TOP ENGINEER

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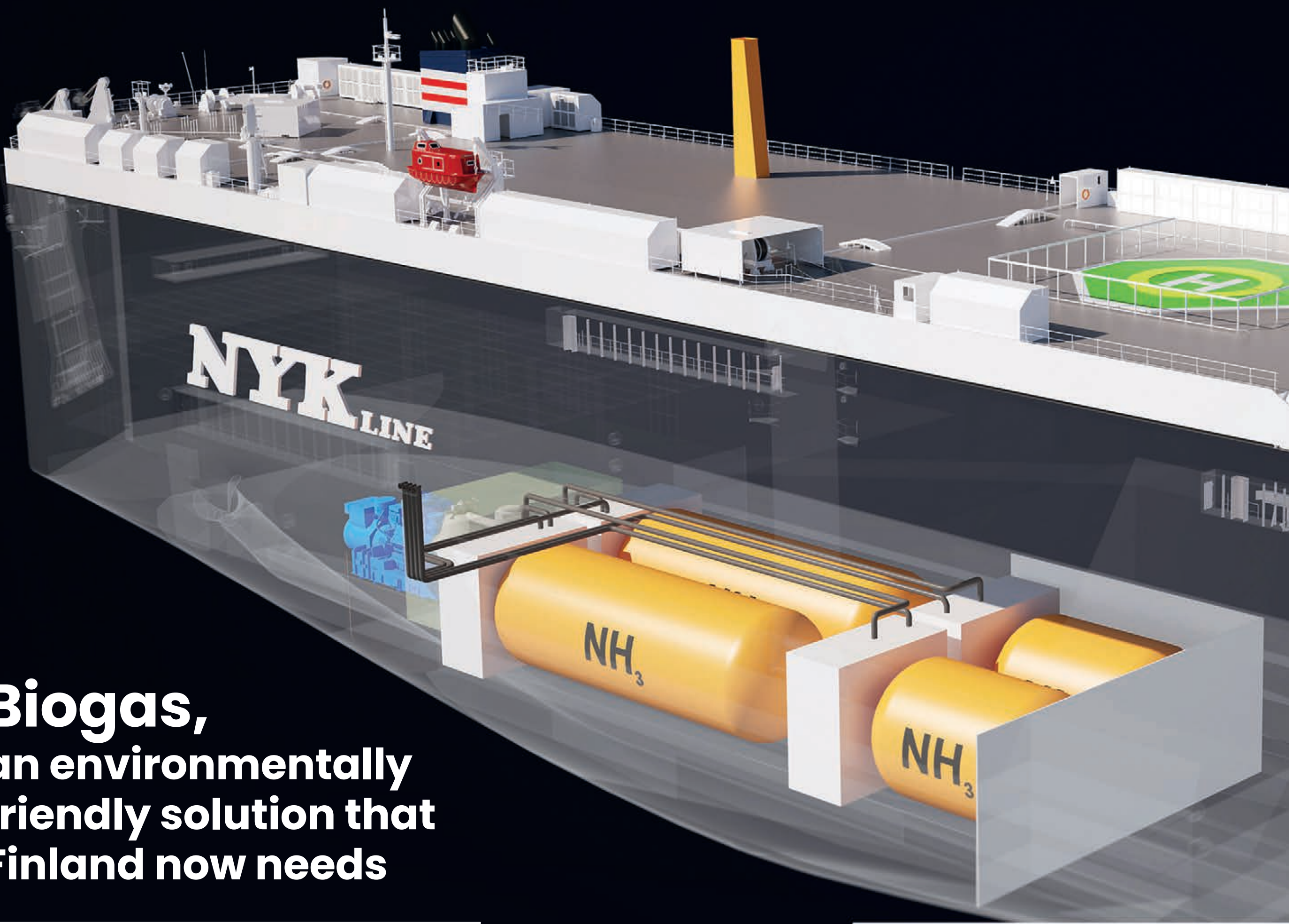

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How secure is our energy supply?

Fast developing 3D printing is one solution to component shortage

Green Ammonia – the needed solution to combat climate change?

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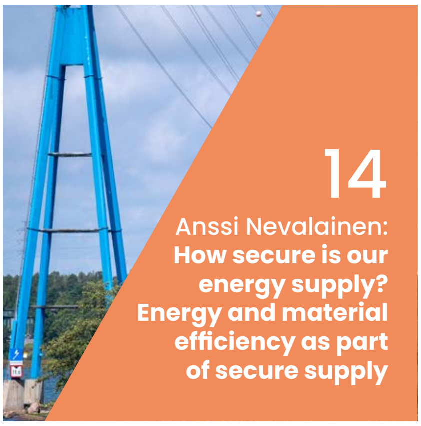

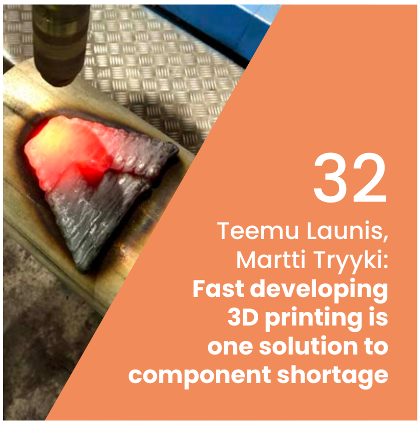

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Towards the sustainable and self-sufficient future

Recent events have pushed European countries to break away from dependence on Russia on a short schedule. As has been said, this is also an opportunity to accelerate the green transition and the abandonment of fossil fuels. However, our society will continue to be part of a global network affected by various crises. That is why we need to make sure that we are able to function and, if necessary, be self-sufficient in changing situations.

To ensure energy self-sufficiency, the first step is to remove the obstacles to wind power. Licensing and complaint handling should be swift, and wind farms should be able to be built in the state's offshore areas with minimum fees and permits. With regard to energy storage, there is a need to increase hydropower capacity and pumping stations next to hydropower plants to store energy. In addition, the automation of new electrically heated properties needs to be made more flexible. Old coal, peat and gas power plants should be kept as regulating energy until we reach a level where we can do without them.

