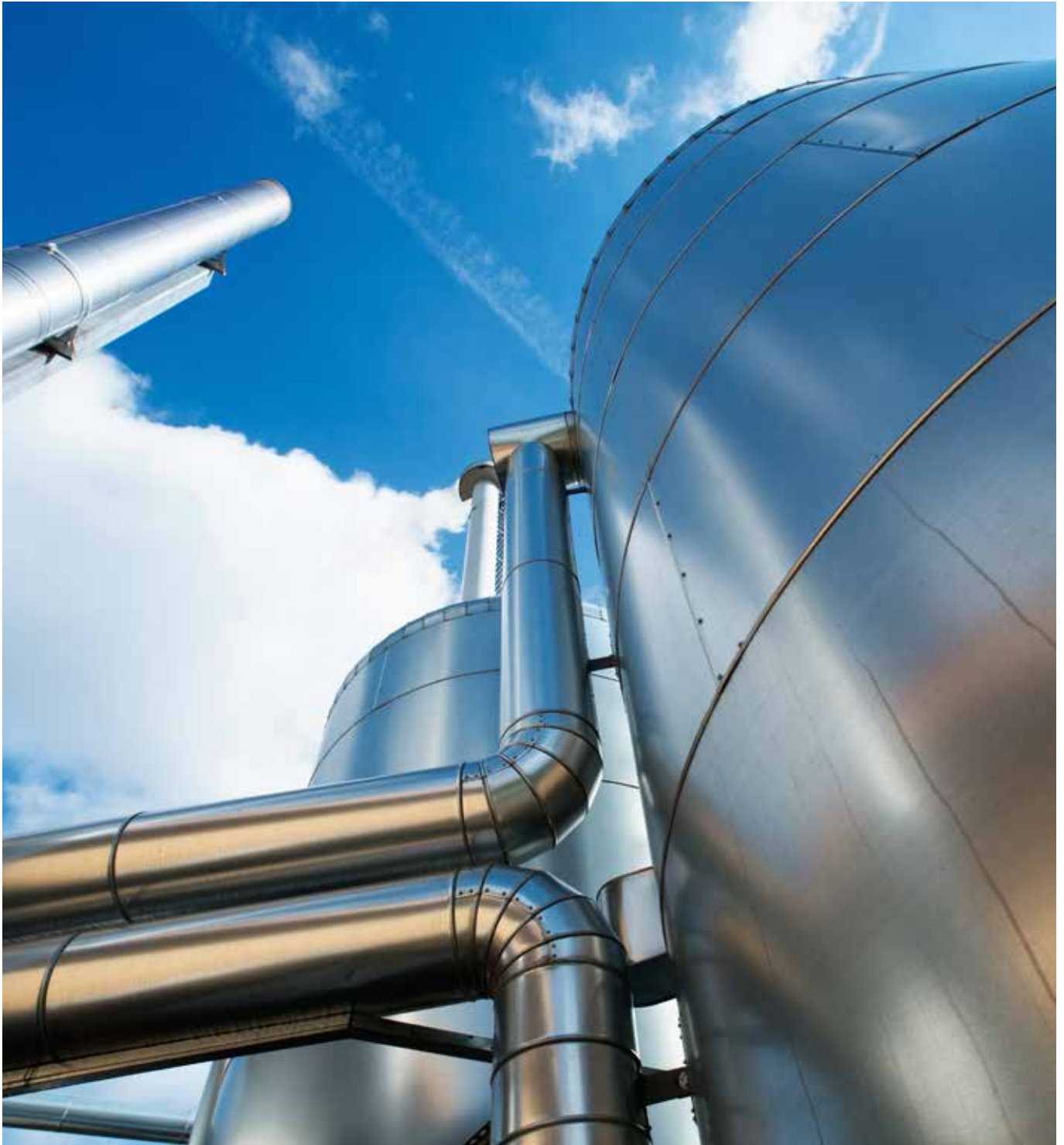


INNOVATION+ RINA

RINA MAGAZINE - INNOVATION EDITION



FOCUS
on hydrogen

SUSTAINABLE
solutions

FUTURE VISIONS
of energy trends

- 2 [Ready and prepared](#) UGO SALERNO, RINA
- 3 [On the cusp of a hydrogen revolution](#) MARCO ALVERÀ, SNAM
- 4 [Tailoring the solution to the need](#) CHRISTOPHER PAPILE, PROTON VENTURES
- 6 [Promoting gas turbine innovation](#) MAURO MORETTO - MIRKO BOTHIEN, ANSALDO ENERGIA
- 8 [Driving change in the fuel cell industry](#) PER EKDUNGE, POWERCELL SWEDEN AB
- 10 [Incentivising change](#) EMMANOUIL KAKARAS, MITSUBISHI HITACHI POWER SYSTEMS (MHPS) EUROPE
- 12 [One size does not fit all in shipping](#) MASSIMO DEBENEDETTI, FINCANTIERI
- 14 [Energy vectors key to Europe's goals](#) ALBERTO DOSSI, H2IT
- 16 [Feeding the energy hungry industries](#) PIETRO GIMONDO, RINA
- 17 [The future is hydrogen](#) GIORGIO URBANO, RINA
- 18 [Choosing materials for the hydrogen era](#) LAURA ALLEVA - LUCIANA INTISO, RINA
- 20 [Cleaning the seas](#) ANDREA COGLIOLO, RINA
- 21 [Fueling the transport chain](#) FRANCESCA BONSIGNORE, RINA
- 22 [Stepping on the gas](#) STEFANO BARBERIS, RINA
- 23 [Blending hydrogen with today's gas grid](#) ELISABETTA MECOZZI, RINA
- 24 [Is Ammonia the new frontier?](#) ANTONIO LUCCI, RINA
- 25 [News in brief](#)

Short editorial

Welcome to the latest edition of Innovation+, our magazine devoted to the latest trends and advances in worldwide industrial activity. In this edition we take a look at hydrogen's incredible potential as a clean energy solution. As climate change dominates the headlines and brings new urgency to the need for fresh energy sources, is Europe on the cusp of a hydrogen revolution?

In this issue, our experts outline the key areas for the future, from flexible decarbonised resources, to hybrid systems with integrated storage, to decentralised microgrids. We hear about the application of fuel cell gensets in situations ranging from rock concerts to port operations, and making gas turbines a key part of the new energy landscape.

Our experts also caution on the need for scientific advances to go hand in hand with business cases, and how to take the right approach to get projects financed. With new energy vectors, users will also have to adapt age-old materials for their new applications.

And in embracing hydrogen, we should not forget other complementary energy sources. Ammonia in particular offers major advantages when it comes to energy storage and, as such, is another new frontier for our innovators.

We thank our contributors SNAM, Proton Ventures, Ansaldo Energia, PowerCell, Mitsubishi Hitachi Power Systems, Fincantieri and H2IT for their valuable insights.

Ready and prepared

We need energy. We need energy to feed our houses, our factories, to transport ourselves and our goods from one side of the world to the other. We have been dreaming about sustainable energies for a long time and nowadays, when renewables have reached unexpected results in terms of growth due to improvements in technology and a significant drop in costs, expectations are moving from power generation to energy storage.

In this scenario, hydrogen is a key solution as a clean energy carrier and storage option. Hydrogen can contribute to exploiting the full potential of renewables, enabling power2fuel2power conversion and helping meet targets to decarbonize industries while guaranteeing continuity in energy supply.

Recent key achievements are accelerating the adoption of clean energy carriers: the cost of hydrogen from renewables (green hydrogen) is expected to fall due to the continuously decreasing costs of energy, backed by improvements in electrolyser technologies scaling up from MW to GW.

These achievements today make it possible to organize a complex, energy-intensive event such as the Olympic Games in Tokyo based completely on renewable energy and clean energy vectors such as hydrogen. They also set the basis for a credible development path to the extremely demanding CO₂ emissions targets set by IMO in the marine sector, that is, to halve the 2008 level of carbon emissions by 2050.

In addition, Oil and Gas majors, including ENI, BP, Shell and Equinor, are investing in research and pilot projects, and signing partnerships for hydrogen.

In this scenario, I see a key role for RINA, as we have a unique combination of capabilities, multidisciplinary skills and laboratories that enable us to contribute to technological development, qualification and adoption.

Our engineers and technicians are currently involved in many R&D initiatives. In the marine field we are paving the way to sustainable Short Sea Shipping Systems, as well as working on a zero emission vessel with hybrid propulsion systems and fuel cells for power generation.

Through HORIZON 2020 projects, we are aiming to develop affordable hydrogen fuel cell technologies in large industrial contexts (EVERYWH2ERE) and demonstrating innovative power2gas2power solutions which exploit the potential of RES with the flexibility of natural gas combined cycles in power generation (FLEXnCONFU).

Distribution and storage of hydrogen is a key domain for RINA: from feasibility engineering concept design, to testing materials and components in full-scale project-specific conditions as a key to optimize supply-chains and improve material selection and design.

