests in vessel motions. More simplified methods were also tested. According to the results from these, they could be useful in some rough estimation studies because of the quicker run-through time.

> **In this R&D project, we found methods to provide a computationally effective way for simulating under-100m ships in realistic sea conditions.**

A few irregular wave simulations were run to estimate the power requirement in different sea conditions. The wave-added resistance matched that of the model test closely, but with the calm water result aligning more closely to the sea trial corrected values. This means that the simulations could predict the performance in several sea states more accurately than the model test.

Vessel size impact to simulations

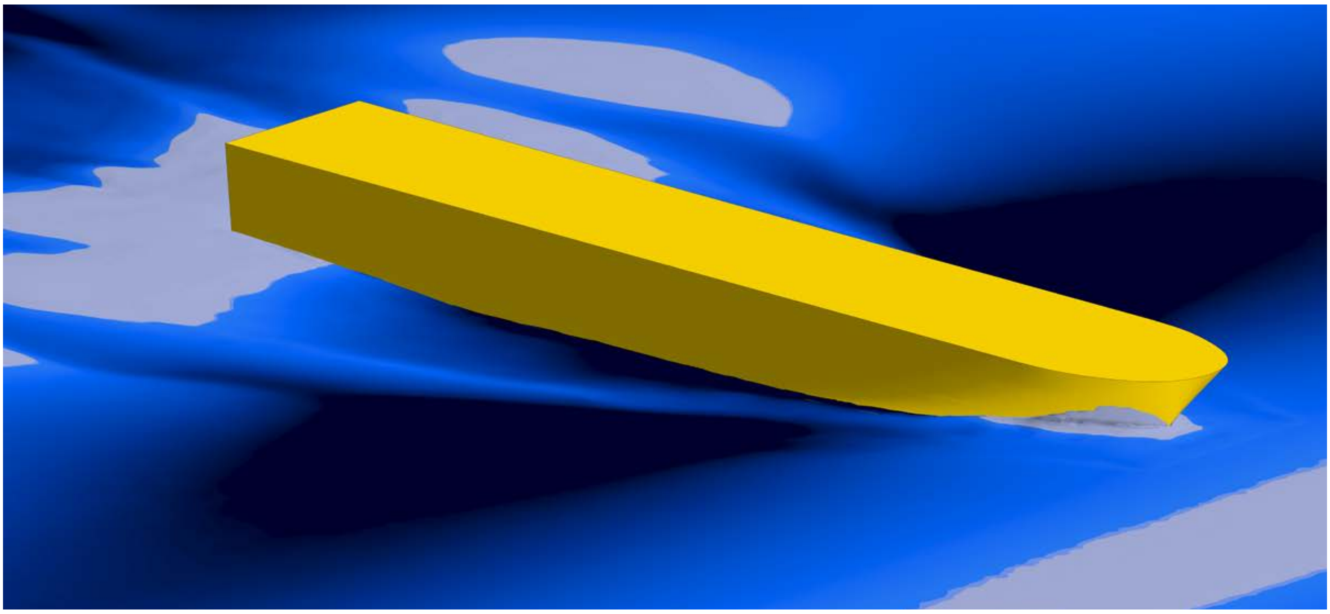
Rough sea condition simulations were run for the 100m patrol vessel and the 20m patrol boat, but only in regular waves. The simulation method was selected after several tests completed for the alternatives existing. The most promising method satisfied the reliability of the simulation but also kept the calculation time reasonable.

A structural model existed for the 20m patrol boat providing an opportunity to combine structural simulation with fluid dynamics. The fluid structure interaction (FSI) allows detecting the highest loads contributed by the rough sea conditions to the boat structure. In an FSI model, the loads from the CFD solution are transferred as boundary conditions into the structural analysis, in which they can be used to analyze the fatigue and vibrations of the structure over a specific wave condition. The simulation method was found to work nicely giving reasonable results, however at the moment we would need to get proper data from measurements in similar conditions to evaluate the outcome of FSI simulations.

Conclusions

The simulations for ship hull shape optimization in real sea conditions is not a common practice yet, as big ships usually behave in a similar way in calm seas as they do in most

Wake formation of Superfast III in regular waves.



typical wave conditions. For ship sizes below 100m, the wave impact becomes more important when optimizing the ship hull, when the ship movement increases.

In this R&D project, we found methods to provide a computationally effective way for simulating under-100m ships in realistic sea conditions. The sea conditions have impacts on the requirements of the ship hull forms, providing wave-contributed structural loads from the CFD simulation to be used in FEM analysis.

