Project Title: Promotion of green maritime technologies and new materials to enhance sustainable shipbuilding in Adriatic Ionian Region

Project Acronym: NEORION

T.2.2.2 Identification of Technology Based Opportunities

WP: T2 Sustainable Shipbuilding Cluster

Executive Summary

The current report has been elaborated within the framework of the project "NEORION - Promotion of green maritime technologies and new materials to enhance sustainable shipbuilding in Adriatic Ionian Region", funded under the 1st call of Proposals of the ADRIATIC – IONIAN Programme. NEORION belongs to the Programme Priority "Innovative and Smart Region" with the specific objective to "Support the development of a regional innovation system for the Adriatic-Ionian area".

The main aim of the project is to establish a transnational Cluster in the Adriatic-Ionian on Green Shipbuilding that will accelerate both the cooperation of key actors & innovation in the industry and will both foster economic growth of the sector and benefit the regional business ecosystem, through actions targeted to and initiated by representatives of the Quadruple Helix.

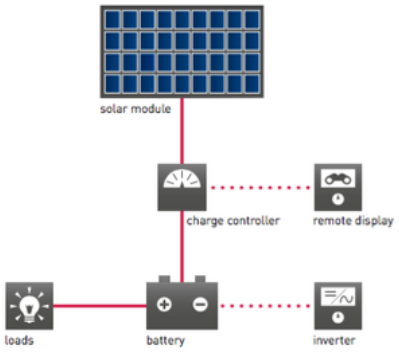
This report constitutes the deliverable "T.2.2.2 Identification of Technology Based Opportunities", which has as an objective the identification of common Technology Based Opportunities (TBOs), i.e. ideas for commercialization of "research based" products & services in the field of shipbuilding, ship repair, ship convention and complementary areas that enhance sustainability of the sector in the region. In total 57 Technology Based Opportunities (TBOs) are collected, as also foreseen by the Application Form and the instructions of the task leader for the partner.

Contents

Technology Based Opportunities

1. Solar energy for boats and yachts

The SOLARA Type M-Series is specially designed for boats. The non-slip, fully accessible and



resistant modules guarantee a reliable power supply in the sea, even without access to a power supply. The modules are designed for navigation, are extremely flat, accessible and flexible.

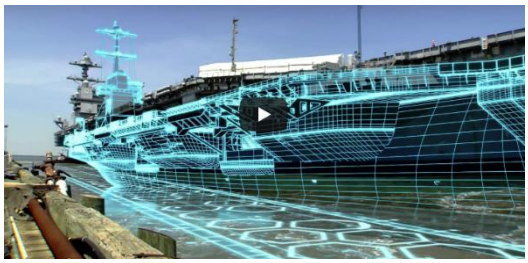
The main advantages of the technology are:

- Extremely high efficiency due to the use of monocrystalline cells with reverse contact with over 22% efficiency
- Yield is high in all seasons, even in diffuse light
- UV-stable solar connection cable as well as cable output

The technology based opportunity can be used as a power supply source utilizing renewable energy (sun) for sailing vessels.

2. Digital Shipyards

The aim is to apply specific technologies to specific phases of a shipbuilding lifecycle, which if used effectively will reduce the time to delivery (claims of up to a 43% reduction in time-to-market) and also improve safety and the end quality of the platform. The concept of digital shipyards employees technologies such as 3D Modelling, Industrial Internet of Things (IIoT), 3D scan, Augmented Reality etc and more



technologies based mostly on the fourth industrial revolution (Industry 4.0).

3. Additive manufacturing for Building Ship Components

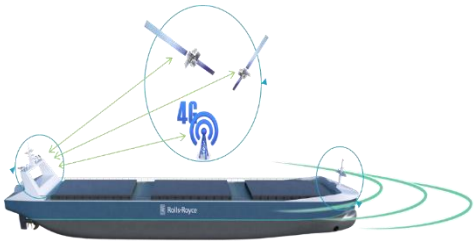
Additive manufacturing is best known as 3D printing. It provides the capability to print parts, jigs, templates and pretty much anything that can be digitally modeled and loaded onto the printer. In recent

advances of the technology, the printers have the ability to use more mediums than just plastic and the achievable size of the components is also bigger. Nowadays, a number of additive manufacturing platforms can create metallic parts in order to be useful for shipbuilding applications. This kind of technology can be very useful in shipbuilding both in the build and support phases of a ship's lifecycle. Instead of having to order parts when they are damaged they can simply be printed in-situ reducing the turnaround time for the repair, provided that a CAD model is available for the part.

4. Autonomous Ships

The term 'autonomous ship' is mainly used to depict a self-sailing crewless vessel, but there are actually various degrees of autonomy.

Safety4Sea has defined levels of autonomy, based on the classification done by Lloyd's Register:



- Manned ship – traditional crewed vessel with a human operator making decisions
- Remote ship – controlled by a human operator ashore
- Automated ship – running pre-programmed software and can only operate within the scope of the algorithm
- Fully autonomous ship – operating system can calculate consequences and risks, and make decisions by itself.

The advantages of autonomous ships are many. They eliminate human error, reduce crewing costs, increase the safety of life, and allow for more efficient use of space in ship design and efficient use of fuel.

5. Industrial IoT for Measuring Ship Operation & Efficiency

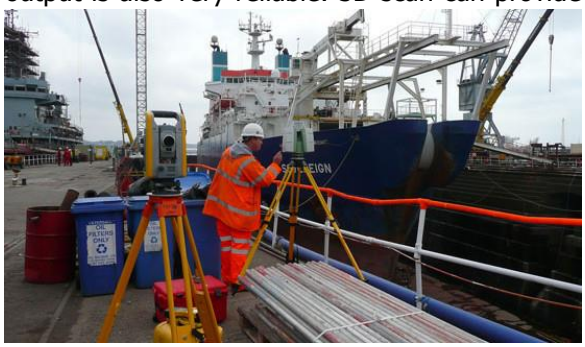
Industrial Internet of things (IIoT) is a very promising technology that is gaining traction in the shipping industry and has potential application in shipbuilding as well.

As one application, IoT sensors can be used onboard (Wireless Remote Monitoring & Performance Analysis system) to enable the diagnosis, prognosis, and timely alerts by collecting and transmitting data to the operations' center anywhere in the world in real time. In this manner, the vessel's yields are increased, while the safety and efficiency of operation are significantly improved. The technology can achieve about 3-6% less fuel consumption.

The technology can also work for predictive maintenance purposes.

6. 3D scanning for Ship Modelling

3D scanning is a technology that creates a digital environment based on a mapping to a physical version. Modern scanners usually use a combination of optics and laser using triangulation and time-of-flight to map out the physical environment. Time-of-flight determines distance using an algorithm involving the known speed of a laser, speed of light, which is extremely accurate and therefore the digital output is also very reliable. 3D scan can provide



a number of benefits in shipbuilding. The most significant in a shipbuilding scenario is "Retrospective Modelling".

Retrospective Modelling allows to quickly build a 3D design based on an existing physical platform. For instance, a compartment of a ship can be scanned, turned into a digital twin and then used for engineering change or other tasks. Effectively this bypasses the need for a draftsman to create the model from 2D diagrams.

7. Augmented reality for Ship design

AR is being developed for maritime applications and has been demonstrated on ship bridges and remote operating centres to deliver different levels of information to end-users. Rolls-Royce is using AR technology in its remote operating centre demonstrator in Copenhagen, Denmark.

AR is also able to speed up the build and maintenance phases of a ship's lifecycle since it simplifies the processes by getting rid of printed drawings of a ship and all the process that relates to it (requirements for portable printers, laptops, Wi-fi etc.). Maintenance activities can be significantly simplified by bringing up step by step routines in video to guide the technician.

8. Drones for Measuring Ships Emissions

A related application for drones is testing ship emissions. The drone must be equipped with emissions measuring sensors and potentially with different kinds of cameras (thermal, Photogrammetric etc.) so as to provide a full picture of the situation. There are commercial units available and being tested for these applications.

9. Robotic Ship Operation Process Automation

Robotic Process Automation (RPA) is essentially the application of Artificial Intelligence (AI) to processes. In shipbuilding, same as other industry environments, there exist tasks or processes that humans do that would be classified as repetitive, monotonous and inefficient (i.e. maintenance and other manual operations, such as line handling).

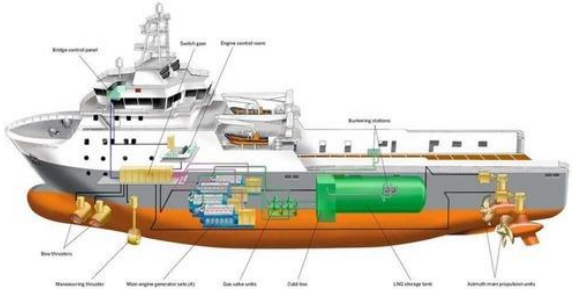
RPA can be exploited in such cases to focus at getting bots to do that repetitive work and free up significant time for humans to concentrate on more value add work.

Especially with the increasing trend for developing autonomous vessels, there will be greater need for robotics. It can also be used as a method to prevent workers from doing dangerous tasks such as welding.

10. LNG Fueled engines

Liquefied Natural Gas (LNG) increase in popularity as an alternate fuel for ships is getting so much hype due to its environmental friendliness and thus the market of LNG fueled ship engines is projected to be very high.

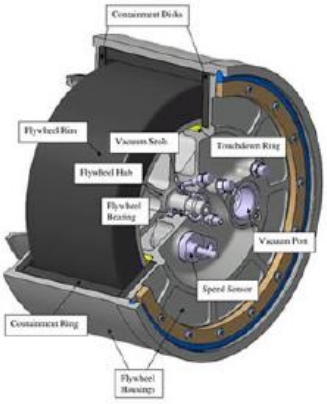
In the LNG engines, CO2 emission is reduced by 20-25% as compared to diesel engines, NOX emissions are cut by almost 92%, while SOX and particulates emissions are almost completely eliminated. Moreover, the TIER 3 restriction of



2016 introduced by the IMO, require this new generation of ship engines to be designed. In addition, LNG is also cheaper than diesel which significantly reduces the costs.