We are also looking closely at developments concerning ammonia, an energy vector with incredible potential.

Indeed, this energy revolution demands rigorous testing and reliable technologies. However, with RINA's capabilities in verification, validation and certification, we can provide confidence to the market.

The world is on the verge of exploiting the full potential of clean energy vectors. RINA is ready and prepared.

Ugo Salerno
Chairman and Ceo,
RINA



On the cusp of a hydrogen revolution

Marco Alverà
Chief Executive of
Snam, President
of GasNaturally,
and Author of
“Generation H –
healing the climate
with hydrogen”



We are on the cusp of a hydrogen revolution. Europe can and should lead the way.

CO2 emissions continue to rise worldwide and evidence of global warming is all around us. We therefore need a new tool to meet our commitments to the Paris Agreement.

Accelerating our current “green electricity” strategy is only part of the answer, as it leaves two major challenges unresolved: how to keep the lights on when an expanded power system is reliant on intermittent, unpredictable renewables; and how to decarbonise the 50% of consumption which according to international renewable energy agency IRENA will not be electrified by 2050.

Hydrogen (H2) can help solve both these challenges and provide a definitive, affordable, and global path to solving climate change.

Using green electricity, hydrogen is produced by splitting water (H2O) with an electrolyser or natural gas (CH4) with carbon capture. It is virtually infinite, clean, easy to transport and store, and behaves like a fuel. It even offers a route to decarbonising steel – a sector that, if well-tackled, could help preserve jobs threatened by the energy transition.

Although scientists have long recognised its potential, until recently clean hydrogen was prohibitively expensive. In 2000, it cost 40 times as much to produce as oil. By 2010, this ratio had fallen to 15, and today it costs approximately twice the cost of oil. Breakeven is in sight.

So far, we have been assisted by the reduction in the cost of renewable power, but to move forward the cost

of electrolyzers must decline. With a still relatively small market, there is a lot of room to scale-up. The expected 7-fold reduction in electrolyser capex will bring the cost of green hydrogen to half the price of oil today.

What we need is a policy nudge to build scale. Europe should lead the way, as it has already done: despite its shortcomings, the Energiewende created significant demand for solar panels and wind turbines, driving down ultimate costs. We should learn from these successes and failures.

By creating demand, Europe can change the world, and it can do so using its existing gas network. Ongoing studies and Snam’s initial pilots in Italy suggest it is possible to blend 5%-10% of hydrogen with natural gas without having to invest in infrastructure or equipment. This would effectively decouple the development of production and consumption infrastructure.

However, this time Europe should ensure that it reaps the industrial benefits of climate leadership, rather than creating a market only for cheaper producers to undercut it. One possible way forward would be to join together to create an “Airbus of Hydrogen”, pooling skills and resources in a mega-factory large enough to push down the costs of electrolyzers from the early stages. This would in turn create a market leader and make the hydrogen revolution affordable for consumers and industry worldwide.

Tailoring the solution to the need

When it comes to discussing the most promising energy vectors for the future, the common theme is greenhouse gas minimization. But there should not be a one-size-fits-all approach: different applications require different energy solutions.

There are several important energy vectors moving forward, which we believe hold promise for the future, and should facilitate a greener, more flexible future for the EU energy system:

Green Ammonia as a fuel, particularly for ocean-going vessels. Ammonia or NH_3 is easily transported (as opposed to hydrogen), which means it can be produced in locations rich in solar and wind power and then sold elsewhere, particularly in areas where fuel costs are high. Proton Ventures is a leader in flexible ammonia production, including processes that do not co-emit any CO_2 ; they term it NFUEL. And, of course, ammonia burns without carbon emissions and has flexible uses: chemical, energy storage medium or fuel.

Blue and Green Hydrogen fuel, where carbon sequestration and/or carbon reuse plays an important role. These forms of CO_2 -free hydrogen may be converted to power in fuel cells or hydrogen turbines, which are under development by several companies.

Green Methanol for use as transportation fuels.

This is in deployment in some countries in vehicles specifically designed for use with methanol, while some countries have also introduced specific tax advantages.

Short-time batteries and +4 hour electrochemical energy storage. Here we are referring to battery systems such as Proton Ventures' battolyser under development with TU Delft, and, in general, redox flow batteries.

Proton Ventures' battolyser technology produces either hydrogen or electricity in one device; thus can address several business cases in one product. This technology is quicker to return on investment because it can provide energy storage in the short

Interview with
Christopher Papile,
Senior Advisor to
Proton Ventures



Ammonia facility in Northern Europe - Courtesy of Proton Ventures

or long term, as well as hydrogen gas; thus wherever the most sale value is at any given moment, the product has a revenue stream.

Innovation must work hand-in-hand with the business case. We must find a way to create more value with fewer resources, always keeping in mind the customer's need. Proton Ventures' approach is always to solve the customer and environmental issues simultaneously.

Proton Ventures is most known for their work with flexible ammonia production, and I am sometimes asked if the 'ammonia economy' or the 'hydrogen economy' is more viable. Such questions need to be rephrased, however.

Indeed, the ammonia economy is a subset of the hydrogen economy, since ammonia can be, amongst many things, a hydrogen vector, one that is more easily transported and offers additional applications such as fertilizer and deNOx. Proton Ventures is currently working with catalyst provider Haldor Topsøe to offer an industry-leading NOx and N2O reducing process.

But one can say that there are certain applications in which ammonia excels.

For instance, hydrogen does not perform as well when it comes to long-term storage CAPEX and OPEX, which is a necessity for inter-continental transport. Furthermore, ocean-going vessels cannot easily use hydrogen fuel, since the available space on the vessel is needed for cargo. Ammonia is therefore more suitable for energy storage of more than a week, as the loss of NH3 in storage is less than when using hydrogen or batteries.

On the other hand, we are unlikely to see ammonia used as a passenger car fuel. Here, however, hydrogen functions very well. In particular, 'working vehicles' such as tractors, warehouse forklifts and buses are very well suited to hydrogen. In some instances, hydrogen Fuel Cell Vehicles (FCVs) make technological and economic sense, while in other cases battery powered vehicles makes sense.

There are also some outstanding challenges for the ammonia industry

to resolve. For instance, there is considerable new work developing ammonia synthesis catalysts in order to reduce the energy cost of ammonia production. Proton Ventures is committed to R&D work for the next generation of developments.

With all these projects, the challenge is often around financing the projects: constructing a good business case, taking into account the timescale needed to engineer, procure and construct projects that run up to some billions of euros.

We need political will, but we also need all stakeholders working together, focused not only on CO2 reduction, but also on sound business cases that generate value and jobs.

We are happy to be on this journey with a highly responsive organisation such as RINA and its large contact base. Third-party certification services will become increasingly important as the EU launches its decarbonization goals. The various types of processes, projects and products will all have to be certified and verified.

The two companies also have a deep and shared history in marine: RINA has long been an expert in this area, while Proton Ventures, which is located in the port of Rotterdam, has marine applications in its DNA.

BIOGRAPHY

Proton Ventures BV is a leader in ammonia storage facilities, and alternative ammonia production facilities called NFUEL. Its unique engineering approach enables the production of CO2-free ammonia using renewable energy sources. The company is headed by CEO Hans Vrijenhoef.

Dr. Christopher Papile is a Senior Advisor to Proton Ventures BV and a recognized energy transition expert. Christopher is a former head of Thyssenkrupp's Global Renewable Solutions Task Force, with responsibility for industrial batteries, renewable hydrogen, ammonia, SNG and methanol. He also led Research & Development at the ExxonMobil/Technip 50/50 Joint Venture, where he and his team developed an industrial catalyst system for the polycarbonate market, and co-started Nuvera Fuel Cells.

 www.protonventures.com

"Innovation must work hand-in-hand with the business case"



Mr. Hans Vrijenhoef, founder and CEO of Proton Ventures - Courtesy of Proton Ventures

Promoting gas turbine innovation

Interview with
Mauro Moretto,
VP Technology at
Ansaldo Energia



and **Mirko Bothien**,
Head of Combustion
Technology at
Ansaldo Energia
Switzerland



Climate change is one of the most difficult yet most important socio-economic and technical challenges facing us in the coming decade. Increased public awareness has created expectations of a fast reduction in global greenhouse gas emissions, but at the same time the reality is that today's energy systems are highly reliant on fossil fuels.