The comparison of Superfast performing in different sea conditions were in relatively good agreement with model tests. The max speed detected in sea trials was underestimated in model tests, while simulation results at full scale did not differ much from the observed speed.

This work has provided Elomatic great insight into the ship wave simulations, and in the future we can offer an array of new simulation products for our customers.

With these new tools, we can design better performing ships in a more effective way, with increased accuracy from sea conditions included in the modeling. ◣

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Teppo has 7 years' experience of working in fluid dynamics consulting. Experienced in a wide range of different types of simulation projects, covering everything from in-cylinder simulations for combustion engines, waste water simulations to polymer extrusions. His main focus is in marine simulations with emphasis on hydrodynamics and performance. Teppo joined Process Flow Solution in 2014, which was acquired by Elomatic in 2017. He currently holds the position of Consulting Engineer in Technical Analysis team.

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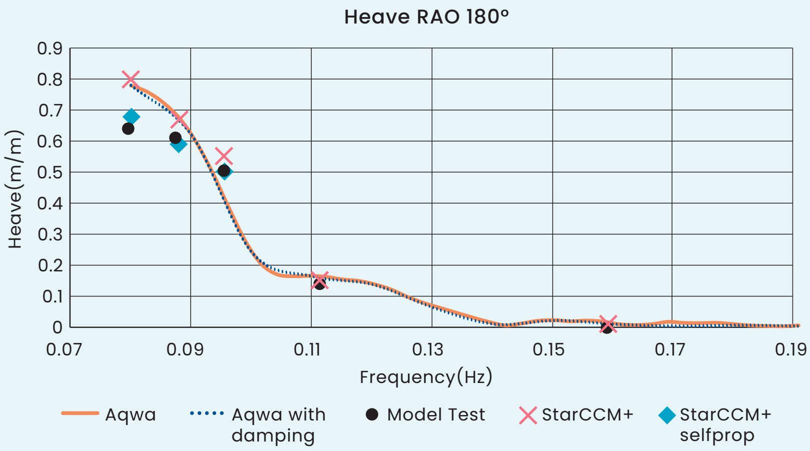
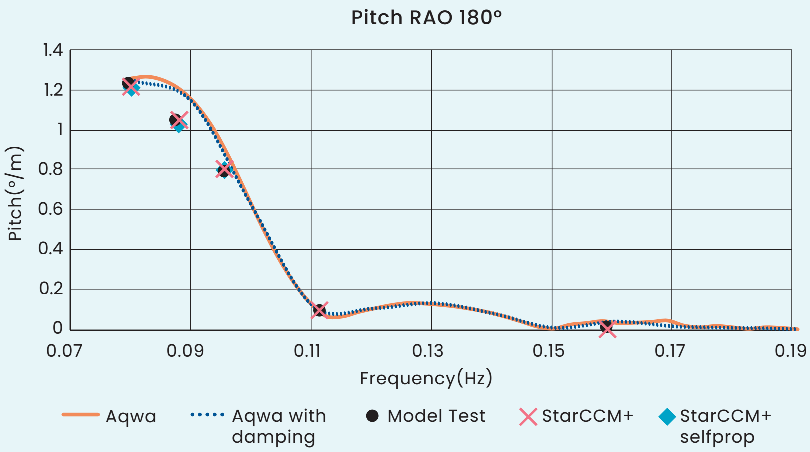
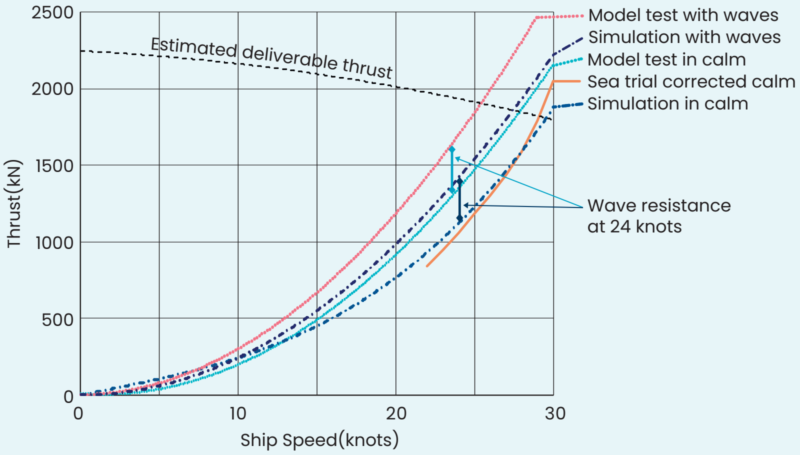


Response Amplitude Operators calculated for Superfast III with different methods in heave direction.