To replace fossil fuels, it makes sense to turn our attention to ammonia, which is clearly the closest to the market price of any synthetic fuel. The production of green ammonia also guarantees self-sufficiency in agricultural fertilizers. Industrial natural gas must be replaced by biogas and hydrogen powered by electricity, and all bio-based waste must be utilized in order to increase biogas production. Synthetic fuels should be subsidized by fuel taxes, in addition to which fuel taxes should be raised if and when the world market price of fossil fuels falls.

In order to secure the future, investments in research and product development should focus on battery technology, hydrogen production and refining, offshore wind power construction, green fuel ships, work machines, and modular district heating plants.

In this magazine, our experts also shed light on other ways in which we can secure self-sufficiency while paving the way for a carbon-neutral future. I hope you enjoy reading it!

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Green Ammonia

– the needed solution to combat climate change?

Text: Heidi Käkelä

The war in Ukraine has spurred developments in the European energy mix that took most of us by surprise. The need to move forward with the plans for a green hydrogen-based economy is now more crucial than ever. Green ammonia is among the best solutions for a speedy transition to the carbon-neutral Europe. It is economically feasible and a wholly carbon-free alternative, which means that its combustion contributes directly to carbon-neutrality targets. The most promising future destinations for ammonia include its use as marine fuel.

It is touted as the solution to cutting emissions from shipping. It is said to be one of the only scalable fuels able to achieve the reduction targets of the Paris Agreement. It is set to be built on a multiple hundred megawatt scale in Oman, Australia, Portugal and India. It is not hydrogen – but it could well be.

At the face of it, ammonia is a relatively strange alternative for climate-friendly technology. In the European Union, 35 metric megatons of GHG emissions stem from the fertilizer industry, where the production of ammonia accounts for the vast majority, approximately 30 Mt[1]. Most of these emissions are due to the production of gray hydrogen through Steam Methane Reformation (SMR), which is an essential part of the Haber-Bosch process, the foremost method of ammonia production globally.

The global average emission factor for ammonia production is around 2.6 tons of CO_2 per ton NH_3 [2] making it one of the more emission-intensive chemical production processes today. Since approximately 1.8 percent or 500 million metric tons of the world's total CO_2 emissions are caused by ammonia production, the reductions attained through greening the process are not insignificant. They might be a central way to make large parts of the world economy carbon neutral.

From gray to green ammonia

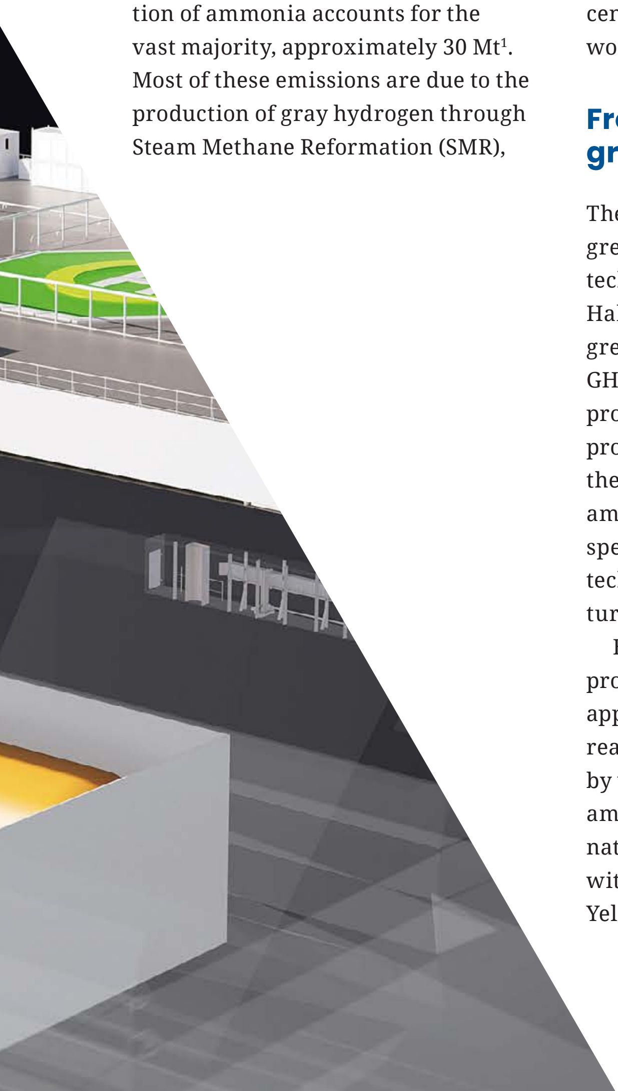
The easiest way to make ammonia green is to plug the conventional technology for its production, the Haber-Bosch process, into a source of green hydrogen, which cuts away the GHG emissions from its production process completely. As the production process for the hydrogen determines the environmental friendliness of the ammonia production process, the color spectrum used to denote potential technologies is the same: gray, blue, turquoise, yellow, pink and green.

Blue and turquoise hydrogen production are carbon-neutral applications of the Haber-Bosch reaction, particularly the SMR process, by which the hydrogen needed for ammonia synthesis is separated from natural gas and the carbon is reacted with oxygen to form carbon dioxide. Yellow, pink and green hydrogen, on the other hand, rely on electrolysis to produce hydrogen with the help of an electrified membrane. While yellow hydrogen is made with electricity from the grid and pink hydrogen is made with the help of nuclear energy, green hydrogen is produced with renewable energy, making it emission-free.

Ammonia is used widely in industrial applications around the world

Ammonia is used for a number of important applications world-wide, although perhaps none so important than the production of fertilizers. Ammonia, nitric acid, phosphorus, calcium nitrate and potassium are among the most important additive sources of plant nutrition today, forming an array that has allowed for gains in agricultural yields supporting human culture and society as we know it. Beyond them, ammonia has a variety of other important uses in applications such as a refrigerant, a key ingredient in many plastics and dyes, as well as in NOx emission control through the SCR process.

The most promising future destinations for ammonia include its use as marine fuel, which would allow for significant and rapid emission reductions in yet another field of strategic importance and high emission-intensity, since marine shipping today accounts for 3 percent of the world's GHG emissions. Although much remains to be done, ships and engines are being both retrofitted and redesigned globally to contend with the



2018 pledge of the IMO and the shipping community to reduce shipping GHG emissions by 50 percent by 2050.