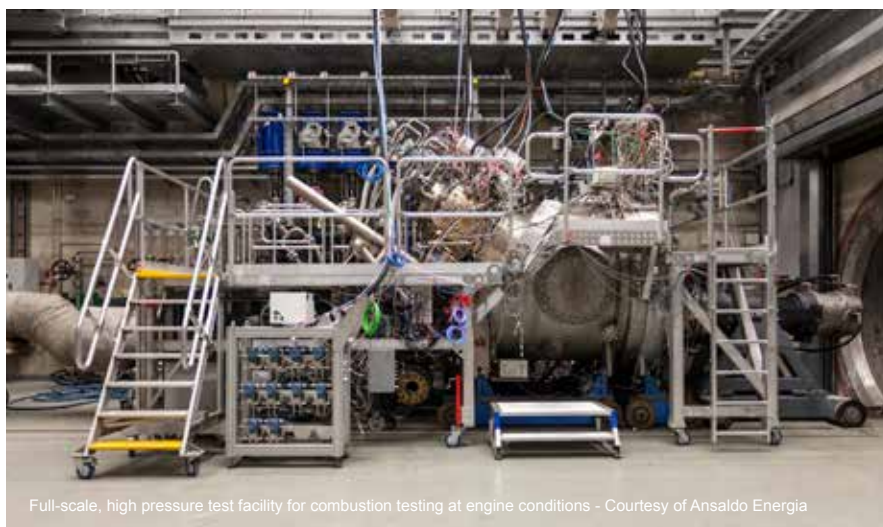
If we look at the main dynamics in the evolving energy landscape, it is clear that we collectively need to take responsibility and together drive change. We need "a grand coalition encompassing governments, investors, companies and everyone else who is committed to tackling climate change", as per a recent call by the Executive Director of the IEA. Only a concerted effort will be successful in achieving decarbonized power generation by 2050.

Being part of the solution is a great motivation for Ansaldo Energia. In this complex situation, we look for opportunities to make an important contribution.

Decarbonization is imperative, and storage and digital technologies will further accelerate renewable use in a form that will include a higher share of decentralized systems. The EU is set to lead this global process by pushing for a climate neutral economy by 2050.

As energy systems strive to achieve function and stability, we can recognise the following as key areas for the future: flexible decarbonized resources, hybrid systems with integrated storage technologies, decentralized digitally integrated energy microgrids, and intense deployment of digital technologies for asset exploitation.

Our goal at Ansaldo Energia is to make gas turbines an integral part of the future energy mix. We see a strong trend towards extending the fuel flexibility of gas turbines to incorporate green fuels, particularly hydrogen and ammonia. Indeed, in 2019, the EU Turbines Association pledged to meet customer demands for gas turbines operating 100% on hydrogen - both for new engines and retrofits - by 2030.



Full-scale, high pressure test facility for combustion testing at engine conditions - Courtesy of Ansaldo Energia

The trend has been fuelled by the rapid increase in volatile renewable energy (VRE) and the coal phase-out. A VRE share above 50% requires mid- to long-term energy storage due to longer periods of deficit and surplus energy. Hence, in future it will be crucial to deliver flexible and dispatchable power for load levelling. This is where Power-to-X-to-Power schemes come into play, with green hydrogen the best candidate for the energy vector “X” to be used in gas turbines.

The European Investment Bank is also considering a proposal to finance only projects with a maximum 250g/kWhe CO₂ from 2021 onwards. This would exclude any coal power plants, and even natural gas fired combined cycle power plants only meet the criteria if they feature 80% CC efficiency.

Ansaldo Energia’s sequential combustion engines achieve 250g/kWhe for 50% vol. hydrogen in natural gas. Our flagship model, the GT36, is today commercially offered with this value – NO_x compliant and without dilution – while the GT26 will be ready for this shortly (currently 45%).

Our challenge is to continue developing this work for our entire engine portfolio including retrofits and offer flexibility in terms of engine size. Our sequential combustion technology already leads the field in low NO_x, high hydrogen.

We are also pushing forward with hybrid power generation plants. We are working to identify the most promising hybrid plant configurations, and we

have launched a dedicated line of digital plant control systems for better integration of generation, storage assets and grids.

Certification bodies like RINA are set to play a key role in this energy transition, particularly in setting up schemes to assess CO₂ emissions per kWhe by power plants. This will be required in cases of financing limitations such as those discussed by the European Investment Bank. Power plants would receive a corresponding certificate, and this CO₂ footprint should include a lifetime verification, taking into account transport, fuel generation and potential storage aspects. The development and application of innovative new materials is also a strategic area in which certification bodies can play a significant part.

RINA also has an excellent track record in obtaining funding for future energy supply projects, such as, for example, those taking part in the framework of EU Horizon2020 projects.

Our task going forward is to enable Ansaldo Energia’s teams to develop the technologies which will enable gas turbines to play an integral role in the future energy market.

This task will also include building and fostering strong collaborations with the private sector, as shown by our recent collaboration with Equinor, as well as convincing government and funding bodies of the importance of gas turbine participation in tomorrow’s market.

BIOGRAPHY

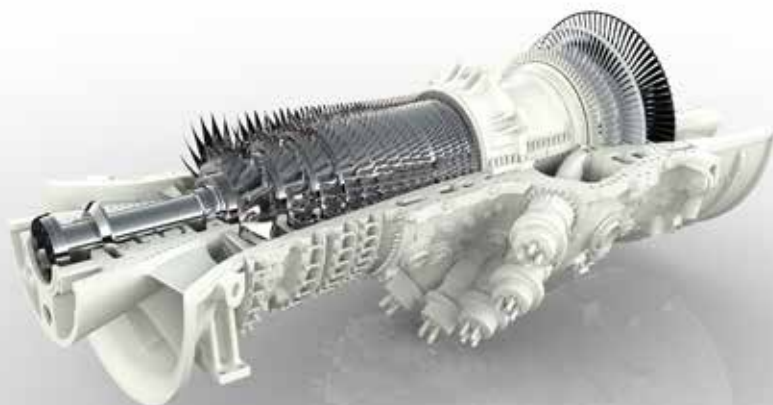
Mauro Moretto

Mauro Moretto is VP for Technology at Ansaldo Energia and leads the Technology Development Programs in the group’s Product & Technology Division. He was previously based in China where he was the Chief Technical Officer for the gas turbine joint venture business between Ansaldo Energia and Shanghai Electric. Prior to that, he occupied several management positions at Ansaldo Energia, including Program Manager for the H class Gas Turbine Development, and Head of Service Platform in the Product Development organization. Mauro started his energy career with GE Oil & Gas.

Mirko Bothien

Dr.-Ing. Mirko Bothien leads the Combustor Technology Team of Ansaldo Energia Switzerland, where he is responsible for the development of novel combustors with a focus on alternative green fuels. Mirko has 15 years of experience in gas turbine development with Ansaldo Energia, Siemens and Alstom. He has co-authored 75 technical publications and 46 invention disclosures in the field of gas turbine combustion. In 2018, he was awarded the Rudolf Diesel Industry Fellowship of the Institute for Advanced Study, TU Munich, for conducting research in thermoacoustics.

 www.ansaldoenergia.it



Ansaldo Energia GT36 H-class gas turbine - Courtesy of Ansaldo Energia

“Our goal is to make gas turbines an integral part of the future energy mix”

Driving change in the fuel cell industry



PowerCell MS100, our Power system, 60 to 100 kW - Courtesy of PowerCell Sweden AB

Interview with
Per Ekdunge,
Executive Vice
President of PowerCell
Sweden AB



Developments in the fuel cell industry are gaining momentum, as the urgency over climate change and air quality accelerates a push for change.

We are observing a surge in interest for hydrogen and fuel cells from both the private and public sector. Major industrial companies such as Bosch, Cummins and IVECO are entering the space, while we also see renewed interest politically, as governments increase their support as part of strategies to tackle pollution and curb global warming.

The application of these new energy vectors is now starting to take off in the heavy transport sector. Increasingly, they are being used in the road transportation network on buses and trucks, but also in maritime and rail systems.

Here at PowerCell Sweden AB we are

100% devoted to fuel cell and hydrogen technologies.

Our history dates back to the early 1990's, when founder Per Ekdunge recognized the potential of fuel cells. PowerCell was subsequently founded in 2008 as an industrial spin-off from the Volvo Group, with the aim of developing and producing fuel cells and fuel cell systems.

Today, the company is producing fuel cells and fuel cell systems with unique high-power density for automotive, marine, and stationary applications. The fuel cells are powered by hydrogen, and produce electricity and heat with no emissions other than water. As the stacks and systems are compact, modular and scalable, they are easily adjusted to any customer requirement.

The company offers both fuel cell stacks and fuel cell systems. The latter includes the fuel cell stack, together

with air supply systems, hydrogen management systems, cooling equipment, and control and safety systems.

Expertise and knowledge of hydrogen and fuel cells varies widely among companies. We sell fuel cell stacks to those customers with a high level of experience, and expertise in designing and building their own fuel cell systems, for example original equipment manufacturers (OEMs) in the car industry.

However, the majority of customers have less experience and expertise and prefer to take delivery of a complete fuel cell system.

We also offer customers engineering support in order that they can integrate the fuel cell system into their own applications.