11. SeaKERS – generating electricity on boats by buoyancy

The amount of energy a yacht consumes means that sailors look to preserve as much power as possible, particularly on long journeys. Electricity consumption must be carefully managed in order to limit or avoid the use of onboard generators which, as well as being large, loud and possibly damaging to the environment, are not as reliable as they could be.



SeaKERS is an innovative device for generating electricity on boats by recovering the inertial energy created by buoyancy – the longitudinal movement of the boat caused by waves. The Kinetic Energy Recovery System (KERS) device is able to generate a surplus of clean, free energy for recharging batteries. The system works by following the wave's pattern and combines all the advantages of other renewable energy converters into a single unit, with added benefits.

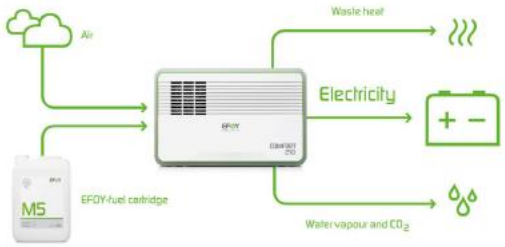
The SeaKERS approach involves:

• An innovative electric device , known as a Magnetic Flux Switching Permanent Magnet machine, that can be used both as a generator when recovering energy, and as a motor to put the SeaKERS device into the right position in relation to the wave. To harvest maximum energy, the device and the waves must move in time with each other.

• A dedicated system controller, which reads sensor data, computes the optimal trajectory for maximizing energy harvest and activates the power converter to kick into action.

12. Efoy

The EFOY COMFORT charges the on-board battery fully automatically. The integrated charge controller permanently monitors the charge level of the 12 V battery. If necessary, the EFOY COMFORT starts automatically and switches off again once the battery is charged. This gives more than permanently fully charged power reserves. Batteries will also last a lot longer because constant recharging protects them against a damaging exhaustive discharge. With an inverter, it can also operate 230 V devices. The



EFOY COMFORT produces electricity using the fuel in the fuel cartridge, adding oxygen from the air. In addition to the electricity, it only produces waste heat and water vapour containing an insignificant amount of carbon dioxide.

Every EFOY fuel cell employs DMFC (Direct Methanol Fuel Cell) technology which transforms methanol directly into electrical current. That's a real advantage, especially for mobile applications, because liquid methanol is easy to transport anywhere in practical EFOY fuel cartridges. It is extremely eco-friendly. EFOY COMFORT provides a reliable electricity supply on the road or at sea, irrespective of the weather and all year round - even at sub-zero temperatures. The developed insulation and the sound damping system ensure quiet operation. It supplies electricity as soon as all connections are properly made. All to do is to make sure that fuel is always supplied. There is not even need to clean or maintain the EFOY COMFORT.

13. Wind generators

Wind generators have a natural appeal to sailors in need of extra power. They harness the same element that we rely on to get from A to B, and the technology behind them is well proven and reliable. Despite the growing popularity of hydrogenerators and ever more efficient solar panels, wind generators are still a common sight on bluewater cruising routes.

At the outset, it's important to note the advantages and limitations of wind power for keeping the batteries charged. On the plus side, the generator will keep pumping out power at anchor or in port, as well as on cloudy days. It is also largely maintenance-free and requires no launch or recovery. These can be powerful units, churning out 400 watts of power or more—enough to charge 800 amp hours (Ah) of battery capacity per day on a 12-volt system.

On the downside, the world's cruising routes tend to be downwind, robbing the generator of some of its power. In fact, the relationship between wind speed and the energy it contains is cubic, so power decreases exponentially. To put that in context, a boat doing 8 knots dead downwind in 20 knots of true wind would experience an apparent wind of just 12 knots. A turbine might generate 40 watts in 12 knots of wind, but most manage 200 watts in 20 knots. Furthermore, ports and anchorages appeal to sailors precisely because they offer protection from the elements, so wind speeds will be lower than forecast offshore.

However, the power curves quoted by the manufacturers are usually based on results from smooth, constant airflow in a wind tunnel. Real-world results can be rather lower. That's why some cruisers with heavy power requirements opt to install two turbines, and most are designed to be easily connected in parallel through a single regulator. In order to optimize output from a wind generator, there are a couple of things to consider. First, it needs to be as stable as possible, because any pitching or rolling will temporarily rotate it away from the wind. Second, it needs clean air—as much of it as possible.

To some degree, these two requirements are at odds with one another. Wind speeds at the masthead can be 50 percent greater than at sea level due to wind shear, so the higher up to put it, the more power will get. Of course, the pendulum effect of a moving boat means that putting a wind generator higher up will increase the effects of pitch and roll. (This is less true of catamarans, which provide a more stable platform).

14. Wind generator combined with solar panels

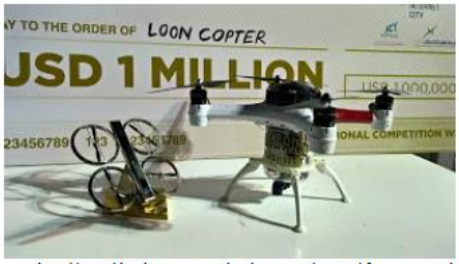
The most important decision when considering a wind generator for boats is determining whether or not there is generally enough wind to generate the power to satisfy your needs and it takes a lot of wind. Along the United States southeast and gulf coast, the average wind speed is less than 10 mph. To be realistic, the output from wind generators needs to be considered for winds between 10 and 12 mph. On gusty days, a wind turbine may put out a lot of power. The power available from the wind varies as the cube of the wind speed.

A wind generator or a solar panel can save fuel. The engine in a boat drinks almost as much fuel while just charging batteries as when motoring. Running an engine just to charge batteries can be tough on engines. An engine in a boat is generally not built to run efficiently below its rated level. Low level running causes excessive build-up on valves, shortening engine life. Instead of revving up all those RPM's just to charge batteries, it is much better to charge batteries with a wind generator or solar panel, or both.

A wind generator or a solar panel can also be a safety backup. If your engine is disabled or you have an outboard without charging ability and your batteries run down, at least you have power to run a radio or other instruments. After a few hours, you may have enough charge to start the engine. The best alternative may be a blended system with both a wind generator and a solar panel. Having both would protect your independence from having to continually charge your batteries by running your engine.

15. Drones for aerial flight, on-water surface and sub aquatic diving

The Loon Copter is a novel multi-rotor platform capable of traditional aerial flight, on-water surface operation and sub aquatic diving. The drone flies like a normal quadcopter drone, but can also land and rest on the water's surface, or it can use its props to push itself along the surface, pumping water into its buoyancy chamber, causing it to sink.



Developed by Oakland University, the drone can be used for many applications, including search and rescue operations, bridge foundation inspections, underwater pipeline inspections, tracking of oil spills at different depths, and marine life studies. Currently at proof-of-concept stage, the drone was successfully demonstrated in 2015. Its third prototype won the 2016 UAE Drones for Good competition in Dubai and was awarded $1m in funding.

16. Hydrofoils

Design a way to support the weight of five saloon cars on a plate the size of your desk on the water. That was the task that faced America's Cup designers in their bid to make the new breed of Cup boats fly. Getting boats to fly above the water surface is simple in theory, but tricky in practice and has challenged designers for over a century, but in the last decade one class appears to have cracked it.

At high speed, drag and seakeeping become big issues aboard any vessel, particularly offshore monohulls, and while yacht design has made some big steps forward since the days of hauling half the ocean behind in a pair of breaking quarter waves, there are other issues holding back performance.

Razor-straight wakes ironed flat by beamy after sections are clearly a step forward. Yet the problem for monohulls is that, as they slam and crash their way into the waves, keeping the

structure in one piece is a big challenge. Rising above the water's surface not only reduces drag, but might help to reduce structural risks and make handling at speed easier.

But today foiling is more popular than ever. The French tri-foiler and former world record holder L'Hydroptère was the first sailing boat to break through the 50-knot barrier.

Cruising catamaran manufacturers Catana launched a 59ft luxury cruising cat that has curved daggerboards that the builders claim produce half a tonne of lift at ten knots. The Dynamic Stability System (DSS), which uses a hydrofoil in the horizontal plane, doesn't aim to raise the boat out of the water, but instead uses hydrodynamic lift to improve its performance.

Super Foils 15, a unique boat in the world, the result of design, studies and testing of the highest level that hides a technological secret that will revolutionize the concept of navigation. Placed under the hull, flaps are allowing, while running, the lifting of the hull itself. Wings setting acts on the boat position on water as well, guaranteeing in complete safety very high top speed, extremely low consumption, and unreachable comfort as no other boats can claim if not supported by such a technology. The automatic leveling system keeps the vessel trimmed optimally making the passengers feel a new experience of comfort at high speed.

As the boat increases its speed the hydrofoils lift the hull up and out of the water, greatly reducing wetted area, resulting in decreased drag and increased speed. The system dynamically sets the foils optimal angle of attack.

17. Acoustic design of lightweight cabin walls for cruise ships

A separation structure between two adjacent cabins, comprising two partitions facing opposite one to the other, separated from each other by

an air gap. Each partition wall consists of at least one partition panel comprising: at least a first metal sheet made of an iron alloy and a thickness between 0.5 and 0.9 mm; at least one layer of soundproofing material associated to the metal sheet. The soundproofing material comprises mineral wool having a fibred structure with a content of non-fibred material of less than 1% by weight, an apparent density between 80 and 120 kg/m3 and a resistivity to airflow between 50 and 300 kPa s/mi. The layer of soundproofing material has a thickness between 12 and 28 mm.. The structure has an apparent sound reduction index R'w between the two adjacent cabins of not less than 43 dB ±1 dB. A panel of such a structure, a passenger ship with such a structure and the use of said soundproofing material are also described.

18. The manufacturing of a 100% recyclable sail-racing boat

A sailing boat operates in one of the most difficult environment for composite materials (with exposure to UV and salty water), adding to that the requirements of lightness and the mechanical solicitation the structure has to withstand.