Solutions planned to be implemented before mid-2020's include both fully ammonia-powered engines and LNG engines retrofitted for ammonia use, which will grow the demand for ammonia in a global market further. One example is the concept developed by Elomatic (ARLFV), which allows the LNG-fueled vessel to be converted to ammonia-powered at a minimum cost once green ammonia is available. Market analysts have predicted that the value of the ammonia market is set to grow from nigh on USD 72 billion in 2021 to over 110 billion by 2028, spurred particularly by population growth in East Asia. In the future, green ammonia may be used even more broadly.

Green ammonia allows a rapid transition into a hydrogen economy

Green ammonia has, at least in the short and medium run, benefits that make it a good companion to hydrogen. Perhaps the most obvious of these is its economic feasibility. While the winnings from emission cutbacks accrue from transforming the hydrogen production process, hydrogen itself is notoriously difficult to store for long periods. As the world's smallest molecule, it permeates tanks and pipelines at the rapid rate of approximately 1 percent/day. These features in the composition of the hydrogen molecule make it necessary for produced hydrogen to have a carrier in order to be feasible for global supply chains. Today, the most central suggestions for these carriers are synthetic methane and liquid fuels, produced from captured carbon dioxide, and green ammonia.

The benefits of green ammonia vis-à-vis its competitors are, on the one hand, its relatively quick ability to reach price parity with gray ammonia and, on the other hand, its lack of carbon. The price of ammonia is strongly tied to the availability of affordable natural gas, which has been subject to a volley of shocks since 2020, including two prolonged winters, one destructive hurricane season, high competition for LNG in Asia and sub-par electricity generation from hydropower in Europe and the US – in addition to the uncertainties posed by the global pandemic. A volatile and high market price and a steadily tightening regulation against the use of methane as an alternative to other fossil fuels are, at least presently, allowing green ammonia to bridge the gap to its fossil alternative sooner.

Perhaps more importantly, however, ammonia is a wholly carbon-free alternative for both a fuel and a hydrogen carrier, which allows its combustion to contribute directly to carbon-neutrality targets that fix many of the parameters of business today and will continue to do so in the foreseeable future. It is perhaps no wonder that many of the largest green hydrogen projects on a global scale already include capacities for ammonia conversion, such as the 600 MW project by Meridian Energy in New Zealand, Yara's multiple projects in Norway and the H2 Magallanes project in southern Chile.

The Nordics have a lot to offer to green ammonia production

Although Finland has not published a separate hydrogen strategy, opting instead to include hydrogen as a part of its overall energy strategy, there are many advantages to basing hydrogen and ammonia production domestically. Some of these are obvious, such as the highly competitive price of electricity, the strong electricity infrastructure, and the ambitious goals for wind power production capacity, which will chase 5,000 MW by the end of 2022, and 10,000 MW by 2025. Others are more idiosyncratic, such as the option to recover waste heat from the electrolysis process to be injected into Finland's sprawling

"Due to both the price and the scarcity of natural gas, global interest in green ammonia abounds and attracts cooperation between companies in the European Union, as well.

district heating networks or the ready availability of clean water.

The capacity of Finland, and of other northern European states, to drastically reduce the emissions and consequently the economic risks of ammonia production also has impacts on the security of supply in Europe. Hydrogen and ammonia production in the European states has relied strongly on the availability of Russian natural gas, which has long been an energy security issue and has, since February 2022, become the sign of an era of world politics headed steadily for obsolescence. The European Union and its member states must now restructure their ammonia demand to contend either with a hopefully less volatile supply of methane from China, India or the US – or they must concentrate on new, domestic production that is better shielded from international crises altogether.

Global interest has arisen

Due to both the price and the scarcity of natural gas, global interest in green ammonia abounds and attracts cooperation between companies in the European Union, as well. A number of significant investments are being planned in combining hydrogen and ammonia production, such as the ACE