To cover the full range of applications and requirements, PowerCell offers fuel cells with power CER outputs ranging from a few kilowatts to several megawatts.

At the lower end of the scale we offer micro CHP for households, while the top end of the range includes power stations and back-up power systems for hospitals, factories and other large buildings. PowerCell's two fuel cell stacks have outputs from 1 kW to 125 kW. With modular fuel cell systems based on these stacks, PowerCell can deliver megawatt solutions.

PowerCell always strives to innovate with the aim of developing products that represent real technological development which may be pioneers in their field. We allocate extensive resources to protecting our products with international patents covering the fundamental technology.

This strategy is aimed at building a strong and competitive patent portfolio so as to strengthen the company's market position and facilitate investments in new products, services and technologies for our clients. One of the major barriers for the commercialization of hydrogen and fuel cell products is the lack of harmonized regulations, codes and standards, however.

Here we believe certification bodies and consulting engineers such as RINA have an important role to play. A comprehensive set of applicable requirements and procedures for hydrogen and fuel cell technology installation and operation would reduce the time and cost of compliance.

Recommendations aimed at the simplification of requirements, and procedures for facilitating compliance, would also greatly increase efficiency in the industry.

We are benefiting already from RINA's project coordination on the Everywh2ere project, where it is leading several work elements and tasks such as logistics, safety and health analysis, as well as the regulatory framework and routes for replication.

Going forward, we are excited to start 2020 with our new Chinese subsidiary, PowerCell Fuel Cell (Shanghai) Co Ltd, up and running. Over the last two years, China has introduced important subsidies for vehicles which have been electrified using fuel cells.

PowerCell's S2 is the only fuel cell stack with PEM (proton exchange membrane) technology in the market that can tolerate high levels of contamination in hydrogen and can be run on both reformat hydrogen and residual hydrogen.

The Chinese industry produces vast amounts of industrial residual hydrogen, making this stack ideally suited for the Chinese market. China is at the forefront of developments in the fuel cell industry and we believe it is crucial to have a presence in this key market going forward.

“One of the major barriers is the lack of harmonized regulations, codes and standards”



PowerCell S2, our Versatile Stack, 3- 35 kW -
Courtesy of PowerCell Sweden AB

BIOGRAPHY

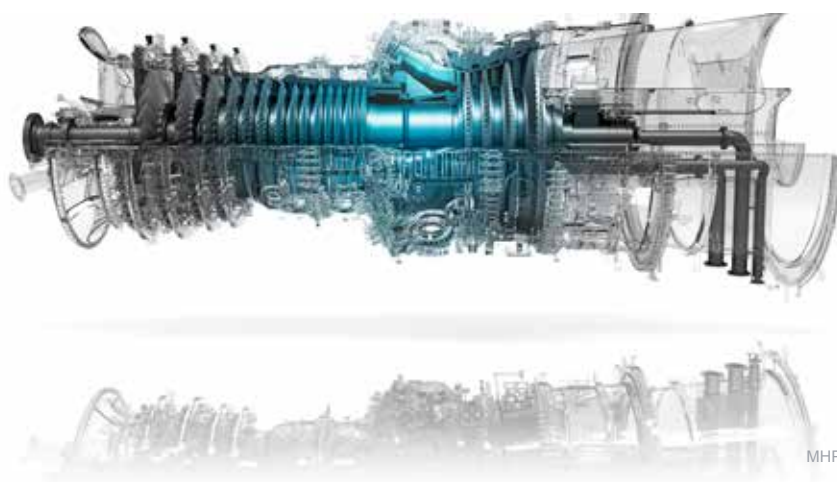
Dr. Per Ekdunge is the Executive Vice President of PowerCell Sweden AB, and the Chief Executive Officer of PowerCell Deutschland GmbH.

Per studied at the Royal Institute of Technology in Stockholm, Sweden, where he graduated with a M.Sc in chemical engineering. He obtained his PhD in electrochemistry at the same school and worked as a postgraduate fellow at the Dechema Institute in Frankfurt am Main, Germany. He was appointed associate professor in Applied Electrochemistry at the Royal Institute of Technology in 1987 where he headed fuel cell research from 1990 to 1993.

In 1993 Per joined Volvo Technology, where he held several management positions in the field of alternative drive trains and fuel cells. In 2008, he participated in funding the company PowerCell Sweden AB, where he is currently Executive Vice President. He is also Chief Executive Officer for its German daughter company, PowerCell Deutschland GmbH.

 www.powercell.se

Incentivising change



MHPS Europe - Courtesy of MHPS Europe

Interview with
Emmanouil Kakaras,
 Senior Vice President
 for Energy Solution
 and New Products at
 Mitsubishi Hitachi
 Power Systems
 (MHPS) Europe



With environmental issues at the forefront globally, there is a growing hope that we can answer the main questions surrounding carbon emission reduction through renewable electricity and the use of hydrogen as a new energy carrier.

We believe the most promising energy vectors going forward are biomass, blue hydrogen, and green hydrogen. However, each has its limitations. Biomass, and biofuels in general, are limited resources, and are also in demand by multiple competing sectors. Blue hydrogen, i.e. the hydrogen derived from natural gas or other fossil resources and where CO₂ emissions are reduced by Carbon Capture and Storage, also currently faces challenges: storage will be limited to only a few regions in Europe, while infrastructure to transport the captured CO₂ needs to be developed.

Green hydrogen, i.e. that from renewable energy sources (RES) and produced by electrolysis, is an ideal solution but supply is only increasing slowly. Moreover, the hydrogen needs to be re-distributed from areas where ideal boundary conditions exist for the

RES (such as offshore wind energy in the North Sea, and photovoltaic energy in southern Europe) to the ultimate consumption point.

To be fully functional, more infrastructure must be built to distribute the hydrogen, and also for its seasonal storage. Here in Europe, the EU needs to continue building additional RES electricity capacity to further decarbonise its electricity system.

In the meantime, there is now the potential to generate blue hydrogen at scale, and this will incentivise investment in infrastructure and in numerous applications. Later, these assets will be able to integrate a higher share of green hydrogen, as the latter becomes widely available on a cost-effective basis.

There is no doubt, however, that while huge progress has been made, there are still challenges to overcome.

These include:

1. Identifying business models and opportunities in order to start deploying available technologies today.

2. Ensuring security of supply and energy affordability. The growth in RES is relatively slow and requires different types of back-up, which inevitably increase cost.
3. Integrating more quickly sustainability into business strategies: industry is progressively learning that redirecting operations towards cleaner solutions can go hand in hand with a good business case
4. Creating public outreach and education programmes: society has a fundamental role to play, and education campaigns are necessary to teach people about new technologies, their costs and benefits.
5. Ensuring clarity and certainty from policymakers, and the removal of regulatory hurdles that could impede innovation or new and cleaner business models. We can look at sector coupling as an example. Until recently, we looked at systems in silos and therefore this is how those systems have traditionally been regulated, without taking into consideration the overall efficiency that sector coupling technologies bring to electric and gas grids. Meanwhile the myriad taxation systems and levies/feed-in tariffs in different EU countries sometimes make electrons too expensive to enable hydrogen production at a competitive cost. The recent EU ETS (Emissions Trading Scheme) reforms are now yielding results but it is paramount that such mechanisms incentivise

low-carbon solutions across the different industrial sectors. Another example is the recently adopted Renewable Energy Directive (RED II). This is a first step in providing a reliable framework for synthetic fuels in the transport sector but gaps remain which the European Commission must address in the coming years.

As long as low-carbon hydrogen is not legally recognised in the transport and heat/power sectors in the same way as other alternatives such as biomass and biogas, the respective premium price cannot be realised and projects cannot be launched. Thus, while technological development is essential, regulatory improvement is also necessary.

This latter point also applies to standards. All new energy vectors bring specific challenges, and harmonized standards and regulations would greatly assist their introduction, allowing industry to switch easily to a 'hydrogen' or 'ammonia' economy. This will of course involve certification bodies.

We already enjoy a good relationship with RINA, which has proved to be an experienced partner in R&D projects. Our project "PUMP-HEAT", which is funded by the European Union under its framework programme Horizon 2020 and deals with the integration of heat pumps into CCGT power plants, has greatly benefited from RINA's input on business models, techno-economic

requirement, and project management. MHPS is also looking at further collaboration with RINA in its potential involvement in NESOI (New Energy Solutions Optimised for Islands). At MHPS, we want to be at the forefront of development, both locally and globally. Therefore, our global subsidiaries are working in close cooperation to identify the specific needs in each of the regional markets, and also the opportunities.

BIOGRAPHY

Professor Emmanouil Kakaras is the Senior Vice President for Energy Solution and New Products at Mitsubishi Hitachi Power Systems (MHPS) Europe, and was previously Head of Research & Development at the group.

His current R&D activities focus mainly on the flexible operation of thermal plants, fuel cells and electrolyzers, and the development of large-scale energy storage and CO₂ utilization.