LOOP 650: A sustainable cradle-to-cradle composite sailing boat built with Filava™ basalt fiber has been nominated for a JEC Innovation Award. GS4C Sustainable Solutions is building a 100% recyclable sailing yacht, designed to race in the 2019 Mini-Transat, a single handed race across the Atlantic Ocean. The boat will be

entirely made of sustainable basalt fiber and recyclable epoxy resin. A first phase of scouting for sustainable technologies was followed by weaving tests and lamination testing. Suppliers were selected among the ones sharing the vision for sustainable development of the two GS4C founding partners. The recycling process was verified in the lab at LinseT in Fano, Italy. The recovered fiber was sent to the fiber

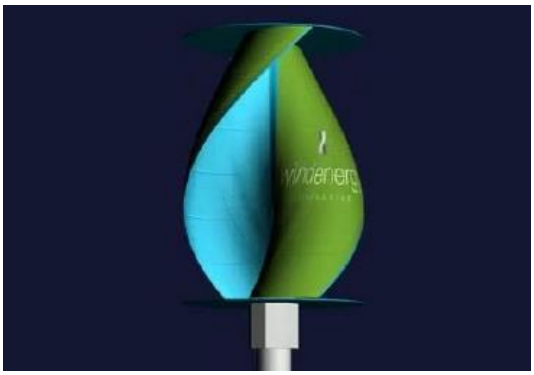
manufacturer to verify that it could eventually be re-entered into the production cycle.

The fiber is Filava™ from Belgian Company Isomatex S.A. The production of Filava™ is unique thanks to a genuine and innovative treatment of the raw material, basalt, which is enriched with various mineral additives to increase and guarantee its original mechanical and chemical properties.

The resin is Super Sap bio-based epoxy from Entropy, a high end solution with very low embodied energy when compared to similar fossil based products.

19. Vertical axis turbine sails

Wind Energy describes the device as a "drag-based" turbine – with its spiraling, upright "sails" grabbing the wind and being pushed into rotation. As it turns, energy is transferred from the sail surface to the central shaft in the form of torque. Since it has a relatively large surface area, the result is quite impressive, even in light winds. Like all vertical-axis turbines, the WindSail also has the advantage of not needing to be pointed to face the wind. As Wind Energy put it, the turbine is always facing into the wind. Other benefits are the low noise, bird-friendly and looks dang sharp. Moreover, much shorter vertical-axis



turbines, placed in a tight array with each turbine turning in an opposite direction to its neighbors, can be at least 10 times as efficient at capturing the wind power in a given area.

20. Keeping ship hulls free of marine organisms

Special underwater coatings prevent shells and other organisms from growing on the hull of ships, but biocide paints are ecologically harmful. Together with the industry, researchers have developed more environmentally-friendly alternatives. If a ship is at anchor for longer periods algae, shells and barnacles will colonize it. Every year, this so-called biofouling causes economic losses of billions of Dollar. Biological growth on the underwater surface promotes

corrosion. The deposits increase the roughness of the hull below the waterline which has a braking effect as the ship travels. Depending on the roughness of the basified bio layer, the consumption of fuel can increase by up to 40 percent. In the case of a large container ship this can result in additional annual costs of several millions.

All the countermeasures used to date have considerable drawbacks: Cleaning the hull by sandblasting in a dry dock removes also the

painted coating and can only be used every three to five years. There are effective hull coatings preventing the growing of adhering bio layers, but in most cases by ecotoxic biocides. Both copper ions and synthetic biocides accumulate in the coastal water and in the sediments.

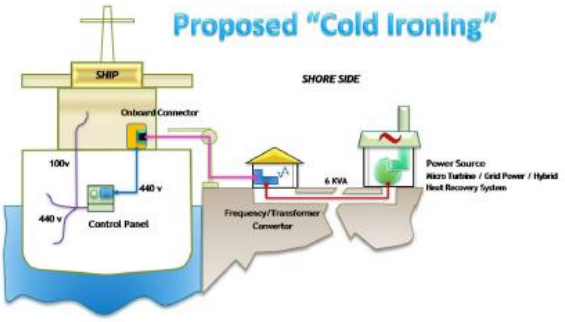
For this reason the particularly toxic tributyltin (TBT) is banned since 2008 and the currently preferred and still permitted copper oxide containing coatings are to be replaced by non-toxic alternatives in the foreseeable future.

Controlled Antifouling System based on Nanocomposits for Shipping is a more ecologically-friendly alternative. The electrochemically active coating system produces regularly changing pH values on the surface of the hull. This effectively prevents colonization without having to use any biocides.

21. Cold Ironing

The maritime-port sector contributes in a rather massive way to the spread of toxic substances in the atmosphere. According to some estimates, the pollution rate attributable to this sector would be around 13% on a global scale. Therefore, in order to resolve or at least limit the negative effects produced by this phenomenon, over the years the IMO (International Maritime Organization) has taken steps to introduce possible solutions.

Among the many, the most important one certainly concerns the stipulation of the so-called Marpol 73/78 convention (agreement including two international treaties, aimed at preserving the integrity of the marine environment), with which in addition to imposing on shipowning societies the use of low sulfur fuels, an attempt



has also been made to remedy the serious question regarding the accidental and / or intentional spillage of harmful material connected with the carrying out of maritime activity.

Also on the infrastructural side, on the basis of the above, it should be pointed out that many port calls in the world, and for some time also some in Italy (Livorno), have joined the ambitious project of electrification of the docks, a practice known also with the Anglo-Saxon expression of "cold ironing".

It is essentially an innovative system that ensures the electrical supply of boats moored in the port, while still guaranteeing full efficiency during parking, without the need to turn on the onboard engines.

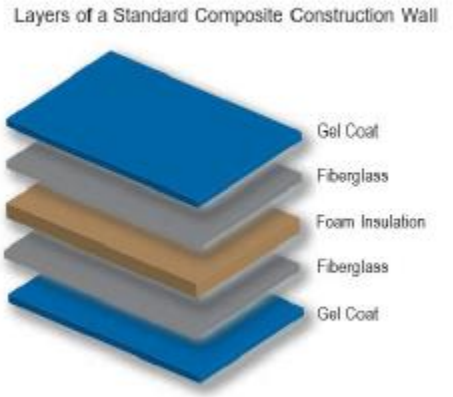
With this procedure the containment of noxious fumes is therefore potentially feasible, also with reference to the benefits for the public health of seaside resorts, which as we know in our country are certainly not few.

Within this context, the important mitigations from the point of view of acoustic emissions should also be included, a problem that is particularly felt especially in densely populated areas with a high tourist flow, like almost all of our port cities. However, despite the indisputable advantages that a greater implementation of cold ironing could bring in terms of pollution reduction, unfortunately some obstacles remain to its concrete use, both in terms of the works (on the ground) to be carried out, and in relation to the cost of the interventions to deal with for the consequent adaptation of the fleets.

22. The use of composite material in nautical applications

It's a known fact that composite materials are used in a variety of different applications.

Interestingly, composite materials have been used for decades not only in cars, aerospace equipment and air crafts. They are also used extensively in nautical vessels, electrical



equipment and consumer products. These materials have become an extremely popular and cost effective way of creating products that can withstand some serious wear and tear. In years past, composite materials were considered space age materials. A lot has changed since the days of the early composite history. No longer are composites considered space age materials designed for use in aircraft designed to explore the skies. Now, composite applications are used in a number of products. The approval of using composites in ships allowed shipbuilding companies to save money associated with building ships, which steel predominately dominated as building material.

The shipping industry itself saw some major benefits as well. Composites are cheaper to create then steel and their lightweight nature and strength allowed for decreased maintenance. Additionally, because composites are so lightweight, the ability to decrease fuel consumption was a huge benefit.

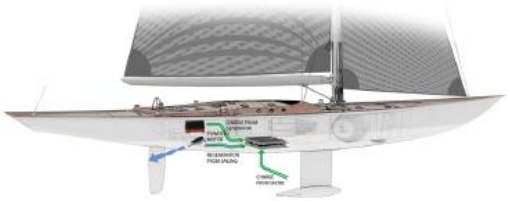
Once it had become determined that fiberglass composites could be safely used in the construction of ships, further attempts to use materials like carbon and aluminum were sought.To this day, shipbuilders are still experimenting with ways to use composites and further improve the fire rating and safety of these materials. While the rules for using composites in large vessels (ships) was changed in 2002, composites materials have been used for quite a while in the boating industry.

Fiberglass, a combination of a weaved cloth material and glass fibers were incorporated into the building of boats around the early 1950's. The catalyst to create a composite out of these materials was resin, which when mixed created fiberglass after it was set and dried.

23. Hybrid propulsion for nautical applications

Every sailor is familiar with the wet cough of the diesel engine, and the acrid smell of its exhaust. For some it's the sign that an adventure is starting, for others it is the reassurance that all is well on board the boat. The traditional engine is perhaps your boat's most important safety feature, but its days may be numbered. The electric sailing revolution is coming.

Even with the current crop of advanced lithium-ion batteries, the range of an electric system is measured in tens of miles, not hundreds. So a 35ft monohull with 10kWh of lithium battery (four units weighing 96kg in total) would have a range of just 24 nautical miles at 3.8 knots, or less than



16 nautical miles at full throttle. Taking into account the incredible wastage of combustion engines, which dissipate more energy as heat and noise than they provide in propulsion, diesel is still ten times more energy dense than batteries.

The traditional diesel engine could be replaced by an electric motor, hooked up to a bank of lithium batteries. This can be charged via hydrogeneration – when the speed under sail turns the propeller and puts charge back into the batteries – and solar or wind. But when extended periods under power are required a standalone DC generator, which can be installed anywhere on board, supplies the electricity.

The electric propulsion pioneer Torqeedo proposed a system that has the advantage that the generator is only needed on longer passages, so the boat still manoeuvres silently in and out of ports and anchorages.

And a well-designed, correctly sized generator is much more efficient at turning diesel into electricity than an engine not originally designed for the job. Some sailors opt for an in-line hybrid

system, like those offered by Hybrid-Marine, which bolts onto the existing diesel.