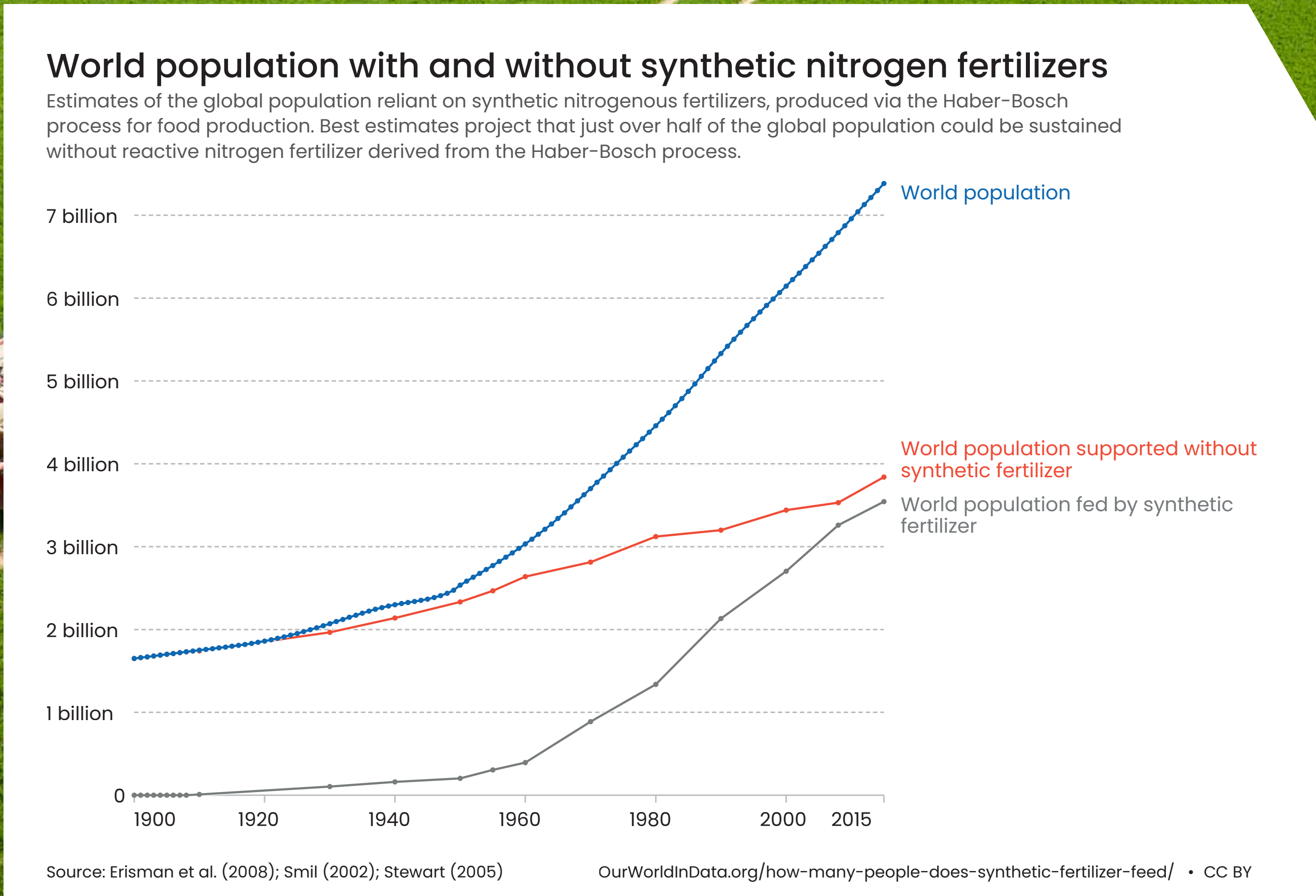


Figure 1 *World population with and without synthetic nitrogen fertilizers.*

Terminal project, whose plans were recently announced for Rotterdam port by a Dutch consortium. The terminal will be central to the port's efforts to offer a large-scale hydrogen network at Maasvlakte, including green and blue hydrogen and ammonia availability from companies such as Uniper, Horisont Energi and Chariot – tying together projects on two continents at the center of Europe. Concentrating the trading of ammonia in Europe at Rotterdam will be a clear step in the direction of establishing open markets.

The window for joining in this development is wide open for Finland and for the other Nordic states, and it will likely allow us to transition to a carbon-neutral economy sooner than other synthetic fuels will. Boosting the creation of a hydrogen-based economy through ammonia comes recommended not only by its financial benefits, but also by the very real concerns over the security of supply exacerbated by the war in Ukraine.

Smelly old ammonia may be a strange recruit in the fight against global climate catastrophe, but it is a readily available one – and we could stand to win some time. ◣

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2 Contrasted with the EU ETS average of 1,604 tons CO_2e per ton NH_3, representing some of the best technical solutions for production today.

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Heidi is an environmental anthropologist and energy engineer. Before dunking her foot into STEM, she worked as a researcher studying community responses and disaster reconstruction in the Caribbean, Australia Pacific and Asia, and as an educator in Finland. She is part of Elomatic's International Finance Institutions (IFI) team, which provides engineering expertise for large international development projects, particularly in Central and East Asia as well as Ukraine. She also goes spelunking in EU regulations and funding.

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Biogas is an environmentally friendly solution that Finland now needs

Text: Teemu Turunen

The war in Ukraine has led to a situation where we should be able to move away from natural gas on short notice. Biogas is the quickest sustainable alternative, as its implementation does not require drastic changes to the existing infrastructure. Biogas is also an environmentally friendly solution: it can help reduce greenhouse gases, promote the circular economy, and close nutrient cycling loops. However, the availability of biogas is limited and investments are required in its production.

The war in Ukraine has driven Europe into an energy crisis, in which the availability of natural gas plays a key role in Central Europe. In some European countries, the share of Russian imported natural gas makes up nearly a sixth of the country's total energy consumption, which makes it hard to move away from.

The situation in Finland is less critical, as the corresponding share here is less than three percent. Currently, roughly half of natural gas goes into the industrial sector and half into electricity and heat production, where it is possible to replace it with tanker-imported LNG, wood, coal, and peat.

However, it is important to remember the sustainability aspect: while replacing natural gas with another fossil fuel may be a temporary solution to an acute crisis, the direction must clearly be toward a more sustainable transition.

> **While replacing natural gas with another fossil fuel may be a temporary solution to an acute crisis, the direction must clearly be toward a more sustainable transition.**

The situation is challenging for industrial undertakings

Moving away from natural gas may require significant technological investments from industrial undertakings, and these can be difficult to implement on short notice. One possible solution would be electrification, where the industrial processes that use natural gas would be replaced with processes that use electricity instead. In practical terms, this can be done with direct electrification using electric boilers or, for example, replacing industrial gas furnaces with electrical ones.

In some cases, it is also possible to use indirect electrification, where heat pumps and electrical resistance used for priming play a central role.

The easiest way to replace natural gas is by using biogas. This way, the changes to the existing infrastructure are small. However, in our acute situation, the availability of biogas is limited and investments are required in its production. Let's take a closer look into what these investments could be in Finland's case.

Biogas projects require public support

In our current situation, various elements are required to support biogas projects, one of which is the act on promoting the use of renewable energy sources in transport that entered into force in 2022. In the legislation, biogas becomes part of the must-carry obligation with set limitations.

At the time of writing this text, a change in the legislation has been proposed, where increasing the share of the must-carry obligation is postponed. It is important to note that this proposal does not seek to change the additional obligation for advanced biofuels and biogas. This is a good direction, and we hope the round of statements sees the approval of the proposal as is.

The state should support biogas projects also through other means, such as by clarifying and harmonizing subsidies for operators. This would make it easier for smaller operators to plan projects and implement cooperation projects with multiple operators collaborating. Various benefit-based financial instruments where the price of the subsidy is tied to the environmental gain from the project would make it easier to get projects started.

Tax-related decisions also play a role

Tax-related decisions play their part with regard to the profitability of projects and the market development. From the perspective of biogas, the excise tax and electricity tax are relevant.

At the start of 2022, the legislation made biogas a fuel subject to the excise tax, with the exception of biogas used for heating, which was classified as sustainable. Producers of biogas need to have a sustainability system approved by the Energy Authority in place in order for the gas to be classified as sustainable and therefore tax-free. In other cases, gas is subject to the full excise tax for biogas, also when used for heating.