He also serves as a member of the Board of Directors of "Energy Technologies Europe" (ETE, former EPPSA), and "EU Turbines". He is also participating in working groups run by the European Commission (CAG, Energy Committee), the Advisory Council of the Technology Platforms on Zero Emission Power Plants and on Smart Networks for Energy Transition, as well as the Scientific Board of Industrial Associations (VGB, Rhein Ruhr Power, BDI). Prior to joining MHPS Europe in 1991, Prof Kakaras was a Professor at the National Technical University of Athens, Greece.

 www.emea.mhps.com

"There is now the potential to generate blue hydrogen at scale"



MHPS Europe Headquarter - Courtesy of MHPS Europe

One size does not fit all in shipping

Interview with
Massimo Debenedetti,
Corporate Vice
President for
Research &
Innovation at
the Fincantieri
shipbuilding group



Reducing air emissions through the use of new propulsion and energy generation technology is a key challenge for the shipping industry.

The future fleet will rely on a broad range of different fuels, propulsion solutions and energy efficiency measures depending on the different voyage profiles.

The technology portfolio will include alternative fuels such as LNG, LPG, methanol, biofuels and hydrogen, as well as emerging technologies such as energy recovery systems, advanced high-storage batteries, fuel cell systems and different power plant configurations. Each option comes with benefits and challenges related to reduced emissions, different Technology Readiness Levels, and impact on general arrangement and payload.

For these reasons, we do not see yet a consolidated consensus on the fuel of the future. In the long term, fuel leadership will emerge based on environmental neutrality, price, energy density, fuel availability, production issues, storage and distribution infrastructure and impact on general arrangement and payload.

For the coming decades, we see several fuels and technologies applied in different segments of the maritime industry, according to their viability as a business model:

- In the short-to-medium term, fossil fuels with a better environmental footprint and lower carbon content (e.g. LNG, LPG and methanol) will be widely adopted to significantly reduce greenhouse gas emissions. Synthetic and bio-fuels may also represent an intermediate solution to facilitate the energy transition in a medium time-range, especially

when carbon neutrality is ensured in the entire life cycle.

- Hydrogen and hydrogen carriers (e.g. NH₃, LOHC and synthetic hydrocarbons) will play the role of game changers, thus delivering significant positive results. These will require the creation of a supply chain based on renewable energy sources which is able to satisfy the increasing demand. Their potential in terms of decarbonisation is huge, even though applicability on a large scale will be slowed down by regulatory and technological constraints. These are currently being addressed by the most innovative industrial stakeholders.

Alternative fuels, electrification and the overall integration with port infrastructure are the key enabling factors for long-term sustainability in maritime and shipping.

Ships are very different in terms of size, service and operational profile, and applying a new technology to a variety of different applications requires high adaptability and fit-for-purpose to operational conditions. Therefore, we do not think the one-size-fits-all can be the right approach.

Beyond R&D challenges, we must also overcome several non-technological barriers in order to achieve the cost-effective application of the technologies described above.

First, we do not yet have a clear regulatory framework enabling the use of hydrogen-based technologies. Then, we, as shipbuilders, must minimize the impact of fuel cells, batteries, fuel tanks, energy recovery systems and auxiliary systems on general arrangement and payload: after all, ships are made to carry goods and passengers, not fuel...

Furthermore, there is not a clear picture about future availability and pricing of the above-mentioned fuels: production capacity and a widespread bunkering network are fundamental enablers to ignite the decarbonisation of shipping.

Finally, incentive schemes in the form of R&D, Capex and Opex grants, which reward greenhouse gas reduction, are needed to catalyse the adoption of greener technologies.

Fincantieri is working hard to identify the future evolution. We are committed to implementing green technologies, and we are convinced that future competitiveness is closely connected to the first-mover advantage.

The internal R&D programmes we are developing and the partnerships we have established are going into this direction.

Shipyards can play a key role. We can support the promotion of alternative energy vectors, and disseminate information about the most cost-effective technologies and how they interface with the ship.

Participating in technical committees and cooperative research projects is fundamental for this cross-fertilization of information, as is providing technical support to national and international authorities in order to develop rules and regulations.

Onboard a ship, the biggest constraints are space and weight. As a result, energy transition represent an

engineering challenge not comparable to similar applications onshore. In brief, the shipbuilder can become the technological enabler in the value chain.

As mentioned, we imagine a set of alternatives fuels will replace the current ones. Some small-scale applications are already showing the future. At the same time, we need to frame such transformation in a typical S-curve evolution of technology, albeit with a significant difference: we are entering this transformation not because we have a technology enabling the transformation, but because we, industrial players, want to evolve into a paradigm of sustainability and climate neutrality.

Therefore, being at the beginning of the S-curve for large-scale hydrogen-based fuel applications, we need to accelerate adoption by closing the gap on full scalability. This means that, if we manage to identify solutions to increase energy efficiency and reduce power needs, this will in turn accelerate the uptake of GHG-free solutions.

Embracing the open innovation approach and establishing core partnerships is of paramount importance. The Fincantieri Group is participating in a range of groups, including Sea Europe, Hydrogen Europe, Waterborne Technology Platform, plus expert groups in the European Commission such as the European Sustainable Shipping Forum, and the International Maritime Organization. Working closely with classification societies is also key because when

breakthroughs occur, traditional design paradigms and regulatory frameworks are challenged. RINA is one of the preferred classification societies for addressing these challenges.

Some alternative fuels, for example, do not have a coherent regulatory framework developed yet. This is the case for the Tec-Bia project supported by the Italian Ministry of Economic Development, where Fincantieri and RINA are cooperating with the Italian Coast Guard to define rules and regulations enabling sea trials of a sea-going vessel equipped with a fuel cell propulsion system.

At Fincantieri we feel the responsibility to lead change in the business, and we are proud to consider ourselves key players in creating a more sustainable future for the generations to come.

BIOGRAPHY

Massimo DeBenedetti is the Corporate Vice President for Research & Innovation at the Fincantieri shipbuilding group, which he joined in 2012. His responsibilities include defining the R&D corporate strategy, plan and budget; managing and executing the R&D corporate plan; driving the Innovation Process; and managing Intellectual Property. Previously, Massimo worked at the Fiat Group, where he held several leadership roles in Research, Innovation and Product Development and Strategy. He currently serves as a director on the boards of the Trieste International Foundation for Scientific Progress and Freedom, Isotta Fraschini Motori, and Decomar.

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Delivery of cruise ship Scarlet Lady to Virgin Voyages - Courtesy of Fincantieri

“The future fleet will rely on a broad range of different fuels”

Energy vectors key to Europe's goals



Interview with
Alberto Dossi,
President of H2IT -
Italy's Hydrogen and
Fuel Cell Association



If Europe's objective is the full decarbonisation of the energy system by 2050, energy vectors will be key to integrating vast capacities of renewable energy. In this context, hydrogen is a necessary solution for the reduction of emissions in sectors that are very difficult to decarbonize but have a strong impact on climate.

These include transport, freight logistics, industrial heating, and industry feedstock. Moreover, hydrogen can play an important role in the decarbonisation of the gas grid and power production, maximizing the use of renewable energy sources.

The European framework envisaged by the Green Deal puts hydrogen at the centre in the fight for clean, secure and affordable energy, and underlines priority areas such as "clean hydrogen, fuel cells and other alternative fuels, energy storage and carbon capture, storage and use".

To achieve these goals, hydrogen production is required on a large scale. The Hydrogen Roadmap Europe shows that to meet the objectives Europe

needs to generate approximately 2,250 terawatt hours (TWh) of hydrogen in 2050, representing roughly 24% of total energy demand.

A McKinsey study in Italy showed similar results; hydrogen could supply as much as 23% the total energy consumption by 2050, with very high potential in transport, building construction and industrial applications.

There are still challenges, however. Firstly, costs are currently too high to provide the same technological performance as traditional applications. To date, more than 90% of hydrogen is produced from fossil fuel sources, which are the cheapest form of production.

Lowering costs is one of the most important objectives in fully exploiting hydrogen's potential. The International Energy Agency's (IEA) report "The future of Hydrogen" states that the cost of producing hydrogen from renewable electricity could be lowered by one third by scaling up production and with a lower cost of renewables.

The future is not far off though; producing green hydrogen from renewable sources in suitable sites with excess energy production and a proximity to the end users could soon become cheaper than traditional production.

In Italy, where there is good availability of renewable energy, green hydrogen may soon arrive at break-even point using grey hydrogen from natural gas. This means Italy is a suitable place to start the deployment and scale-up of electrolysis for industrial use.

Integration of renewables will also not be possible without large-scale storage solutions which can function for large quantities and for long periods of time. In this regard, hydrogen is a high energy density storage medium, suitable for seasonal storage. It allows the connection of energy networks, such as gas electricity grids through power to gas solutions, and other forms of conversion that enable the use of extra production from renewable energy in many areas such as transport, industry and buildings.