Response Amplitude Operators calculated for Superfast III with different methods for pitching angle.



Hull resistance in calm sea and a single sea condition, comparing the model test, simulation and sea trial corrected values.

Ammonia fuel for carbon-free shipping?

Text: Mika Vuorinen

The maritime industry often ranks high when comparing global greenhouse gas emitters. But when measured by tonnage of transported goods, the benefit of the global shipping industry becomes even more apparent. Energy demands on the maritime sector require a bunker fuel to store energy for long periods of time in order to move the vessel and sustain the people onboard. Alternative fuels are one method to decrease the reliance on fossil fuels and to cut emissions. Low-carbon fuels can motivate growth and bring new opportunities to the maritime industry ranging from shipyards to component manufacturing, bringing a green transition to the business.

The industry's development is not waiting for new technologies to make a breakthrough on the energy utilization front. Fuel cells, solid-state batteries and small modular nuclear reactors will have a major impact once the technologies have been proven reliable, but in the meantime the transition away from fossil fuels is already taking place at an accelerating pace and the preparations for future implementation have already started. To fully utilize a vessel over its lifetime, a newbuild ship in the 2020s should be designed to allow a simple transition to adapt to more energy efficient technologies and evolving regulations. The initial step towards the goal here is to concentrate on the energy carrier on board the vessel, beyond natural gas.

In June 2021, I wrote an article discussing the necessary steps towards the utilization of hydrogen as a bunker fuel and the lifecycle emissions of hydrogen production. To recap, hydrogen as an energy carrier for maritime use is the first step towards a carbon-free maritime sector. An economically viable leap towards a hydrogen-economy requires production of hydrogen from purely renewable energy sources and rapid transition from natural gas-based grey hydrogen and carbon capture-proposed blue hydrogen to green hydrogen. Relying on grey and blue hydrogen as the main source of hydrogen will affect the end-goal and can lead to a higher environmental load than the utilization of the initial source-fuel. Hydrogen gas and liquid are especially challenging to store, and alternative ways to store hydrogen are being actively sought.

The pivotal role of green hydrogen in the transition away from fossil fuels is in finding a sustainable way to store and transport it. Discussions today on which fuel will become the dominant energy carrier in the maritime sector varies between different fuels, and subjectively the prime candidates are ammonia and methanol. Both chemicals have well established infrastructure and transportation chains, as well as multiple uses as fuels. But most importantly, both have a relatively simple synthetic production method from hydrogen. We may have to wait for a balance between these two to form over a decade or two, and meanwhile we will have to follow the debate between different

> The pivotal role of green hydrogen in the transition away from fossil fuels is in finding a sustainable way to store and transport it.

camps promoting their own favorites and agendas. For this article I will be investigating ammonia, even though it comes a few years behind methanol regulation and in sense of maturity. But here I am all about reaching zero carbon emissions.

Well-to-Tank

Ammonia fuel is taking a further step toward physical hydrogen storage and toward converting the hydrogen to ammonia, NH_3, which in itself contains no carbon. As an energy carrier, ammonia is easier to store and more energy-dense than hydrogen, allowing more possibilities for maritime utilization. The annual production capacity of ammonia is close to 175 million tons, and new many ammonia plants have been planned and announced for the near future. All this ammonia is reserved for agricultural needs and the planned increase will serve the same purpose.

The current production method follows the Haber-Bosch process, which is the origin of the industrial production of ammonia and present fertilizers. Generally, the Haber-Bosch process takes methane from natural gas and nitrogen from the air, and with high temperatures and energy produces synthesis gas, which is further refined to separate hydrogen. The hydrogen and nitrogen produced are used to synthesize ammonia gas. The composition of ammonia, NH_3, is one of its major perks as it does not contain any carbon. The result of its simplified combustion reaction is water and dinitrogen, N_2. However, incomplete burning might result in N_2O emissions, which is a nasty greenhouse gas and the amount needs to be next to nothing for viable ammonia burning process. For possible NO_X emissions and NH_3 slip, a catalysator unit (SCR) should be considered.