With regard to the electricity tax, the industrial production of recycled materials and processing afford operators with energy tax subsidy, as in practice electricity used by these factories belongs in the electricity tax class II. As for biogas, the interpretation remains somewhat unclear, but the lower tax class naturally affects the profitability of the factories.

Tools of direction need to account for predictability

We also need to remember that, at some point, the limited production of biogas may need to be directed where its use produces the greatest benefit and most significant environmental effects. We need to carefully consider these direction tools and communicate in a predictable manner to help operators adapt to the changing situation.

In general, all the direction tools of the state need to account for predictability. This way, there is no need for the operators to hesitate to drive their projects forward. In addition, the state should attempt to streamline the permit process and clarify the financing and subsidy concepts.

The attractiveness of the biogas sector should be promoted

As investing in clean solutions is seen as a central risk management tool in the financing market, the circular economy and the production projects for renewable energy sources are currently highly interesting as potential investments. This development can be expected to be highlighted especially with regard to biogas, as it can be used to influence various areas of sustainability: reducing greenhouse gases, promoting the circular economy and closing nutrient cycling loops.

However, it is important to remember investors inspect opportunities from a holistic perspective in relation to other potential investments. Therefore, we should seek to promote the attractiveness of the biogas industry as a potential investment.

The Finnish biogas market is still developing

In 2020, the production of bio methane in Finland was approximately 110 GWh, and the production of biogas was approximately 768 GWh (total sum corresponds to roughly 3.5 percent of natural gas use in Finland). At the time, there were around 79 reactor plants:

- 25 farm-scale plants
- 9 industrial plants
- 26 biowaste and sludge co-digestion plants
- 19 sludge digestion plants.

In addition, bio methane was processed in 21 plants.

It is worth noting that the market sees the sector divided between one strong operator in Gasum and heterogenous smaller operators, with a focus on promoting individual projects. This division may in part reduce the interest of investors toward projects in the sector.

Especially with regard to smaller projects, the technological risks and business risks are highlighted, which is reflected in financing for the projects.

The environmental perspective of biogas should be emphasized

State action has its own significance in promoting financing opportunities, but the development of the biogas industry's visibility and image is just as important. Farm-scale opportunities have yet to come up in any large capacity in the public debate.

In part, the image has been influenced by past technology producers' technical and financial challenges, which have ultimately resulted in bankruptcy and several unfinished factory projects.

Now would be the opportune moment to develop the public image

How to improve the profitability of biogas projects?

The profitability aspect of biogas projects has proven to be challenging despite various forms of support having been available. Developing the entire value chain plays a key role in promoting the profitability of projects. In practice, this means development with regard to both raw materials and end products.

Developing the end product market plays a central role: the end product should meet an adequate degree of refinement based on the need, and a market should be found for the process side products, such as digested sludge.

For instance, at the farm scale, the leftovers from the digestion of manure-based biogas can be processed into recycled fertilizer, which could be used to replace manure in the fields. The benefits of recycled fertilizer are smaller rates of phosphorus washouts in the waters as well as the type of nitrogen, which plants can more effectively use.

The current problem is that spreading manure directly in the field is more profitable for the farmer, as the recycled fertilizer market is still developing. The development of the market calls for clearer legislation, new research, and active operators in the market.

Factory location and project size play a key role

The profitability of biogas projects is greatly influenced by the location of the factory, which contributes both to the profitability of the raw materials and the end product logistics.

A suitable industrial-scale user of biogas who commits to purchasing the end products of the factory in the area can also positively affect the convenience of the location.

Both with regard to small- and large-scale production, increasing the size of the project usually improves profitability on the whole. In practical terms, at the smaller scale, this means joint projects between several farms, and at the larger scale, the involvement of notable industrial operators in the projects.

The food sector in particular has been active with projects as of late. For example, Valio has started developing a carbon-neutral milk chain in cooperation with its producers. The involvement of industrial-scale operators usually also increases the interest of investors toward the projects.

Projects should be developed with a focus on the value chain

Projects can involve, for example, an industrial enterprise, who supplies the raw material, a consultant or a design expert, a biogas plant operator, an operator who purchases the main product and a possible operator who processes the side products. In this case, the project is developed with a focus on the value chain, which makes it possible to demonstrate the benefits more comprehensively.

One possible developmental direction is for individual projects to be compiled as part of a more extensive project portfolio at as early a stage as possible. Such a model would call for an operator who would focus on the subject, be responsible for the development of the project, construction, or maintenance as well as the coordination of financing. The operator could possibly also take the role of owner.

Thereby, individual projects would gain access to the operator's competence, which in turn would speed up the start of the projects and reduce the financial risk as a result.

Profitability is largely determined in the planning phase

On one hand, the profitability of the projects can be influenced through technological development and, on the other hand, by seeking to account for the use of the factory already in the planning phase. Biogas plant technology is constantly developing, and as efficient and scalable technologies become available on the market, the profitability of the projects is improved both through decreased investment costs and more efficient operations.

It is important to note that most of the ways to affect the profitability of operations can only be utilized at the design stage. Due to this, it is important to sufficiently make use of available or external expertise in the planning phase.

"The environmental perspective of biogas should be further emphasized in the public debate.

of the sector as, in the industrial sector, many operators would like to utilize biogas as part of the process of moving away from natural gas. On the other hand, securing the viability and security of supply in the agricultural sector have become ever more important themes following the war in Ukraine. Therefore, the environmental perspective of biogas should be further emphasized in the public debate.

Cooperation will play a key role in the future

The technological side of the sector has been characterized by relatively small operators whose limited resources have not easily allowed for the development of scalable technologies. For this reason, there is clearly room for technological suppliers in the sector who can implement large-scale projects.

On its part, technological development is limited by the lack of competence both on the side of project operators and the authorities. It is worth noting that the production of biogas requires interdisciplinary competence. For example, the heterogeneity of raw materials has affected technological reproducibility and scalability.

In a typical project, competence is required from biology, design, and logistics to financing and profitability. For this reason, it is especially important to "projectify" the whole as part of more extensive ecosystems and cooperation networks.