Italy's national gas transmission network is also a strategic asset, and could offer large-scale seasonal storage capable of receiving quantities of energy for long periods.

Hydrogen produced from renewable sources and blended with methane, and potentially transported in its pure form in dedicated pipelines, would not only allow decarbonisation of

various sectors such as industry and residential, but would transform the gas network into a buffer to store energy excess.

The lack of a clear regulatory and legislation framework, however, is also a barrier to development, and is hindering the path to commercial application. The role of certification bodies such as RINA will be crucial. For the hydrogen sector to develop, it will be necessary to build a regulatory-legislative-technical framework of reference, enabling investments and validating applications.

H2IT, the Italian Hydrogen and Fuel Cell Association created in 2005, is committed to gathering stakeholders from the entire value chain from production to end use, and our members are playing an important role in opening the market for hydrogen applications.

Italy's whole industrial sector is exploring opportunities. At the Hydrogen Table launched by the Ministry of Economic Development in June 2019, more than 30 Italian hydrogen projects for 2020 were presented.

Industry is supported by internationally renowned research centres, whose strength is demonstrated by the strong Italian presence in European projects financed by the FCH JU (Fuel Cell and Hydrogen Joint Undertaking). In 13 years of the program, Italy has been involved in 140 projects with €98 million of funding.

Thus, Italy can be considered a leader in several reference sectors of the hydrogen supply chain: production, logistics and transport, end use in transport, industry and residential.

BIOGRAPHY

Alberto Dossi is the President of the Sapio Group, a privately owned family company specialising in the industrial and medicinal gas sector.

Since 2018, he has also held the position of President of H2IT (Italy's Hydrogen and Fuel Cell Association), and since 2019 he has also been Vice President of Assolombarda, the regional association for entrepreneurs. Alberto is responsible for Industrial Policy at Assolombarda, which is also a member of Italy's national Confindustria association.

Alberto joined the Sapio Group after graduating in Law at the State University of Milan and working for a brief period at a law firm.

As President of the Group, he has received three medals and six silver plaques from the President of the Republic, and a silver plaque from the Chamber of Deputies in connection to the Sapio Prize for Research and Innovation.

 www.h2it.it



“Hydrogen could supply as much as 23% of total energy consumption by 2050”

Feeding the energy hungry industries

Around 25% of all global greenhouse gas (GHG) emissions are produced by industry. However, today, investments in zero-emission technologies are rapidly catching up with investments in fossil fuel energy.

The energy-hungry or so-called energy intensive industries¹ (EII) face important challenges in order to mitigate their CO₂ emissions: the application of best available technologies (BATs) will only be able to reduce emissions by 15–30%. Reductions beyond this limit will require new investment and fundamental changes in the core processes used. Furthermore, the latter will be based on new 'breakthrough technologies' that need further development to become both technically and commercially viable.

RINA has been a pioneer in alternative iron ore reduction, and hydrogen-based steel production. In the 1980s, it designed and realised one of the first plasma-based reducing furnaces in Europe which it still operates today. Today RINA is a leading technological innovator in the reduction of energy consumption and carbon dioxide

emissions by the energy intensive industries (EII). Among the many projects RINA is involved in, we can mention:

- **GreenEAF:** (EU-funded project) this is focused on the application of char from biomass as a fossil coal substitute in steelmaking. This brings significant reductions in CO₂ emissions, and will stimulate the development of new business opportunities (15% of CO₂ emission reduction is achieved through biomass utilization);
- **LowCarbonFuture:** (EU-funded project) this is a dissemination project aimed at defining a road map for industry decarbonisation (up to 95%, according to ongoing innovative European projects)
- **Polynspire:** (EU funded project) this project is aimed at the exploitation of low-grade plastics (representing more than 350,000 tons per year in Italy); such materials, which are discharged from the recycling route, can be used as carbon bearing materials replacing fossil coal (an example of industrial symbiosis and the circular economy).

Industry decarbonisation, and the application of breakthrough technologies, will require the following: optimization of production cycles and efficiency improvements, waste heat recovery, the utilization of renewable sources, the application of carbon capture and storage, and the utilization of green hydrogen as a substitute to fossil fuel materials.

RINA is able to support the EII in developing and implementing technological solutions to reduce CO₂. This support can range from analysis of available technologies, to the definition of alternative technological solutions. It is also able to use Digital Twin processes to assess new technological solutions, carry out R&D activities on behalf of the EII on new technologies, identify the most suitable funding schemes, and prepare research proposals. RINA can also assist with full industrial process digitalization with 4.0 solutions, coupled with Machine Learning and Big Data Analysis.

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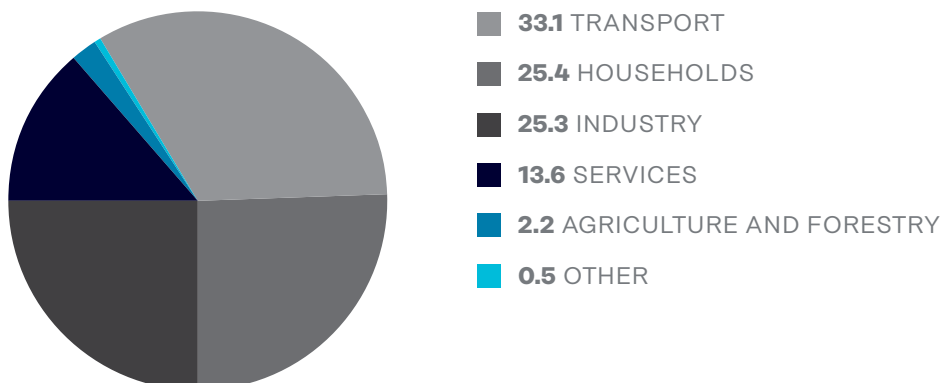


Figure : European energy consumption by sector (Source: Eurostat)

¹ The following are considered EIIs: food, pulp and paper, basic chemicals, refining, iron and steel, nonferrous metals (mainly aluminum), and nonmetallic minerals (mainly cement). They account for about 50% of delivered energy use in industry.

The future is hydrogen

Hydrogen is everywhere. Hydrogen is inside us. We are made of hydrogen. The earth is facing an environmental crisis. Modern day society is hungry for energy, but this requires the consumption of huge quantities of fossil fuels, leading to significant CO₂ emissions.

Europe is tackling the problem and moving towards a decarbonized energy system. The 28 Member States of the EU have signed and ratified the Conference of the Parties (COP21) Paris agreement with a goal of maintaining global warming “well below 2 degrees Celsius above preindustrial levels, and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.”

This will radically change how the EU generates, distributes, stores and consumes energy, and we need to be prepared for this transition. To reach this goal, we need to limit energy-related CO₂ emissions to less than 770 megatons (Mt) per year by 2015 (ref. EIA, 2017).

According to Hydrogen Europe, hydrogen will enable the EU to reach its

decarbonization goal. It allows energy players to convert and store energy as a renewable gas. It is a versatile, clean (when reacted it produces only water), flexible energy vector, which can achieve decarbonization in transport, industry and building.

In building infrastructure, it is important to decouple energy production and consumption. Hence energy storage is crucial to increasing the use of renewable energy sources. Hydrogen would be a competitive way to store energy from renewables, avoiding the use of batteries and fossil fuels.

In the EU, the transport segment contributes to one third of all CO₂ emissions. Hydrogen is the most promising decarbonization option for trucks, buses, ships, trains, large cars, and commercial vehicles, where the lower energy density (hence lower range), high initial costs, and slow recharging performance of batteries are a major disadvantage. Hydrogen refuelling infrastructure also has significant advantages: it requires only about one-tenth of the space in cities and along highways compared to fast charging. Hydrogen can be

supplied in a flexible way (gas pipe, in situ generation via electrolysis, by truck).

Hydrogen can also be burnt to produce high-grade heating, or can be utilised to produce ammonia and fertilizers. The heating industry contributes significantly to European carbon emissions.

Meanwhile, the potential use of hydrogen in industry is well known; it is a feedstock in steelmaking and can be used as a reductant, substituting for coal-based blast furnaces. In conclusion, industry and regulatory stakeholders should continue to develop additional hydrogen and fuel cell applications, and scale up successfully proven ones. The recent success with hydrogen trains, for example, should be the start of a Europe-wide replacement of diesel trains. Meanwhile, boosting the deployment of mCHPs and CHPs in residential and commercial properties would improve energy efficiency in buildings and make the best use of hydrogen and natural gas in this area.

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Choosing materials for the hydrogen era

In the 'hydrogen economy', natural energy is used to produce hydrogen that can be stored, transported and finally transformed again into energy for transport, buildings, farms and industries.