An alternative method to produce ammonia starts from hydrogen and the storage of that hydrogen as ammonia for later use. The method of processing dinitrogen from the air into ammonia electrochemically is already being developed by multiple parties, and with these parties the efficiency of this step seems to be the key to reaching a similar level of viability as the Haber-Bosch process. The key for ammonia replacing fossil fuels as a carbon-free alternative is the realization of hydrogen production through sustainable energy sources. Well-to-wake emissions from ammonia produced by the current method are even higher than burning the initial natural gas.

Tank-to-Wake

The storage of energy as ammonia is not the first step towards sustainable hydrogen production, but from a maritime point of view, the availability

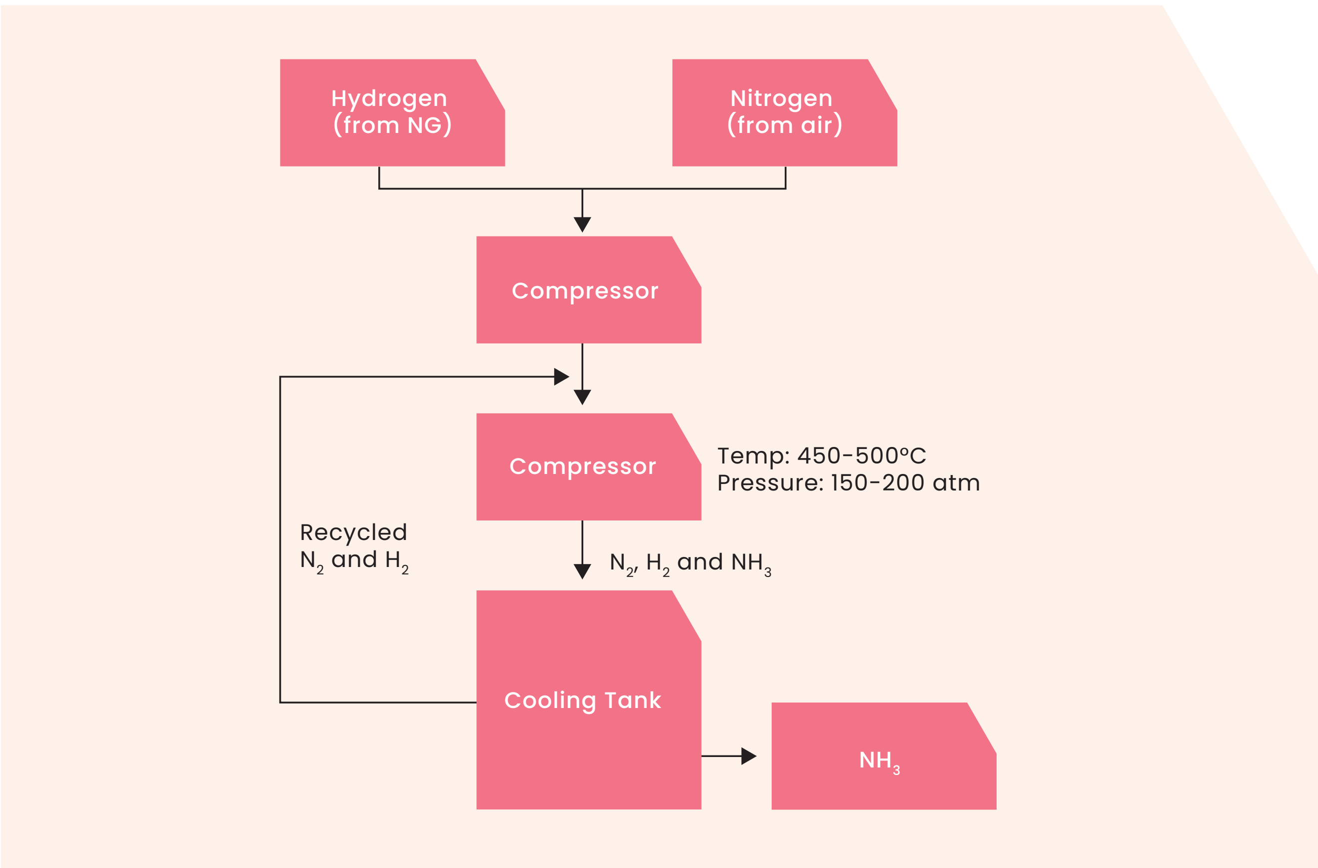


Figure 1. *Haber-Bosch process to synthesize ammonia simplified.*

of a stable, easily liquefied bunker fuel is welcome. Ammonia is liquefied at favorable conditions of 10 bars at room temperature or at -33°C at atmospheric pressure. In its liquefied form, anhydrous ammonia energy density is still low in comparison to fuel oil, weighting almost 1.5 times more and claiming over 3.5 times the volume, but it is stable and ready to be stored for long periods of time. The most appealing aspect of ammonia as a fuel option is the zero-carbon aspect of the emissions. Zero-carbon emissions for ammonia as fuel in reality is only the simplified version, as there is more to ammonia fuel utilization.