The role of the biogas sector as part of the energy system

What is the role of the biogas sector in the future? It is hard to give a definitive answer, but it is my belief that in the short term it will be a significant operator regarding the move away from fossil fuels. According to different scenarios, the need for biogas was estimated at 4–11 TWh before the war in Ukraine, and the ongoing crisis works to speed up this development.

Following the resolution of the acute situation, the focus will presumably move more on the expansion of the use of biogas and mapping new ways to use it. The security of supply perspective will be one that will promote the expansion of the use of biogas and will pave the way for more versatile use of gases both in transport and the industrial sector.

I believe that, in the future, we will be using synthetic methane, bio methane, biogas and hydrogen, which will also open new doors for other electricity-based fuels and solutions in the hydrogen economy. ◣

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How secure is our energy supply?

Energy and material efficiency as part of secure supply

Text: Anssi Nevalainen

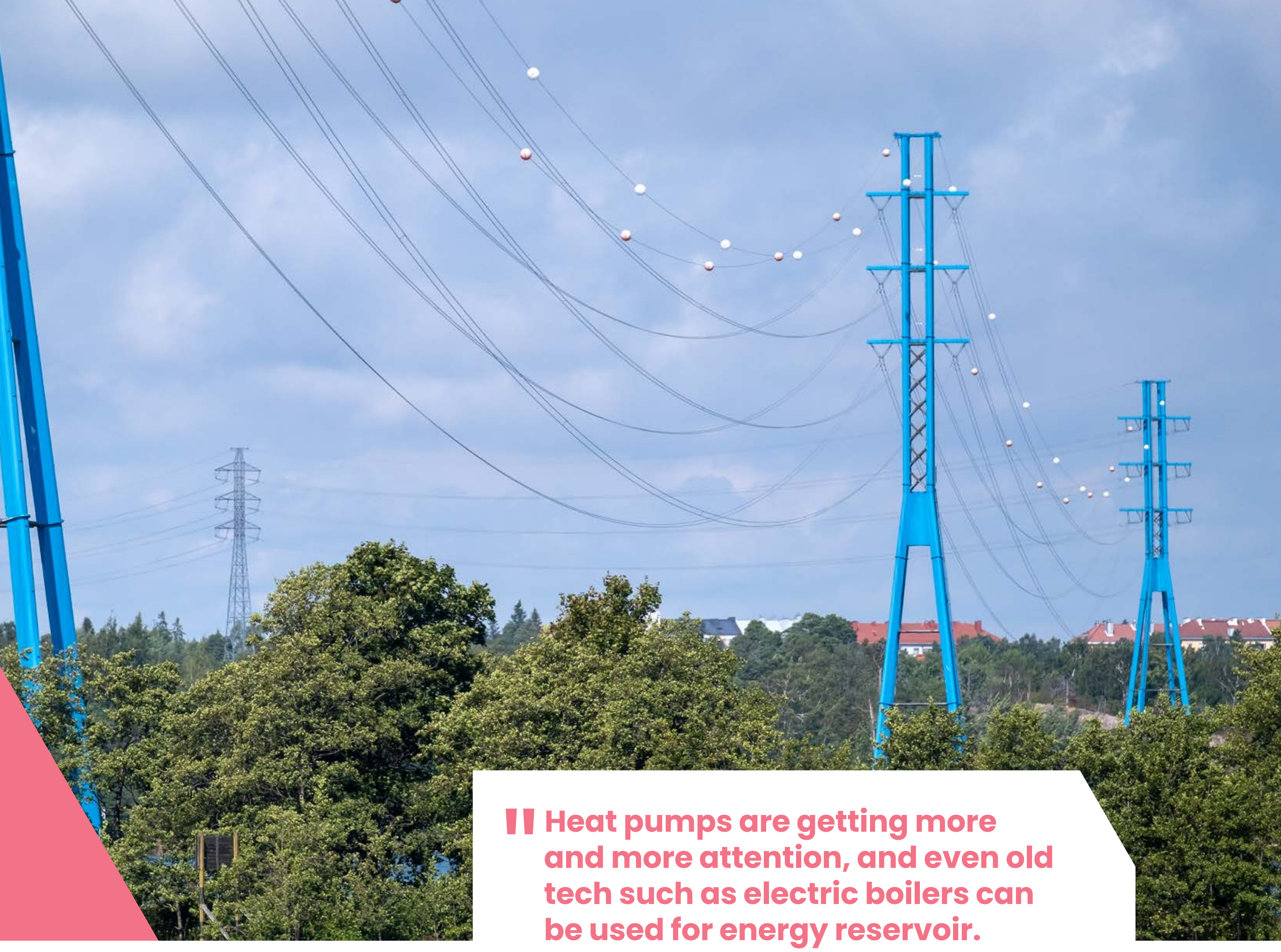
As we struggle to find our way out of fossil-based fuels, the need for sustainable electricity grows day by day. But there are still challenges in low-carbon energy production, particularly with energy distribution and high investment costs. The cyclical nature of renewable energy sources also calls for new solutions such as power-to-x technologies. Before making an expensive investment, it is wise to explore other options for reducing energy usage and timely balancing of the electrical grid. The potential for energy and material efficiency should not be overlooked.

De-carbonization and net-positivity of energy production have been in the spotlight as cornerstones of sustainable development for a long time now. To reach global goals, significant measures must be taken at the roots of energy production. In other words, commonly used fossil fuels must be replaced with sustainable renewable energy sources at a swift pace. But this is not an easy task – usage of low-carbon energy production has its own problems, such as energy distribution and high investment costs further down the road.

Sustainable development goals must be pursued from the consumption side as well. In a nutshell, this would mean that if primary energy usage can be lowered comprehensively and timely consumption better rationalized, the need for sustainable or fossil-based energy is lower.

As part of de-carbonization, I must also mention material efficiency in this context. Material efficiency, such as the efficient use of raw materials, has the same goal of achieving sustainable development. The more efficient the usage of (especially virgin) material, the less energy is used and the lower the burden caused on the environment in the whole value chain.

In pursuit of the sustainable future, enterprises gain savings and improve their competitiveness in the global marketplace. Especially in the current global economy, the energy-intensive manufacturing industry faces significant challenges. For the same reasons, material costs are rising; after all, processing of raw materials is highly energy-intensive in many fields.



"Heat pumps are getting more and more attention, and even old tech such as electric boilers can be used for energy reservoir.