A range of technologies to produce, store and convert hydrogen have already been designed or are under investigation, covering chemical, electrochemical and biological solutions, as well as production of hydrogen by syngas, electrolysis, or metabolic activity from specific microorganisms. The use of hydrides in the storage of hydrogen and fuel cell technology in its re-transformation to energy are also under consideration. However, the introduction of these new technologies requires a new approach to materials and components. In each process, the right selection of materials must be made.

The energy community is currently working hard to find appropriate data and information to assist in making that choice, as well as tests and results from similar or transferable applications.

So, let us look at what happens when hydrogen enters or touches a material, taking the example of metallic materials. What properties can be compromised?

First of all, the amount of hydrogen that can enter into a metal is not always the same. This amount will depend on: the hydrogen source (corrosion, hydrogen gas, cathodic protection, fabrication processes etc); the metal (carbon steels, stainless steels, nickel alloys etc); and physical variables such as temperature and pressure.

We can see that the amount of



hydrogen that enters a metal in contact with formation water exposed to sour gas at 100-150°C (a condition of many metals in oil production systems) is not the same as when gaseous hydrogen is in direct contact with a metal at room temperature and at a pressure of 500 bar (typical of tanks for hydrogen storage).

All the chemical reactions that can occur when hydrogen is in contact with the metal's surface can accelerate or slow down the hydrogen uptake, and affect the way hydrogen is hosted in the bulk material. Thus, the way the hydrogen interacts is the combination of several elementary actions: electrochemical transport, cathodic and anodic reactions, absorption, transport through the structure, accumulation, desorption.

Hydrogen enters the metal in its elementary form, atomic H, which is very small and diffuses within the

lattice, although this is not dangerous in itself and can be easily removed.

When lattice interstitial spaces are empty, the accumulation of hydrogen can increase its hardness and strength. However, this does not result in an improved performance of the material, and hydrogen is not distributed in a homogeneous way as it would be in an ideal lattice.

Atomic hydrogen can also accumulate in defect areas of the lattice or microstructure discontinuities, causing a distortion of the surrounding lattice. Furthermore, in specific conditions, hydrogen can recombine in a molecular gaseous form, creating blisters which result in sudden cracking or reduction of toughness. In the case of a component with an existing defect, hydrogen can accumulate, causing lattice embrittlement and promoting failure at loads lower than those when there is no hydrogen. This



Safety chamber for the full scale testing of components (cyclic pressurization with Hydrogen)

The following metals are of principal interest for hydrogen service: stainless steels, conventional ferritic and martensitic steels, plus titanium, nickel and aluminum alloys which are increasingly being used in specialized applications.

By studying the duality between the metallurgy and the damage mechanisms, a high level of reliability in the produced steel has already been achieved. This knowledge is now being applied to each specific application, with further testing and qualification taking place.

Implementing hydrogen service on a grand scale calls for massive storage facilities that are capable of containing huge volumes at very high pressures. The use of ferrous metal alloys is therefore seen as the most viable solution for large storage tanks, and also large structures with storage cylinders, such as distribution centers and hydrogen fuel power plants where high levels of safety are also essential.

Engineers are also studying the use of composites in hydrogen service. However, the results are at an early stage, and not yet sufficient to demonstrate that composites can be considered for safe, long-term use.

However, taking into account all of the above considerations and with proper testing, the skilled engineer will be able to define the right materials for each application to be used in the new hydrogen economy.

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phenomenon is known as 'hydrogen enhanced fatigue'. With so many possible reactions, material selection for hydrogen service requires a thorough understanding of hydrogen embrittlement in the specific application. It is crucial to know the target properties of the component and how hydrogen can interact with the microstructure features.

This is a very broad subject. There are two well-known 'rules of thumb' regarding strength-level effects in hydrogen embrittlement (although there are a few exceptions). One is that embrittlement becomes more severe as strength level increases; the other is that steels with strengths below about 700 MPa (100 ksi) show no significant embrittlement.

Therefore, it is crucial to have data describing the deterioration of a specific property when hydrogen enters the bulk metal, while it is also

important to quantify the magnitude of hydrogen permeation in the different conditions of gaseous hydrogen service.

Hydrogen testing of materials, including welds, together with scale-up tests for components, should precede qualification of existing material or material selection for a new one.

To address this scope, RINA has created the innovative Delta-H lab, allowing engineers to address most of the material-related issues relevant to hydrogen storage and hydrogen transportation.

It is possible to test materials at very high level of hydrogen pressure, determining the hydrogen effect on tensile properties, on crack propagation, and on low cycle fatigue resistance, as well as component reliability in situations close to in-service conditions.



Cleaning the seas

From 1 January 2020, all ships will have to burn a fuel with a low Sulphur content or install an exhaust cleaning system as part of efforts to limit greenhouse gas (GHG) emissions.

The current strategy of the International Maritime Organization (IMO), the global agency which regulates shipping, aims to reduce total annual GHG emissions by 50% by 2050 compared to 2008. For CO₂ emissions per unit of transport work, the goal is for an average reduction across international shipping of at least 40% by 2030, pursuing efforts towards 70% by 2050 (both compared to 2008¹).

Among the short-term measures identified by the IMO are: further improvement in the existing energy efficiency framework based on the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP); development of technical and operational energy efficiency measures for both new and existing ships; the establishment of an existing fleet improvement programme;

and speed optimization/reduction measures. Based on CO₂ emissions data collection, data analysis will be carried out and decisions taken on what further measures could be adopted. Market-Based Measures (MBMs) and effective uptake of low-carbon alternatives are also on the agenda, plus the adoption of other new mechanisms and zero-carbon, or fossil-free, fuels.

Valid alternatives to traditional fuels will be needed to meet the 2050 targets.

RINA is currently taking part in a Low Environmental Impact Technology project, whose goal is to increase ships' eco-compatibility and reduce emissions of CO₂ and CH₄, NO_x, SO_x and particulate.

The main aim of the project is to develop energy generation systems with low or zero emissions for ship application, and a new energy generation model for hotel services onboard cruise ships. In this regard, it will be analyzed the possibility of

using modular systems of delocalized fuel cells for the co-generation of electricity and heat alongside the main diesel generators dedicated to propulsion and machine auxiliaries.

Among the energy carriers being considered, hydrogen has the highest energy content per unit mass, equal to about two and a half times methane and three times diesel. However, due to its low density, hydrogen has a low energy content in terms of volume. Storage systems are being studied to increase the density of hydrogen.

The adoption of low flashpoint fuels, such as hydrogen, will require new legislation. The International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code) establishes, in its current text, requirements for the construction and management of ships using Liquefied or Compressed Natural Gas (LNG or CNG). However, IMO discussions regarding the use of hydrogen have not yet started due to the lack of concrete agreed proposals.

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¹ The IMO strategy will be revised on the basis of the Fourth IMO GHG Study of fuel oil consumption data collected during the 2019-2021 period

Fueling the transport chain



The use of hydrogen as an energy carrier is emerging on a global scale, being one of the few potentially zero-emission energy carriers. It represents a clear and valid option for exploiting large portions of non-programmable and non-storable renewable resources. In the Mobility and Transports field, the application of hydrogen technology is growing exponentially. However, we can observe that the technological developments and trends are different for each mode of transport.

- In the light transport sector, Fuel Cell Electric Vehicles (FCEV) can provide a transport service comparable to today's vehicles in terms of refueling times and autonomy. The major global car manufacturers have already integrated hydrogen fuel cell technology into their strategic plans. According to a 2019 report by the International Energy Agency (IEA), 11,200 of these cars are currently operating in California, Europe and Japan, while there are more than 300 FCEV buses operative in the public transport

systems in Europe, China and the USA. It is estimated that by 2030 the cumulative sales of FCEVs will reach 8 million vehicles and that by 2050 FCEVs' share of total car sales will be around 30%.

- In the field of heavy transport, heavy hydrogen-powered vehicles can constitute a valid alternative to existing diesel engine vehicles, in particular for long distances. Heavy vehicle fleets are currently being tested in various countries.
- In the railway sector, locomotives with fuel cell powertrains are already competitive with current diesel engines in terms of performance, service guarantee, and also in some cases economically, particularly on non-electrified lines. Germany already has two public service trains and plans to replace a considerable portion of its diesel locomotive fleet with hydrogen vehicles in the near future, to be followed by the United Kingdom, France and other Northern European countries.

- In the maritime sector, hydrogen-powered ships are still mainly at the prototype stage, while military fuel cell submarines are already in use. In Europe, starting from 2021, the first fuel cell systems will be introduced in a cruise ship and two ferries.
- Elsewhere, hydrogen power is also being applied to alternative mobility types, including vehicles for industrial logistics applications, such as material handling.

The mobility capacity and the spread of hydrogen vehicles are strongly dependent on the presence of a comprehensive supply infrastructure network. This network has to guarantee continuity of supply along the major transport routes. In Europe, this already existing network is characterized by the presence of several filling stations on the Denmark-Holland-Germany-Austria route which continue until Bolzano in Italy.