These are easier to retrofit, with many of the same characteristics as the full hybrid system, but there's the disadvantage of still having an engine boxed away somewhere near the middle of the boat. In the near future, a new range-extending DC generator specifically for hybrid sailing boats is under research. Its existing unit is built by WhisperPower and provides 25kW, which is too much power for boats using the pod drive system.

The genset will be designed to operate at optimum revolutions, while clever DC to DC conversion decouples the battery voltage from the charging voltage, for much greater efficiency.

With boats, just as with cars, the breakthrough that will make all the difference is around battery capacity. Until range under electric power can match that of diesel, there will be many sceptics.

In the meantime, the prevalent technology is based on lithium-manganese-cobalt, and a process of steady development is making this 5-8% better each year.

24. Ship and boat decks built with sustainable materials

For decades teak has been the most used kind of hardwood used in shipbuilding because of its characteristics, such as stability, resistance to atmospheric and natural factors (rots, fungi and pests), resistance to stress and abrasion, low maintenance thanks to the intrinsic high levels of oils. Nevertheless, the intensive use of teak has also been causing negative environmental repercussions.

Nowadays, technology (with the development of means such as epoxy resins) has evolved so much that it has been possible to increase the use of alternative kind of woods and materials. Hardwoods such as cedar or Douglas fir, and even softwoods such as bamboo, have become concrete examples of the use of alternative woods for construction purposes. These improvements have allowed to limit the use of teak mainly to decking and interior design purposes.

In Veneto Region an architecture studio, TAiSTUDIO Architettura, represents an example of good practice since they have been designing and perfecting a system allowing the use of bamboo wood for the building of decks. The development of said more sustainable technology allows to fight the extinction process of teak wood and the issues concerning the unclear traceability of currently commercialized teak. This kind of technologies and approach falls within the trend of giving more attention to the issues of eco-design and circular economy also in the shipbuilding sector.

25. Circular economy applied to the shipbuilding sector

According to the concept of circular economy, waste should be reduced to the minimum through a process of rethinking and redesigning of both industrial processes and products in order to achieve the objective of a "perpetual" re-use of specific components. Circular economy is achieved through two different, but connected paths: on the one hand, biological waste should be "returned to nature"; on the other hand, non-biological waste should be re-used to reduce the final amount of non-recyclable waste with the added benefit of reducing the consumption of virgin materials contributing to the preservation of the environment.

The reliance on circular economy opens up a series of new possibilities for companies venturing in this relatively new field: reducing manufacturing cost, facing possible supplies shortages, new business opportunities and the opening of new market sectors. The dismantling of ships and boats seems to fit well in the circular economy process. In the last years, various solutions have been attempted in order to reduce the environmental impact of the dismantling of ships and boats. The disposal process of ships and boats materials and components requires multiple diversified activities due to the great number and diversity of components.

The enterprise GS4C has been working on some projects of recycling ships and reusing produced waste in other sectors is of particular interest. The "Loop Mini650" is a composite sail-racing

boat entirely made out of recycled materials. The company is developing a composite sail-racing boat made entirely from a single fiber and a bio-based epoxy that is 100% sustainable and recyclable. This project demonstrates that zero landfill composite manufacturing, including a clear and sustainable cradle to cradle end of life solution, is possible. It shows that this approach contributes to the reduction of polluting emissions: about 30% reduction on emissions when compared to E-Glass/Polyester. The design of this boat put together an ample number of partners, also proving that different design and development shipbuilding processes are possible and that enterprises have the abilities to adapt to new challenges. For instance, LinseT Lab in Fano verified recycling processes, the Belgian Isomatex SA produced the used fiber (FilavaTM), while the company Entropy produced the Super Sap bio-based epoxy.

26. Additive manufacturing applied to the maritime sector

The introduction of 3D printing (additive manufacturing) in the industrial sector has represented a radical change in terms of benefits for supply chain, product design and production. Nevertheless, the maritime sector has not been extensively interested by the opportunities provided by 3D printing, differently from sectors like automotive or aviation. The main reasons for this trend depend on factors such as: the lack of benefits from economies of scale (it is a technology more suited for small series, rather than mass production), knowledge gaps, technology variance, or the rather large and crude components. It should also be kept in mind that 3D printing does not influence the design process per se, but it has relevant effects in terms of performance of components or systems. In fact, 3D printers use layers to build up the components, thus their properties might vary

along the direction perpendicular to the layers with the consequence of post-processing the product. On the other hand, some positive

elements characterizing additive manufacture can be identified in reduced costs, more detailed designs, customization of final products or components, sustainability or more competitive business models. Additive manufacturing can also be linked with the concept of circular economy. A significant example is represented by the "Tom Tjaarda Escondido" Project, developed by the architecture studio TAiSTUDIO Architettura. The project aims at recycling ships and boats and reusing of produced waste in other sectors, namely the automotive sector. It combines the use additive manufacture (3D printing) with the reuse of recycled boat components for the building of an automobile. The pictures show the 3D model of the frontal part of the one-off automobile "Tjaarda Escondido" which will be realized with the use of fiberglass recycled from the dismantling of boats.

From the "research" point of view, it is interesting to register the presence of the TE.SI Lab of the University of Padua. The lab aims at developing, mastering and exploiting the enabling technologies for the manufacturing of the future. Additive manufacturing has been recognized as a sector of interest, with particular attention to industrial applications related to the direct laser sintering of metal powder and laser lithography systems for 3D micro-fabrication, which could be applied to the maritime sector. This part of the lab is currently focusing their activities on the

fabrication of multi-material (gradient) micro-parts, influence of process parameters on part accuracy in the direct-laser-sintering process, advanced monitoring and control strategies of the direct-laser-sintering process, fabrication of 3D micro- and nano-scaffolds, design and fabrication

of 3D micro- and nano-fluidics and elements for lab-on-a-chip systems, mechanical meta-materials and micro-optics.

27. Aluminum applications to shipbuilding sector

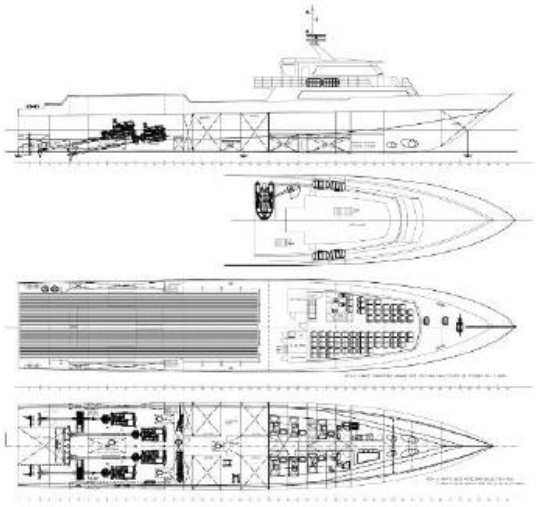
The structure of fiber metal laminates (FML) presents high potential also for the shipbuilding sector. Their simple metal structure grants

advantages thanks to their specific properties, such as metal fatigue, impact, corrosion resistance, fire resistance, weight savings, and specialized strength properties. Aircraft industry started to focus on these forms of laminates in order to increase material and flight performance. One of the most used FML, as fuselage skin material, is the so called Glare (glass reinforced aluminum laminate based on high-strength glass fibers).

The shipbuilding sector offers concrete opportunities for the successful introduction of fiber metal laminates and, particularly, aluminium alloys. These alloys are suitable for the building of big ships, yachts, motor boats, cutters, underwater craft or sport boats. The use of Al-alloys in shipbuilding can result in sensitive performance improvements: reduction of the total weight of the ship (with respect to those built with low carbon steel) with a consequent increase in the payload and a reduction of fuel consumption; reduction of loss of cargo dead weight, due to the lighter structure; increased ship stability; increased manoeuvrability; building of more effective on-board fire resistance solutions.

FMLs consist in a laminate of several thin metal layers bonded with layers of composite material, like fiber reinforced adhesives. The B.Al.i (basalt aluminum infusion) FML is a patented technology uniting the FML concept (layers of aluminium and fibres) with the cold moulding construction from the shipbuilding sector. The outcome consists in an autoclave solution for panels and large shells

obtained by alternatively placing layers of metal and non-pre-impregnated fibres on a mould, which will ultimately be consolidated by vacuum-assisted resin transfer. This FML is composed of layers of enriched basalt and aluminium which contribute to make the material sustainable and recyclable.



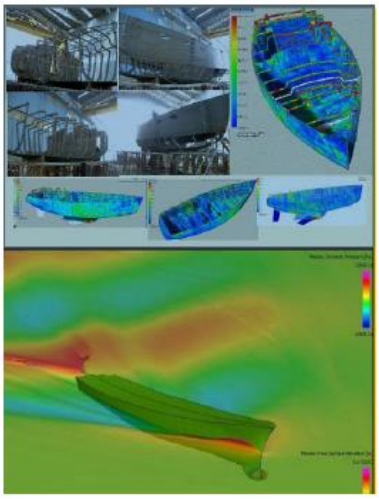
At the moment, a small prototype of three layers of Aluminium and two layers of basalt fabric (plain) has been produced by VARTM and its impact tested. Moreover, a five layers laminate has been tested for ballistic resistance with encouraging results. Further implementations will have to address issues such as: optimization of fibre size, preparation of aluminium layers and use of recycled ones, pyrolysis and recycling for end-of-life, mechanical features, etc.

Another example of best practice is the Vittoria C834 Blue Daddy, a 52 meters supply vessel entirely made of aluminium, developed and built by Cantieri Navali Vittoria as a support to the workers on offshore platforms. The boat has been completed with the addition of the Kronensberg DPK-POS positioning system for circumstances of scarce visibility and heavy sea, along with the features for environmental protection and for the compliance with the IMO "Code of Safety for Special Purpose Ships.