Together these costs make it difficult to predict cost structures and may reduce the profitability of enterprises in the extreme.

Finland's energy security will improve with the use of wind power

The total energy consumption in Finland was 1,277,041 GJ in 2021, of which 30% was fossil fuels. There are no coal, oil, or natural gas reservoirs inside Finnish borders, so all the fossil fuels must be imported from outside. Approximately half of the energy used in Finland was imported, and about 60% of imports came from Russia.[1]

In addition, nuclear fuel is being imported, so its supply is not fully secured – although current fuel supply can last for several months or even a year, and more can be bought from many OECD countries. Furthermore, profitable Russian wood has been widely used in Finnish energy production, but it is said that it would not be a problem in terms of energy security, even if imports came to a complete halt.[2]

Completely self-sufficient energy sources are biomass (wood and biogas), hydro, wind, and solar. The capacity of hydro power cannot be increased, but the production of wind power in particular will increase in the future. Solar power is currently very minor in the whole picture, but technological advances may increase interest and growth in the future.[3]

Energy Source	Energy [TJ]	Percentage [%]
Wood	355,404	28%
Hydro	56,410	4%
Wind	28,577	2%
Other renewables	62,085	5%
Oil	267,428	21%
Coal	70,363	6%
Natural gas	74,586	6%
Other fossil fuels	11,440	1%
Peat	43,116	3%
Nuclear	243,864	19%
Electricity import	54,377	4%
Other sources	9,391	1%
Total Usage	**1,277,041**	**100%**

Table 1 *Energy sources in Finland.*

Sustainable electricity is the way to the sustainable future

In general, if the production and use of electricity are in balance in the electrical grid, the grid functions smoothly. The growing capacity of renewable energy production tends to complicate this because of the cyclical nature of renewable power sources. Wind power is available only in the right wind conditions and solar power accumulates during the daylight hours. Wood-based fuels and nuclear are good for base load production but the latter in particular is poor for power regulating. Hydro can be used as a power regulator, but the existing capacity is not even close to the required capability.

Thus, as the amount of wind and solar power will grow in the future, the challenges of grid power balance management are getting harder. Fingrid has accumulated the light fuel oil-based power regulating capacity of over 900 MW, and even today some of this capacity is needed for the grid power balance management and sometimes to overcome larger failures.[4]

Hopefully, these problems can be solved in the future with different energy accumulation technologies. Currently electricity can be stored in batteries, for example, but the price of large-scale battery storages is high, and they need significant amounts of rare metals. For the battery technology to be the answer for the energy storage problems, we need new technological advancements in the field.

There are also many kinds of power-to-x technologies such as water reservoirs, pressurized air, mechanical and hydrogen, to name a few. These technologies use surplus electricity and convert its form for later use. Also, heat pumps are getting more and more attention, and even old tech such as electric boilers can be used for energy reservoir if it is used for heating water during surplus times. Common to all these technologies is the need for electricity to get the work done.

Energy and material audits are a good way to improve energy efficiency

All the energy conversion, storing and new tech for the sustainable future has investment costs and restrictions involved, so before investing in expensive technologies, it is wise to explore other options for reducing energy usage and timely balancing of the electrical grid to minimize future costs. To reach these goals, we could explore the possibilities offered by energy and material efficiency.

To find all the saving potentials, energy and material efficiency should be refined by the local personnel continuously. However, it is known that you can be blind in your everyday environment. There might also be known potentials but not enough time and personnel to report them for the decision making. In this case, it might be worthwhile to hire an external consultant who sees things from a different perspective and has time to calculate savings, investment costs, and pay-back times for the saving potentials found.

Energy audits have a long history, while material audits are relatively new. It could be beneficial for the company to begin their sustainable future from an energy audit and continue development with a material audit to find synergy between them. Material audits follow the MFCA method (Material Flow Cost Accounting) described in standard (ISO14051).[5] In Figure 1 you can be seen the key points and the usual saving potentials of energy and material audits.

Demand-side management is an important part of secured energy supply

Demand-side management is another way of reducing energy usage and timely balancing of the electrical grid. It means shifting electricity consumption from hours of high demand and price to a more affordable time, or temporarily adjusting consumption for power balance management.[6]

In Finland, the balancing markets for demand-side management and electricity reservoirs are maintained by Fingrid together with other Nordic transmission system operators. They offer financial compensation for the participating supplier on the market. Basically, anyone can be a supplier if they meet the technical requirements, marketplace requirements, and Fingrid's supplier code of conduct.[7]

A large operator can be a sole provider for the market, and smaller supplies (for example small manufacturing and domestic users) can be gathered to form a larger reservoir by a Balancing Service Provider like electricity suppliers. Balancing service providers and reserve product can be found on Fingrid's website.[8]

Increasing demand-side management not only benefits suppliers financially but also alleviates future investment needs for the sustainable electrical infrastructure, as it cuts down peak demand, utilizes surplus electricity, and lowers electricity prices overall. ◣

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> **It could be beneficial for the company to begin their sustainable future from an energy audit and continue development with a material audit to find synergy between them.**

Energy Audits	Material Audits
Themes: building automation, heating, cooling, heat recovery, heat pumps, processes, and lighting etc.	Themes: input materials, energy, manpower, and other costs
Usual energy savings 10–15%	Usual cost savings 2–4% of total costs involved

Figure 1 *Usual themes and savings of energy and material audits.*

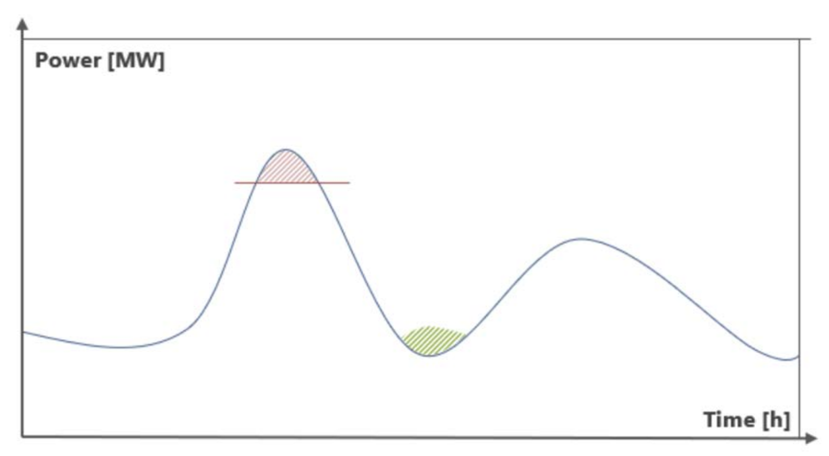

Figure 2 *An example of demand-side management in use.*

How to do energy and material audits?