Ammonia burns like wet wood. The poor flammability of ammonia in maritime use leads to the need for a pilot fuel, typically diesel, which unfortunately shatters the image of ammonia as a carbon-free fuel. The pilot fuel will first be the readily available diesel oil, but also bio-diesels, LNG and even hydrogen make good candidates. With low-speed two-stroke engines where ammonia intake is optimized, there will remain a need for a more flammable substance to ignite the fuel. With medium- and high-speed engines the pilot fuel alone is not enough, and a blend with another fuel for improved ignition properties is required. Under certain circumstances this might become beneficial if a more unstable fuel is blended with ammonia, reducing the risk of explosion and fire.

The second challenge on ammonia storage comes from its toxicity. Unlike other low-flashpoint fuels, ammonia gas is not that explosive but is rather toxic, starting from discomfort and irritation to long lasting and life-threatening effects at very low concentrations in air. To prevent contact with the crew, ammonia is classified similarly with low-flashpoint fuel gasses and requires similar caution in storage and handling. Most importantly, what is needed is detectors, ventilation and double walling and isolation on equipment processing ammonia.

Thirdly, as a weak base ammonia is a corrosive substance, leading to the need for special storage equipment. This means the avoidance of copper and nickel and to the need of special stainless steel. Luckily, storing ammonia is possible for half of current C-type tanks on the market. The issue repeats with fuel handling equipment, piping, pumps and seals which will cause limits to the system design. Handled with proper care as liquefied gas, ammonia has potential to be the fuel of the future, ensuring the availability of sustainable ammonia.

Engine manufacturers are carrying out ongoing progress on ammonia engine development and report a market-ready engine for 2024. These engines from manufacturers such

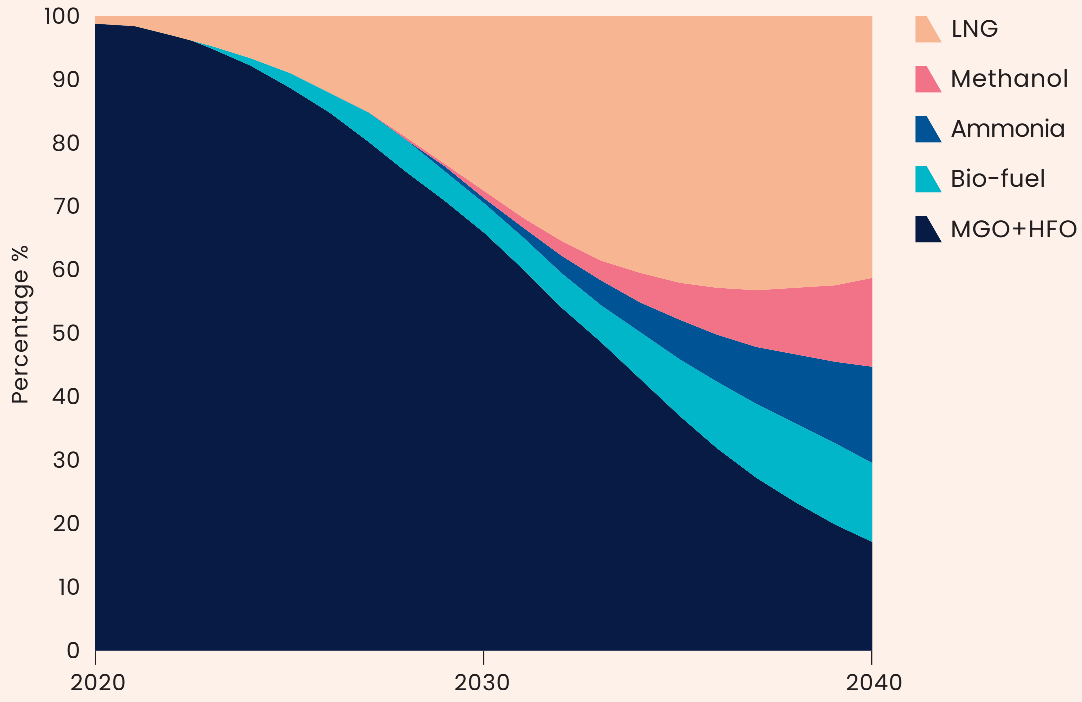
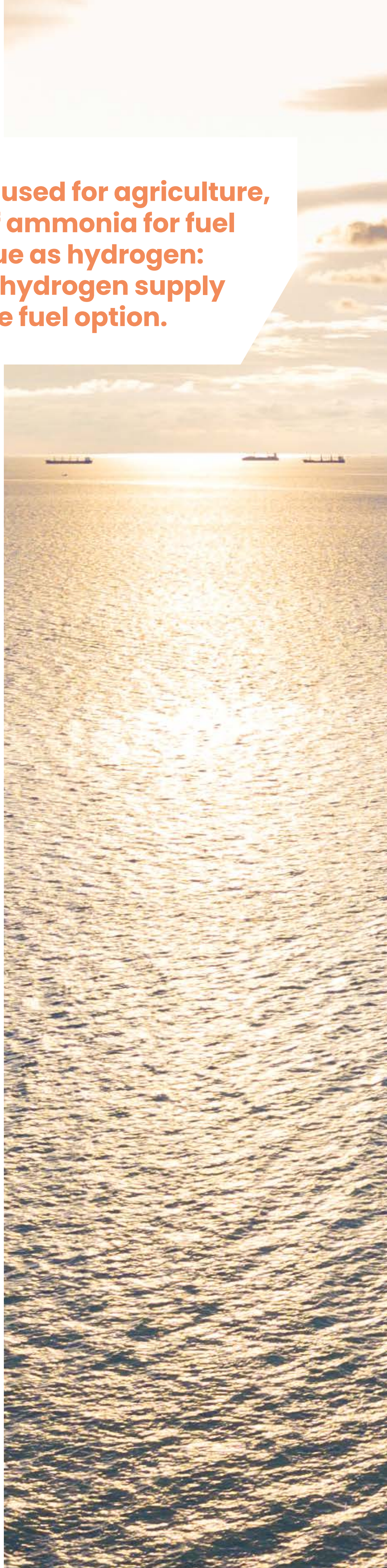