Nowadays, manufacturing costs of ships built with aluminium alloys have sensitively dropped as well making them a competitive solution with respect to ships built with steel. It is reasonable to expect that this building solution is going to be preferred particularly for smaller ships, while present trends show that bigger ships will likely continue to be built with steel. Finally, it is useful to remind the wider potential for aluminium ships also in terms of end-of-life and the possibility of including them in the circular economy cycle, thanks to the recycling value of aluminium.

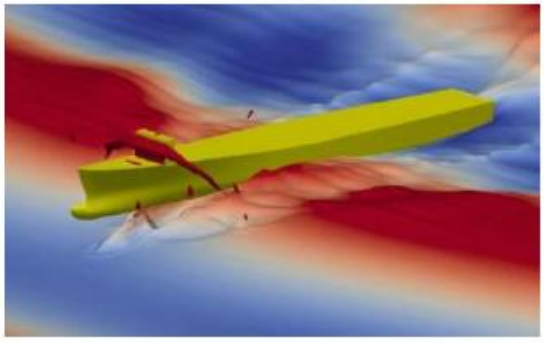
28. Simulation in shipbuilding

Simulation has been one of the first technologies to be developed, thanks to the possibility of creating mathematic models that help with the understanding of both natural and artificial phenomena. Other, more recent, technologies ground their roots on simulation: 3D printing can be considered an advanced form of simulation. The huge improvements which have been characterizing this technology have allowed its diffusion, not only among large industries, but also among SMEs. The latter can use simulation in several processes: verification of operational and productive processes; monitoring of the flow of materials and tools; simulation of industrial environments; improve the designing, prototyping and engineering of products also with specific tests.

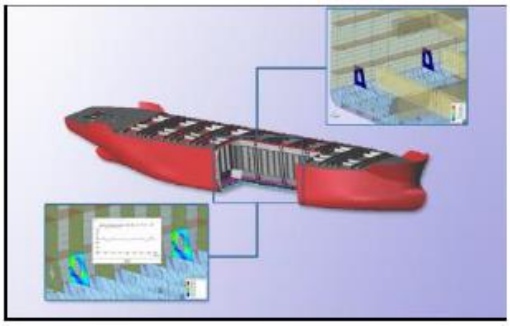


The issue that enterprises intend to solve with simulation can be grouped in the following topics: costs and time efficiency, fluid dynamics resistance, reduction of polluting emissions, increase performance levels, integration of compound materials or the solution of structural problems.

The maritime sector is among those where simulation technologies are more developed and efficient. Generally, simulations are aimed at improving: the design of hulls, propellers and sails; the optimization of structural analysis; definition of the features of ships without the previous drafting of models. Enterprises such as the Slovenian Arctur doo, provide simulation services also to SMEs: CFD (computational fluid dynamics) or FEA (finite element analysis) for structural problems.



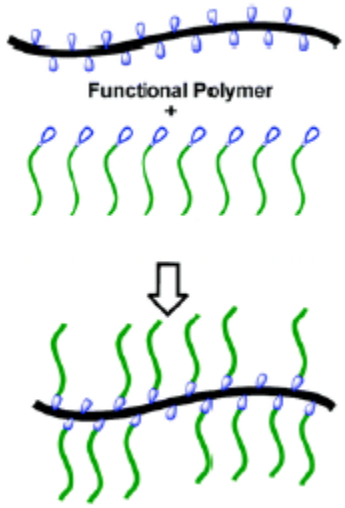
The company also provides High Performance Computing services which allow to obtain more accurate and detailed models at higher speed with respect to the use of normal computers. The company allows to rent those supercomputers



which, otherwise, would constitute an excessive expense, particularly for SMEs. Among the successful cases implemented by Arctur, it is possible to mention the study on the impact of waves on hulls and other marine objects carried out for an Italian and a Spanish company in the shipbuilding field. Another relevant case concerns another Spanish enterprise specialized in ship and yacht design that used the HPC for an analysis and a simulation of the structure of container ships.

29. Chemical compounds applied to the maritime sector

"Cross-linking activators" (CLAs) are chemical compounds favouring the cross-linking of a wide range of materials of natural and/or synthetic origin, without leaving any trace in the finished product. The use of these compounds would have the ultimate benefit of providing products with antimicrobial, hydrophobic, stability to temperature properties. This technology allows the obtaining of highly sustainable products and production processes that will avoid the release of toxic emissions in the environment.



CLAs allow to irreversibly attach antibacterial agents, mould, preservatives, etc. to a polymeric structure implementing its features. Practically, CLAs favour the release of active substances from products (packaging, paint, gelcoat, clincher, fabric, cellulose, etc.) that fail to do so. CLAs act as catalysts and are not retained within the product. The treatment can

be carried out during the preparation of the material or later.

This technology would allow the solution of one of the biggest maintenance issues for ships: the biological fouling contamination of the hull, which can have negative effects in terms of ship corrosion and ecosystem contamination. Fouling contamination entails heavy maintenance costs necessary to avoid the presence of marine encrustations on the hull. The other negative side of anti-fouling treatments available on the market is their high toxicity and scarce biodegradable properties that are a consequence of the need of creating products with ample effectiveness.

Crossing srl is an innovative start-up and a spin-off of Cà Forscari University whose objective is the low-cost production of a new category of CLAs which can be used also at the industrial level. The CLAs developed by Crossing would allow a wide range of applications, interesting the more diverse sectors: antifouling paint, non-toxic and metal-free leather, antimicrobial packaging and fabrics, building materials without allergens, and antibacterial and anti-mould cellulose, etc. The company is currently working on the implementation of a highly efficient anti-fouling product that would also be eco-friendly, by permanently attaching the ample-spectrum biocidal product to a polymeric structure. This approach would have the double benefit of protecting the marine environment maintaining the effectiveness of the anti-fouling product.

30. Batteries with lithium polymers

The interest towards electric and hybrid boats has been a trend that has been consolidating in the last years. Even the performances of these kind of boats have been significantly improving, due to the continuous research on alternative energy supply systems. The performance of this kind of

alternative fuel is not presently able to be compared to that of fossil fuels, at least for boats

of larger dimension. Nevertheless, there has been a change in this trend in particular for smaller boats, pleasure boats or boats destined to public transports.

Enterprises have been understanding the importance of focusing on sustainability, eco-friendly technologies and the necessity of developing alternative energy sources. Both these factors have brought to the design and development of a "new generation" of electric and hybrid boats that are convenient also from the economic point of view, since both production costs and purchase costs have decreased.

Companies designing and producing these kind of boats, like the Italian company Ecoline Marine, have also been working on more innovative and efficient energy storage systems. In fact, energy storage systems are fundamental components in electric and hybrid engines, since the engine starts to charge the attached batteries and accumulate energy during moments of maximum propulsion. Present technologies allow to use batteries with LI-PO (Lithium-Polymer) cells that have several benefits like the ability of storing higher energy quantities (with respect to other batteries available on the market), reduced weight and space-consumption, and the possibility of customising their shape slowing their easier adaptation to the features of the engine. This

kind of batteries are also more efficient since they have about four times the energy of density of nickel cadmium or nickel metal hydride batteries. Nevertheless, the downside concerns their higher cost and the safety issues these batteries may present when overcharged and overheated. For this reason, working on the development of safer LI-PO batteries could only benefit the further development of electric or hybrid engines. The other positive effect would be the reduction of waste deriving from the need of changing and disposing of the substances composing these batteries.

31. Sailing efficiency with modular boats

The innovation of the shipbuilding sector goes

also through the progressive improvement of ships' manoeuvrability with particular attention to sustainable solutions. Easing manoeuvring procedures would have positive effects in terms of decrease of polluting emissions, reduction of noise emissions, decrease of billowy motion, increase of the functional abilities of the ship, cost efficiency of the ship.

The Italian company ECONBOARD has been working on and developing an innovative kind of boat: the Hanna, a modular catamaran hull with interesting features allowing an extreme flexibility of use. In fact, the boat is made out of twin boats that can operate independently or can be united through a rigid connection system which allows to operate them together, as a unique boat. The dimensions of the boat and the decision of using only one part can depend on cargo necessities or on weather condition. This kind of detachable boat would be ideal for operations in more limited areas, such as ports, rivers or lagoons. It would also allow to meet environmental requirements because of its detachable structure, along with the double electric

azimutal propulsion placed at each end of each part of the ship that would favour a reduction of costs and emissions.

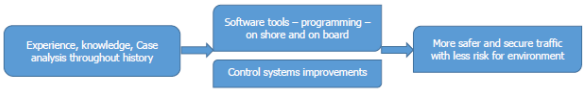
32. Software Technology for increased safety and security measures for Vessels

Due to dense water traffic and deficiencies in safety and security measures and systems of ships, incidents occur quite frequently.

Throughout last years, in the Croatian part of Adriatic, several severe incidents occurred such as: fire on board of Turkish RO-RO ship in 2008, ferry stranding in 2009 etc.

Fortunately, the consequences were not fatal and major pollution was avoided. However, development of strategies and procedures to be

undertaken in such situations will contribute to overall level of safety and security. Special issue represents potential danger of terrorist and cyber-attacks. Actually, accidents are mostly caused by human factors such as omissions, fatigue, stress, negligence etc. Therefore, development of software tools with corresponding procedures for evaluation of risk levels and relating these risk levels to ship functions is of major importance.



Opportunity is to use collected long term experience and data base of incidents which occurred throughout the years as basis for development of software tools which contain scenarios and decision making procedures together with the improvements of control systems on board. These tools should pay special attention to specific geographic details of Adriatic – Ionian region.

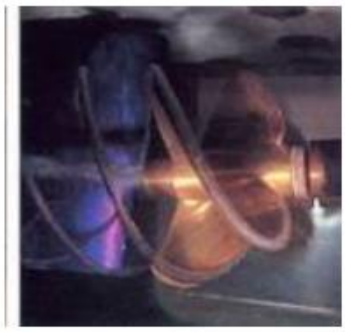
Users of the technology in the first phase can be local authorities i.e. on shore systems should represent first step and then technology should be upgraded to on board systems together with the enhancements of the control systems of the ships.