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Stepping on the gas

In the EC's Political Guidelines presented to the EU Parliament on 15 July 2014, former EC President Jean-Claude Juncker announced that "Europe relies too heavily on fuel and gas imports. We need to reduce this dependency (...). We need to pool our resources and limit the impact of climate change and to keep energy affordable – by using more energy from renewable sources and becoming more energy efficient."

This vision has been reaffirmed by incoming president Ursula Von der Leyen's EU Green Deal, which strongly encourages renewable driven gas production and the interaction of energy grids via power-to-gas solutions (power-to-hydrogen, power-to-ammonia etc.).

This concept is also being promoted by the EC through policies and schemes which aim to facilitate a more sustainable penetration of electric renewable energy sources (RES) through the injection of alternative fuels into the gas grid (for example, by trying to harmonize the EU gas grid regulatory framework and markets ¹).

In 2017, renewable gases (biogas, biomethane, RES driven hydrogen etc.)

comprised around 7% of renewable gross inland energy consumption in the EU, according to Antonio Lopez-Nicolas, the deputy head of the European Commission's energy department, making them already "an important part" of the bloc's energy mix.

In order to bring alternative and renewable gases to technological maturity and into a robust market, the EC is also promoting and funding several R&D initiatives via the H2020 Research Framework Programme.

The Fuel Cells and Hydrogen Joint Undertaking (FCH JU - www.fch.europa.eu), which was set up in 2004 under the 6th Framework Programme for Research (FP6), is a unique public private partnership supporting research, technological development, and demonstration (RTD) activities in fuel cell and hydrogen energy technologies in Europe.

Its aim is to accelerate the market introduction of these technologies, in order to achieve a fossil free energy system in Europe. In 2014, the FCH JU created a Multi Annual Work Plan defining the "Hydrogen EU Roadmap" in order to award funds promoting

collaborative R&D projects and initiatives.

With a total budget of €1.33 billion provided by the EU and industrial funds, it aims to reduce product costs and improve performance, as well as to demonstrate the large scale readiness of hydrogen technology for use in transport (cars, buses and refuelling infrastructure) and energy (hydrogen production and distribution, energy storage and stationary power generation).

Among the projects receiving funds was the H2020 EVERYWH2ERE Project (www.everywh2ere.eu). This project, which is being coordinated by RINA, will design and realize 8 transportable fuel cell based zero-emission gensets to replace diesel gensets. The equipment will be used to provide temporary power to music festivals, construction sites and events all over the EU.

It is another example of a RINA success story, and further evidence of the potential research-to-market opportunities in Europe's current energy transition.

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¹ ("Quo vadis EU gas market regulatory framework – Study on a Gas Market Design for Europe – February 2018).

Blending hydrogen with today's gas grid

To meet the challenge of reducing Europe's greenhouse gas emissions by 2050, green hydrogen produced by water electrolysis from renewable energy sources is set to play a crucial role as an energy vector.

A new research frontier in this respect is the injection of hydrogen into the existing gas grid for short or long term storage and transportation. It can then be used in a variety of different applications such as power generation, transportation and heat supply.

This method offers a promising solution but there are challenges. The main one is the possible degradation of materials exposed to hydrogen at different percentage levels throughout the energy supply chain, plus the durability of the existing components (pipes, compressors and end user applications designed for natural gas).

Furthermore, the effect on grid maintenance, including monitoring issues and the development of adequate standardization, needs to be considered.

In recent years, several projects have been developed in Europe to test the technical and economic viability of such a solution: two in Germany (grid operated by Westnetz GmbH and OntrasGastransport GmbH), one in France (GRHYD), and finally one in the UK (HyDeploy). The latter aims to use a 0.5 MW electrolyser to demonstrate the use of blended hydrogen in the existing UK gas grid.

In October 2019, Europe's leading utility company for natural gas SNAM launched 'The Hydrogen challenge', a 3-day event focused on its Production, Transport and Utilization. RINA was in attendance, with a dedicated stand and a speech by our chief executive Ugo



Salerno. The challenge of how to blend hydrogen was one of the topics.

In April 2019, SNAM performed a 5% injection of hydrogen into the Italian gas pipeline network at Contursi Terme. Recently, at the same plant, a new test was performed injecting 10% of hydrogen. The latter is equivalent to 7 billion cubic meters into the grid every year, corresponding to an annual consumption of 3 million households, which would reduce carbon dioxide emissions by 5 million tons.

RINA is working closely with industry in this area to promote the use of hydrogen, and is involved in all the main steps of the value chain, from market and technical assessment, to material development and component performance evaluation, to inspection and certification.

A recent example is an ongoing project to assess industrial burner performance compared to a natural gas/hydrogen mixture. The project aims to evaluate efficiency and emissions, together with the effect on the heated product and the suitability of existing piping systems.

The project, a cooperation between SNAM and Forgiatura A. Vienna, envisages experimental tests conducted with a full size burner both in the laboratory at a RINA combustion station in Italy and at an industrial site belonging to Forgiatura A. Vienna. The project is aimed at developing operating procedures with a view towards future standardization.

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Is ammonia the new frontier?

The growing need to reduce carbon emissions in all industrial sectors is transforming the current landscape of energy markets and energy carriers.

In Europe, the European Commission has set a deadline of 2050 to achieve a climate neutral economy. This action is driving several new carbon-free solutions. Hydrogen produced from renewables through an electrolyzer represents an effective way to reduce greenhouse emissions, even if it currently comes at a high commercial price.

In 2019, the International Energy Agency (IEA) stated there was a significant increase in development projects in all sectors of the hydrogen value chain. Moreover, its analysis showed that the cost of hydrogen production from renewable electricity could fall by 30% by 2030.

Therefore, it appears hydrogen is in an excellent position compared to other possible solutions.

Nevertheless, it is necessary to widen the spectrum of alternatives. Elements other than hydrogen are also becoming

promising candidates as energy carriers, among these ammonia.

For long distance transportation, energy density by volume is key to achieving economic sustainability, and ammonia has nearly double that of liquid hydrogen. Moreover, hydrogen liquefies at -253°C compared to a significantly lower temperature (i.e. $T = -10^{\circ}\text{C}$) for ammonia, with a small overpressure.

As a result, very high investment costs are required to use liquid hydrogen. By contrast, the technology for storage and transportation of ammonia is already in place. Furthermore, ammonia can be easily stored and burned, and new technologies are developing to convert it back in hydrogen for fuel cell applications.

And this is not the end of the story. The industrial production of ammonia is based on the Haber Bosch process, which involves high plant costs with a long payback period and heavy CO₂ emissions. But there is the potential to improve this.

It is possible to use hydrogen produced

from renewable energy and an electrolyzer to fill the Haber Bosch process, allowing for 'Green Ammonia'.

Meanwhile, frontier research projects are now addressing new solutions for green ammonia production with, for example, a reverse fuel cell using electricity to convert nitrogen and water into oxygen and ammonia (or nitrogen reduction reaction NRR). The aim of this new research is to create small and efficient plants for ammonia production.

This could indeed put ammonia in a leading position compared to hydrogen, since it can be easily produced where needed.

This, of course, is not the last word on the matter. We have a long way to go, but ammonia could become a viable solution as fuel for marine transportation. Studies are at the early stage, and its efficiency still has to be improved, but this option is already attracting investors who see solar, wind and marine energies as a potential infinite carbon-free 'source'.

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RINA mitigate COVID-19 disruption

With reports of coronavirus (COVID-19) spreading worldwide, RINA's priority is to provide the highest health and safety standards for its staff and the best levels of service to customers throughout the emergency period.

Proactive steps have been taken:

- A specialist Task Force dedicated to business continuity during the emergency has been established.
- Remote working for over 2,000 employees has been sanctioned using RINA's proven digital platform.
- A webpage dedicated to the virus has been created, with email contacts to provide extra clarification.
- A "Health and Safety Protocol" reference document has been distributed to all RINA employees.
- Access to RINA's offices is being strictly regulated.

As we navigate this difficult and uncertain situation, RINA is confident that it can continue to support our customers while keeping our employees and community safe.



Remote surveys come to the fore

As the marine industry adjusts to the constraints placed on people's movements, RINA is pleased to announce that it is increasing its offering of remote ship inspections.

In the ten months until February 2020, approximately 30 remote inspections per month have been carried out. However, since the emergence of Covid-19 monthly remote inspections have doubled.

Further, the Liberian International Ship & Corporate Registry (LISCR) recently approved the use of RINA's remote technology for inspections of Liberian flagged vessels. Shipowner d'Amico will take advantage of this facility in a pilot case on its fleet. It is anticipated other Flag Administrations may shortly follow suit.

There are many inspections that can be carried out remotely, bringing clear savings for shipowners in both time and cost. RINA provides a list of all appropriate surveys on its website at the following link: <https://www.rina.org/en/surveys-remote-inspection>