Figure 2. *Fuel transition forecast, DNV GL, Maritime Forecast 2050 (edited).*

Aside from being used for agriculture, the availability of ammonia for fuel has the same issue as hydrogen: awaiting a green hydrogen supply to make it feasible fuel option.



as MAN, WinDG and Wärtsilä have invested in bringing a series of ammonia burning dual fuel engines for vessels of various purposes. The system setup between each manufacturer is unique even though the options on fuel supply and exhaust have the same elements. The main issues to solve are pure combustion to prevent N_2O and NO_X compounds and to optimize the ignition for different engine sets. All parties agree on the upcoming transition in bunker fuels starting from the 2020s.

Summary

Ammonia-ready vessels prepared for conversion are becoming increasingly more common as a basis for new vessels, rapidly capturing the share of LNG-powered vessels. As LNG will still be dominant alternative fuel for newbuilt ships, ammonia is a very interesting environmentally friendly option without the extra emissions from methane slip, to which LNG is prone to. Conversion to an ammonia will require drydocking and replacement on the fuel supply system and engine, and possibly tanks. Room for ammonia tanks is almost double from LNG equivalent, which is a major design aspect that potentially reduces the cargo capacity on a vessel. With innovative design and engineering, there are many options to adjust the fuel tanks inside and outside the vessel so the extra space requirement onboard will be negated and a new generation of ships may surface.

Aside from being used for agriculture, the availability of ammonia for fuel has the same issue as hydrogen: awaiting a green hydrogen supply to make it feasible fuel option. Regardless, the upcoming regulations in the international maritime field on lowering emissions are driving the development of shipping towards less emissions. Even with the current method of providing ammonia being less beneficial in well-to-wake emissions in comparison to natural gas and oil, the engineering today will pave the way for rapid progress towards vessels emitting even less greenhouse gasses. The days of carbon-free shipping are within our reach, and the industry is prepared. ◣

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Mika's background is naval architecture from University studies and has 2 years of experience in project work. His thesis covers hydrogen economy and fuel cells in maritime industry and has been working with energy and machinery solutions for ship conceptual projects with implication of industry standard and novel technologies. Mika has also experience in ship general arrangement and port operations. He has worked as part of marine Life Cycle solutions unit in Espoo since 2019.

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