Existing technology for optimizing ship route may be transferred to safety and security system. Main features consist of: system which automatically sends info of unexpected events, navigation and tracking system (ship shore, ship ship) and freight tracking system development. Crisis management is the focus of the development of such software where based on the existing experience, geographic and weather particularities decision support software tools are to be developed.

Safer transport and less danger for the environment will be final outcome.

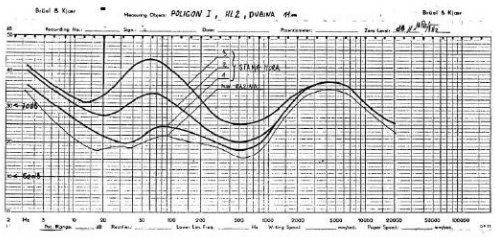
33. Technology for Mitigation of Underwater Noise

Noise emissions such as propeller and cavitation noise influence passengers and residents and can as well affect the crew. Effect upon marine life is also not negligible.



IMO adopted in 2012 Regulation for constructional demands for on-board noise. Mandatory maximum noise levels are prescribed for machinery spaces, workshops and other spaces on board ships. Underwater radiated noise have short and long term negative consequences on marine life, especially mammals. In 2008, it was agreed by IMO to develop non-mandatory guidelines to minimize incidental noise for commercial ships. Guidelines were approved in 2014 and mainly focus on propellers, hull form, on-board machinery and maintenance recommendations such as cleaning of the hull.

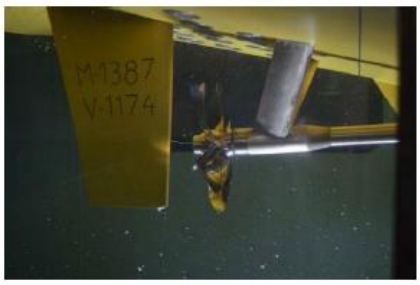
In Adriatic, experience in measurement and mitigation measures for underwater noise were developed back in 70ies and extensive knowledge and data base is collected. Propeller radiated noise is depending in large extent on wake field of the hull and blade loading. Besides these characteristics, when monitoring Adriatic-Ionian region, geographical characteristics also affect noise occurrence such as shallow water conditions. Bottom reflections and scattering losses occur in certain extent i.e. geo-acoustic properties are of importance. Technological



Results from measurements of underwater noise conducted in Adriatic in 70ies

opportunity is to use existing measurement data and experience gathered within shipyards and shipping companies in order to offer analysis and enhancements of propeller-hull improvements oriented towards lower levels of noise.

Model scale testing, numerical calculations, empirical methods based on collected data



together form solid basis for the development of software tools for evaluation of the design based on hydroacoustic properties. Propeller

manufacturers, ship designers and research institutions might join forces related to offering of the propulsion system which is environmental friendly regarding underwater noise.

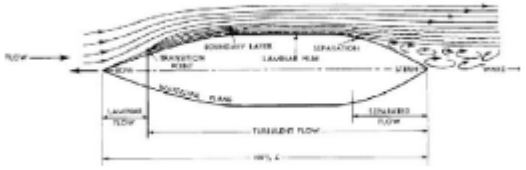
34. Hull air lubrication technology

International regulation regarding reduction of emissions from ships and high fuel costs motivate strongly ship designers to investigate new technologies, but also to research opportunities to revisit existing techniques and enhance their new applications.

Air lubrication systems reduce drag force on ship's wetted surface based on principal mechanism that air has much lower viscosity compared to the water. This technology represents major step towards green vessels. Technological solutions mainly depend on specifics of the ship and its operating conditions.

Successful application of such technology leads to significant decrease of friction forces. There are two main approaches as follows: pressurized air completely removes water from hull surface using pressurized air or bubbles that are injected into the water near the hull. Therefore, air film, microbubbles and air cavity systems can be distinguished.

Air film system requires significant energy to

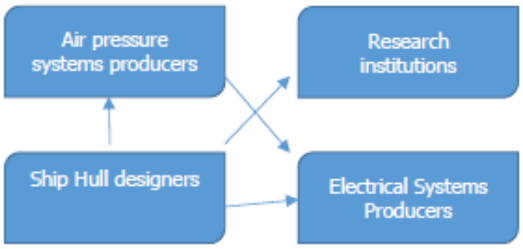


insert pressurized air and the efficiency of the system is dropping significantly with the speed increase or developed sea states. Therefore, air cavity systems are developed where air is held within the chambers, but they are not appropriate for retrofitting systems. Method of microbubbles is developing as well, also suitable for retrofitting.

Gain in efficiency is not questionable, but when offering new technological solutions it is crucial to determine the effects upon manoeuvering i.e. safety.

Also, energy used to inject air should of course be less than energy saved through resistance reduction.

Finally, fuel savings ranging from 3.5 – 15% are achievable (Wartsila, 2009) by application of air lubrication. Main challenges are to maintain seakeeping and manoeuverability characteristics of the ships and to reduce power demand for system for air pressure production.



This technological challenge is opportunity for joint work of manufacturers of air pressure systems, ship hull designers and research institutions as well as for example for manufacturers of electrical systems since combining this technology with on board batteries will present step forward zero-emission ship.

However, this technology has shown significant potential and they are plenty of further possibilities for development and further enhancing.

35. Fish farming and supporting equipment

Due to increase in demand motivated by population growth and raising awareness of healthy nutrition, world's aquaculture production will steadily increase in volume in the future.

Adriatic-Ionian region can be recognized as great potential for more vivid development of aquaculture due to excellent reputation of its seafood and cleanliness of the sea. Main species produced within Adriatic Sea are:

Technology for fish farming is complex and extends to high tech solution. Such technology requires inter-disciplinary approach (biological, mechanical engineering, electrical engineering, marine technologies engineering etc.). Therefore, it is ideal technological platform for cooperation and enhancing development of local industry. Local authorities may play significant role through fastening the procedure of establishing fish farms

and helping in finding investment opportunities and financing options.

We can differ off-shore farming (cages) and land based farming.

Among main challenges for land based facilities are water reuse possibilities through aeration, filtration, disinfection and oxygenation. Ways of handling the sludge which includes feed pellets and fish faeces is requiring development of new technologies and is seeking for innovative solutions.

Off shore installations require extensive knowledge regarding sea keeping abilities and require chain of support activities such as monitoring (cameras, sonars, sensors for temperature and oxygen, motion reference units, quality of the water), ships for support, control systems etc.

Development of aquaculture is opportunity for gathering local industry, especially taking into account that the system which is designed and installed will need constant support and monitoring.

Geographical particularities play an important role in finding specific solutions and higher level of applied technologies guarantee better productivity and more sustainable solutions i.e. environment friendly options.

Fish Farming Examples

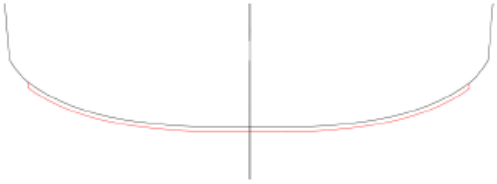
36. Interceptor technology for cargo ships – Hydrodynamic savings

Interceptors are from the production point of view very cheap solutions which may result in significant gains in power saving of the ship. The propulsive efficiency may increase up to 5% depending on a ship type and speed.

Practically, interceptor is metal plate fitted vertically at the transom of the ship and covers as large as possible extent of breadth of the transom. The plate extents vertically beneath the transom for approximately 0.03% of the hull length. Plate bends the flow over aft body of the ship downwards and creates similar lift effect as trim wedge.

37. Application of ducktails for ships

Cruise vessels and RO-RO vessels have so far proven this technology for full scale displacement ships. This is mainly due to the fact that the speed of such vessels is usually high enough that the impact of the interceptor may be pronounced. Interceptor can be easily applied within retrofitting, during regular docking of the ship etc.



Schematic view of Interceptor mounted at the Transom

The technology is appropriate for ship repair companies to be offered for existing ship as simple and cost effective solution to be integrated on ship. Ship design office together with research institution will contribute with the appropriate methodology for calculation of proper dimensions and suitability of the interceptor solution for a particular ship. Energy saving leads to lower level of emissions, while the production and installation is very simple and does not cause any pollution or energy demand.

To conclude, energy saving ranging from 1 – 5 % can be achieved and further in exploitation no further costs or maintenance is needed.

Ducktail represents lengthening of the ship aft part for approximately 3% of the hull length. In such way effective waterline is lengthened and wetted part of the transom is reduced. Resistance is significantly affected by wetted transom parts which was extensively researched and proved in the past. Propulsion power demand may be lowered for up to 10% which correspondingly reduces energy consumption.

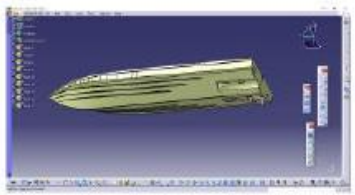
Proper application of duck tail may first be approved by model tests and / or numerical calculations and then construction of the duck tail imposes technological challenges for the construction.

Example of Duck Tail at the Ship

It is also to note that this solution is applicable for existing ships as well and can be considered in synergy with interceptors which means that significant gains may be achieved.

38. Advanced Outfitting Technology

Outfitting technology is improving constantly over the years, however there is still significant potential for further improvements. Main benefits of advanced outfitting are shortening of the production time which can reduce time from contract signing to the delivery of the ship and enables significant savings. Workers have better working conditions since narrow spaces, high ambiental temperatures, work at height may be avoided in certain level. This is important for aspects of protection at work, but also for productivity. Also, less application of erection of parts may be applied which may affect number of cranes and lifts used and enables better human positions for welding. Another very important aspect is clear orientation towards more green and clean technologies in shipyards.



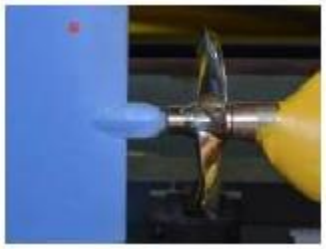
This is primary achieved through enhancement of modularization concept through intensive application of CAD/CAM/CAE tools which are widely available and used. This presents excellent platform for development of improved production technology. Conclusively, knowledge based companies proficient in software application and optimization methodologies may work together with the experienced yards and establish new solutions for advanced outfitting which further enhances industry for production of handling devices (cranes, lifts) to improve their production solutions. New outfitting concepts involve for example assembly of components such as machinery, piping etc. Savings in production processes and less risk for the environment and workers and at the same time better productivity clearly enables orientation towards other means of development of green technologies.

39. Technological solutions for Ship design for energy efficiency based on recovery of Energy Losses

Strict requirements set by regulative authorities as well as sudden jumps in fuel price determine strong need for improvement of propulsive efficiency on ships. Solutions which are applicable

for existing ships and do not cause high maintenance costs are of special interest for ship

owners. Such solutions may be offered by yards and ship designers as well as companies which manufacture ship equipment. However, cooperation between all the parties together with research institutions is required in order to develop and succesfully apply new solutions. Therefore, development of new technologies within this field is of special interest, especially taking into account fact that the achieved results have direct positive influence upon other aspects of savings and lowering the pollution levels such as underwater noise. Such devices differ based on the hydrodynamic phenomena they deal with. Within this proposal of technological opportunities, solutions based on recovery of rotational energy losses will be considered. In this category are contra-rotating propellers, pre and post swirl stator devices and fins, devices mounted on or behind the hub etc. Swirl recovery and aim to have final propulsion device of smaller dimensions which further reduces energy are among main goals during their design. Based on experience and literature, savings in the order of 2 – 8% can be achieved for merchant ships.



Typical sequence of development of new solutions consists of:

- Ship owner monitors ship energy consumption and notices need for improvement
- Ship owner approaches designer or yard and asks for solutions
- Yard / designer develops technologically feasible solution which is further hydrodynamically
- developed in the research institution and tested
- Ship owner performs final tests and verfication and gives feedback to the designer

40. Technological solutions for Reduction of Flow Disturbance at Hull Openings

The increment of resistance of ships and consequently power consumption is significantly influenced by water flow disturbance from openings such as bow thruster tunnels and similar. Paying proper attention towards designing of scallops or grids for openings may lead to power demand reduction even more than 5%, depending on the ship type and speed.

Most often, location of the opening cannot be changed since it is calculated in order to give maximal effect and determined technologically. Therefore, potential lies in design of scallops and grids. Ship Designers together with the Yards and calculations or experiments conducted by

Research Institution offer successful solution to the Ship Owners. This technology is simple and cost effective for construction and also does not require significant maintenance cost.

41. Shipboard Waste Management

Innovative technologies for shipboard waste management are of interest for all types of ships and present opportunity for greener shipping and savings.

Waste requires packaging, handling of biodegradable waste and goal is to enable recycling and reusing in the certain extent.

This has large potential to include companies which already produce solutions for on-shore waste management and to adapt and apply solutions on board ships.

This includes:

- Separation of waste onboard
- Design of storages and disposal areas in integrating these parts in ship design
- Packaging issues
- Organic waste processing – reduction of volume and discharging
- Take special care of PET packaging

42. Energy efficient fishing winch system

Energy savings by using modern highly efficient electric winch systems with regulated electric drives on trawl winches. In heavy seas, winches

operate in cyclic mode by winding up and releasing the ropes, keeping the net hydrodynamically stable in the sea. Generated energy in rope release periods is significant and economically viable by returning it through the VFD and AFD to the ship's electrical grid or batteries. Energy regeneration is dependent on sea conditions, in general it is possible to get 30-50% of the energy input for winch operation. System savings up to 60-70% compared to classical trawl winch solutions.

This technology is put in the group of marine equipment and systems under the renewable energy source on-board type by the maker Adria Winch. They also state it to be at TRL 7 in prototype scaling stage after which it will undergo system demonstration in operational environment.

43. COMPA

COMPA is composite patching and overlay technology for repair and reinforcement of damaged structures and pipes using composite materials (carbon and glass fibres mixed with epoxy resin/adhesive). It features application of carbon and glass fibres mixed with epoxy resin/adhesive onto damaged surface. By curing, the resin hardens and permanently bonds to the surface, impregnating also the fibres that reinstate the strength of the damaged part. Finally, this effectively creates a solid new layer

of material that provides full water tightness.

Benefits of the composite repairs and reinforcement:

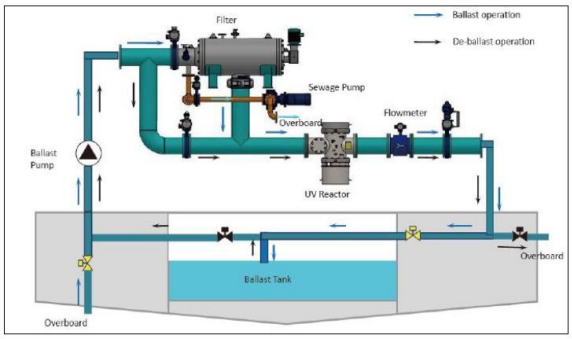
- Cost effective alternative to traditional cut and insert procedures

- Fast and can be done onboard vessel in a port or during voyage.

Company Alveus d.o.o which is the owner of this technology states its readiness at TRL 4 which covers laboratory validations and now proceeding to scaling up and ongoing field testing on ships. It is under the materials group while it could also easily fall under life cycle assessment.

44. Balmaris

Research and development of innovative system for ship ballast water management. System uses combination of mechanical and physical principles to separate bad particles out of water using no



chemical substances. The technology can be also used for any kind of water filtrating or cleaning, kill all the bad microorganisms in water waters. This technology is also in patent stage and rated at TRL 3. Developer company Balmaris d.o.o is building a system for filtration and cleaning wastewater without use of chemicals and it states it can be implemented in any facility and not just ship ballast water systems.

45. Oil collector ship

Ship for collecting oil and oil derivatives from water surface is ship designed to collect oil products floating on water surface in case of environmental accident. It consists of catamaran hull with roller wheel furred with silicone cloth attached at the bow. Next to the roller wheel, scraper is placed in a way to scrape the silicon cloth and collect oil products in oil tanks. Tanks are equipped with oil pumps that can transfer oil to another ship or bigger tank.

As this technology is only formulated as a concept and is patent pending it's TRL rating is 2 but as offshore industry increases so does the need for technologies like this one what might expedite its development. It would be interesting to see if it reaches higher stages of development.

46. Double ended ferry energy management system

Company has technology of Power management system for Diesel generators. Intention is to upgrade existing technology to Energy Management System when using also batteries as power source. For proper energy usage load profiles must be implemented and controlled energy usage from various energy source. The company INMEL d.o.o is still doing basic research and formulating the concept making this technology TRL 2. Since there is a big demand for power efficiency different management system are critical and that could help speed up this technology's placement on the market.

47. Double ended ferry hybrid propulsion system

In our case, we are developing hybrid propulsion system on Jadrolinija's ferry m/v Ston. The system consists of 2 PM motors (290 kW, 400V AC, 485 A, 114 Hz), 2 Vacon® frequency inverters + AFE (input: 400-500V AC / 45-66 Hz, output: 0...400V AC / 0...320 Hz / 536 A) and battery sets. The pictures of frequency converter, AFE, and PM motor can be seen on links in the end of description. The concept of work is simple. When ship's motor is rotating without supplying input power with no load or light load it acts as generator and generates electrical energy. This energy is stored in battery sets and can be used for various purposes. Most of the energy would be used for diesel engine optimisation or short-term battery only operation. Besides previously mentioned power management system INMEL d.o.o is developing their own hybrid propulsion system. They are testing it on a ferry and state that it is especially suitable for short cruises where ship is constantly accelerating and decelerating. It is also environmentally friendy as hybrid propulsion cuts down CO2 emissions and reduces noise levels while cutting operation costs.

48. SailRouter

SailRouter™ is a desktop and cloud software which enables insight into real-world ship performances connecting ship behaviour on waves to actual engine performance data. The overall goal of the SailRouter™ is to offer automatic solutions for gathering and processing all necessary data during navigation to provide

the first tailor made decision support system that could increase both - energy efficiency and safety.

The overall goal of the SailRouter™ is to offer automatic solutions for gathering and processing all necessary data (both ship and sea wave data) during navigation in order to enable the first tailor made decision support system based on gathered real-world ship data. By measuring sea waves during navigation, SailRouter™ will help users to improve fleet energy efficiency (reduce fuel consumption) and safety/ comfort (reduce ship rolling) performance. By using self-learning algorithm, SailRouter™ can learn about real-world ship behaviour on waves and support user to make proper decision during both voyage planning and navigation. Beside operational support, SailRouter™ can be used to make maintenance interval decision since it can warn users about significant reduction at ship performance.

This software solution can be implemented into existing route planning and autopilot systems helping officers on board ships as well as office workers doing logistics for the fleet. It is rated at TRL 6 and currently being tested full scale.

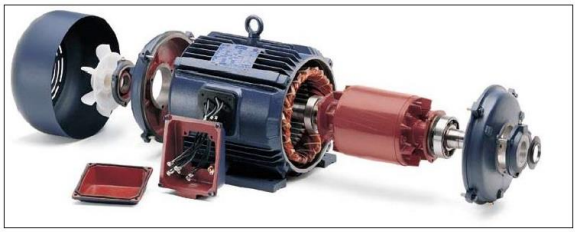
49. Hydroairy ship

Hydroairy Ship is innovative hull form similar to catamaran and SWATH, combining best

from both. Keeping wave resistance at minimum value, power need for propulsion is significantly decreased comparing to mentioned hull form, which results in smaller fuel consumption. Keeping the resistance at low level, with two half submerged bodies, it is ideal hull form for twin propeller electro propulsion. All Hydroairy ship designs are properly registered at the Patent office under the file no. P20010438A. Technology is suitable for building smaller passenger ships in inshore lines connecting islands with coastal area. This technology is validated in the laboratory and the prototype is now being scaled for full size testing. The company Mikrotehna d.d. rated it as TRL 4.

50. Compact permanent magnet motor for marine propulsion (SPM132)

SPM132 is a series of compact permanent magnet motors/generators (PMS, PMAC) which are very versatile. These motors are designed to be efficient, robust and enduring while still compact. Advanced design of these machines offers a larger power concentration and extremely high

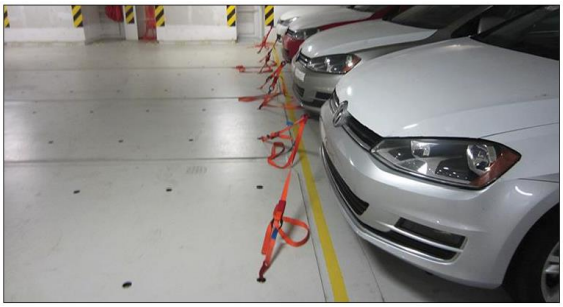


efficiency. SPM132 motor series is developed for demanding applications where a powerful but reliable machine is necessary, which requires minimum maintenance. These motors have proved to be enduring in the hardest conditions like demining and are reliable equipment with a long lifespan. Minimal power dissipation and high power to volume ratio are just some of the benefits these machines have to offer. All synchronous motors with permanent magnets are also generators. SPM132 series can be used as a generator for compact gensets, wind turbines, small hydropower plants or as a motor/generator for hybrid propulsion systems. All power rating in the catalogue are rated for S1 continuous operation. SPM132 is optimal for industrial variable speed drives application and electro propulsion solutions, from marine applications to electric vehicles. Smaller dimensions, less energy consumption, less vibration and lower noise will make your driving experience more comfortable, while leaving no carbon footprint.

At TRL 9 this technology is already proven in the field sailing across the globe. Most noticeable performance test is in service on ship sailing in the North Sea where performance and reliability are most important.

51. Composite cargo decks on pure car truck carrier (PCTC)

Uljanik Group has delivered (July, 2017.) a car carrier "SIEM Cicero" with a large quantity of composite structure introduced for cargo decks. The big novelty is that the three uppermost



decks, of total thirteen decks, are constructed from GRP sandwich panels, saving considerable

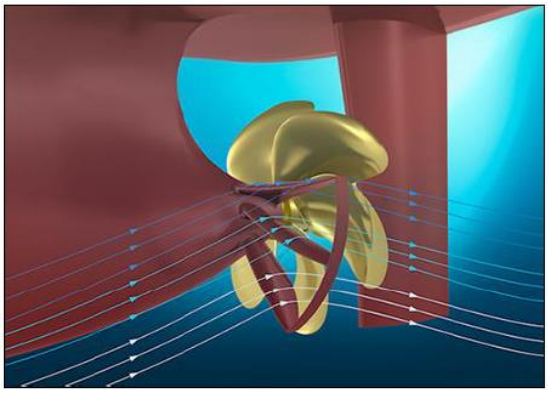
weight high up in the ship. Uljanik has been involved in research and development projects founded by EU for lightweight ships structures since 2006 and the Siem vessel is the first large vessel of any kind to incorporate composite sandwich decks. Challenging design process and approval from relevant institutions, especially with respect to fire safety requirements (SOLAS) results in benefits for the ship-owner, shipyard and the environment. Compared to the traditional steel decks the weight savings for the Uljanik-designed decks is 25% or 200 tons, for equal production cost. PCTCs of this type usually incorporate ballast to counteract their high center of gravity, to fulfil stability requirements. So, reducing structural weight high up in the ship gives a double benefit. The result is a reduced fuel consumption of 4.5 % or an increased payload up to 800 tons. It is understood that the Uljanik-designed vessel has the lowest fuel consumption per CEU of any PCTC in its class. RoRo vessels have numerous internal strength decks. Clearances between decks are fixed and defined by cargo requirements (height of cars, trucks). Reducing the weight of decks results in many benefits regarding general ship design due to large number of decks (lower ship height, lower vertical center of gravity, lower equipment number etc.). Improved flexibility in the ship design, where weight could be traded for ship size, scantlings, cargo capacity, speed, installed power and weight, integration of structures and outfitting. Its rating is TRL 9 and available for anyone who would further use this product/technology. Weight reduction has a direct influence on cargo capacity, fuel consumption, CO2 emissions and maintenance costs.

52. Pre-swirl stator fins

Energy savings and reduction of fuel consumption has been a priority for many ship owners, because of its positive financial and environmental impact. This topic became interesting for existing vessels also in recent years, especially with introduction of Energy Efficiency Design Index. One of the possibilities to reduce fuel consumption and EEDI is the implementation of Energy Saving Devices, to optimise the hull-propeller interaction. To study the working principles of selected energy saving devices, a consortium of 12 eminent European partners, including Uljanik, started the project GRIP, supported by the European Commission

under the 7th Framework Programme. CFD analysis has been applied to pre-swirl stators, pre-ducts, rudder bulbs and propeller boss cap fins to study the working mechanisms in detail. The best Energy Saving Device was selected, designed and built for Uljanik bulk carrier. A set of dedicated trials was performed on the vessel before and after the its installation to validate the CFD calculations and predictions of the fuel saving. 6.8% of the power saving and total disappearance of hub vortex was demonstrated during these trials.

This technology is rated TRL 9 and already proven in operation with almost 7% of reduction of fuel consumption, proven on trials. The technology



has been proven to be ready for retrofitting also. It has been commercialised by HSVA and Wartsila.

53. VOS

The Venturi Oxygen Stripping™ (VOS) ballast water treatment system enables ships' ballast water discharge to be in compliance with the IMO Convention for Ballast Water Management (BWM). The system is based on Stripping Gas Generator (SGG) unit burning Marine Diesel Oil (MDO) or Marine Gas Oil (MGO) that forms a low-oxygen inert gas. Inert gas is mixed with ballast water through venturi injectors, bubbles out the oxygen from water and creates a low oxygen layer above the surface. During the hold period oxygen dependent organisms die off and water can be discharged from the vessel. Adriadiesel d.d. developed this technology and system is in scaling stage ready for prototype testing in operational environment which corresponds with its rating of TRL 7.

54. SOx scrubber

Production, testing and installation of SOx wet scrubber as part of exhaust gas cleaning system (EGCS) for marine industry in cooperation with company Fuji Electric, Japan. Reducing sulphur oxide (SOx) emission from exhaust gases that enable burning cheap, commonly used heavy fuel

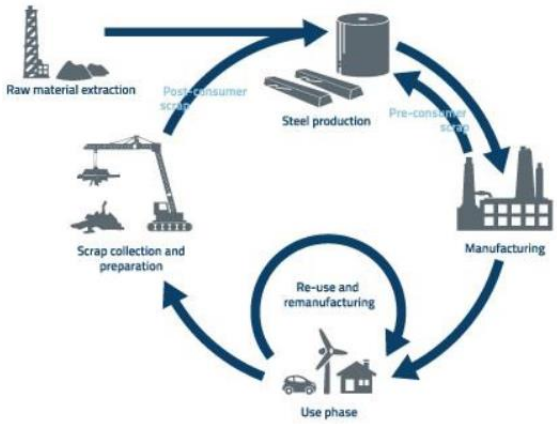
oil (HFO) in marine diesel engines with complying to MARPOL Annex VI requirements.

Another project from Adriadiesel d.d. is

implementing new solutions into already known technology – scrubbers. At the moment they are rated at TRL 7 and testing in operational environment.

55. Secondary steel nesting

When we talk about shipbuilding we can assume it is mostly steel based production which includes a lot of fabrication. That means also a lot of left-



overs and scrap material that is not used anymore and has to be shipped to steel mills for recycling. In some instances, left-over parts can also be used for some smaller parts to be cut out of them. That is when secondary steel nesting technology comes into play. Secondary steel nesting is one of the technologies which if applied reduces amount of waste materials, at the same time reducing production costs and environmental footprint. Making optimized design and elaborate nesting we can improve the secondary utilization ratio of steel.

56. New steel production from recycled steel

Continuing the previous TBO we can mention this part of the process of reducing material waste. As during ship production we cannot avoid having some waste and left-over material, mostly steel left after nesting, it can be recycled. Steel is the world's most recycled material and back in 2014, 86% of world steel was recycled. Although that number grows steadily, demand grows rapidly. Recycled steel is as strong and durable as new steel made from iron ore and can be recycled repeatedly without loss of strength. Steel is one of the trio of materials that can be endlessly recycled without loss (other two being glass and

aluminium which is also used in shipbuilding). It is said that steel is material that is used, not consumed. This trait makes for a great opportunity to better optimize material use in general, reducing at the same time indirectly energy usage in production chain, which cuts emissions and costs. We can say that steel is uniquely sustainable material.

57. H2 as green fuel

Global industry trends require the use of alternative forms of energy storage when used for drive or service needs of the ship. Today's demands are more difficult due to the traditional use of fossil fuels with a view to reducing nitrogen, sulfur and carbon dioxide emissions, as well as the other harmful particles for both health and the environment.

The 'storage' of energy is in various forms such as: heavy fuel, marine diesel, coal, liquefied natural gas (LNG), battery, hydrogen. Hydrogen should be considered as an energy container rather than as a fuel. The reason for this is that although it is one of the most prominent elements in the universe, it almost always comes in molecule formed with other elements, such as water or hydrocarbons. Hydrogen in the compound does not represent an appropriate form for use in fuel articles, but it is necessary to bring it in a suitable state. Today, two hydrogenation processes are commercially used. One is reforming the gas and partial oxidation, and the other one who is ecologically more interested in water electrolysis. When reforming gas (methane) in water-steam mixing at temperatures of 700-850 ° C and a pressure of 3-25 bars, hydrogen and carbon monoxide are obtained. Electrolysis of water has proved to be an environmentally acceptable process if electrolysis is generated from the current obtained from renewable forms of energy such as sun or wind. The drawback of such hydrogen production is high cost.

For marine engines, hydrogen can be used as addition to regular fuel in a specific ratio, thereby enhancing the usability of the internal combustion process, or as a energy storage used in the fuel cells to be used for powering the electric motor. As we focus on green technologies the use of hydrogen in fuel cells with no greenhouse gas emissions is considered.