Energy audits can be done in several ways:

- Voluntary site surveys (consultancy commission)
- A site survey for mandatory energy audit of large enterprises[9]
- Energy audits by Motiva, for example. Energy audits for industry or process industry, or a new precision audit model[10]

Material audits can be done by a consultant following guidelines made by Motiva and subsidized by Business Finland. This material audit model scales up from one production line to a factory scale focusing on material, energy, manpower, and other costs throughout the process. The factory personnel are then involved in finding the best solutions to the saving potentials found, and at the end of the audit, changes can start to happen.

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Can carbon neutrality be achieved in food production?

Text: Riina Brade

In response to climate change, we must quickly decrease the amounts of fossil fuel and food production greenhouse emissions, while simultaneously promoting the sequestration of carbon dioxide in ecosystems. The development of biotechnology, automatic control systems and artificial intelligence accelerate the transition to more sustainable primary production of food when fields and productive livestock can be replaced with, for example, microbes and bioreactors. However, we also need approaches with a more immediate impact. Investments in renewable energy play a key role.

The climate has already warmed an average of 1.1 degrees Celsius since the pre-industrial era, and the temperature is still climbing year after year. Carbon dioxide has been calculated to have caused two thirds of the warming until now. In addition to warming, the entire climate system is undergoing changes and extreme weather is becoming more common: some places receive too much rain, while others suffer increasingly from drought. According to the Finnish Meteorological Institute, rain affects food production capacity and people's living conditions more than the temperature alone: by 2100, the amount of rain will have increased a good 30% during winter in Finland and about 10% during the summer, when compared to the current day.[1]

Globally, the greenhouse gas emissions of the food production systems of agriculture have increased by about a third over the last 20 years. Emissions are primarily a result of plant and animal production increase to meet the needs of a growing population, which in turn increases the use of fertilizers (nitrogen), the amounts of manure and pastures, the use of fuels in domestic animal production, and the production of gases from the digestive processes of ruminants[2].

Finland's greenhouse gas emissions have started to decrease in accordance with targets, although they vary a little from year to year. The food industry in Finland causes relatively few direct emissions, as the biggest sources of emissions are made up of indirect sources – from primary production and energy production. The agriculture sector's share of Finland's total greenhouse gas emissions has been about 10–14% over the last few years.

Carbon footprint of food products*

*Shares are based on the answers provided by companies that responded, and may vary significantly by industry and company

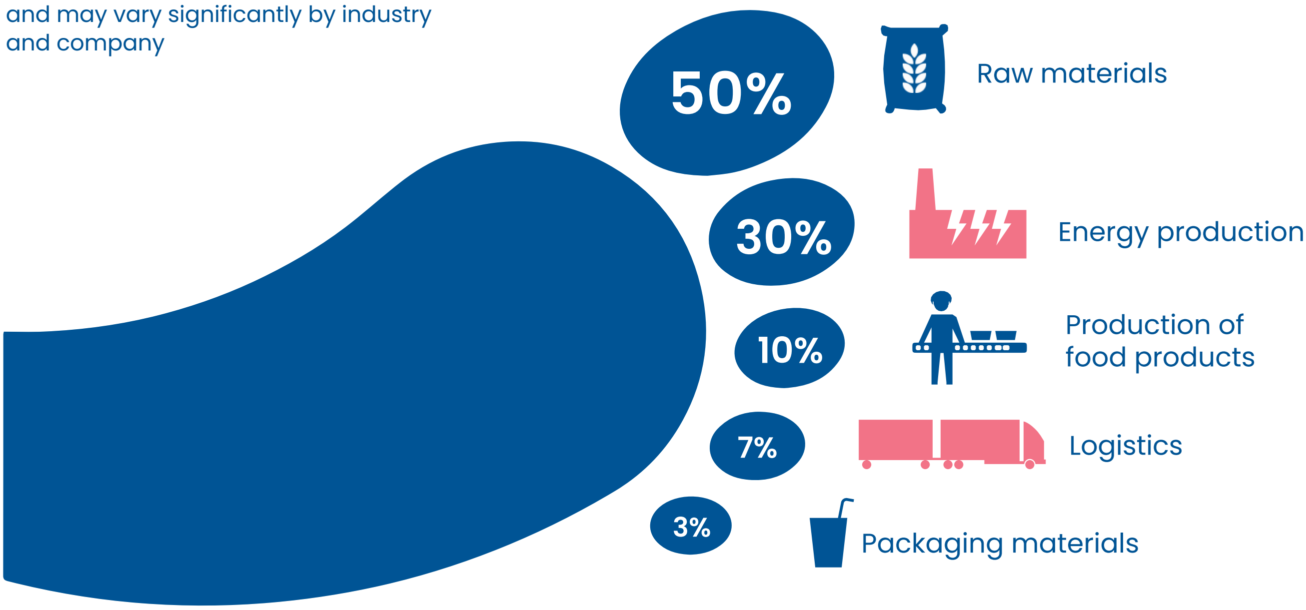


Image *Carbon footprint of food products in Finland. Source: ETL's electronic survey and interview results (2020).*

Sustainable food production value chains are based on renewable energy

Different countries have mapped out different kinds of strategic paths for achieving carbon neutrality, but due to the diversity and dependencies of systems, reducing carbon emissions to a net zero remains challenging. In addition to radical changing in our eating habits and food waste amounts, we also need innovative new technologies and solutions based on multidisciplinary research.[2]

One of the most important and efficient ways of achieving carbon neutrality is to make use of clean energy from renewable energy sources, such as solar, wind, and hydropower. All in all, new innovative technologies – which are designed to speed up the transition to carbon neutrality in different sectors – offer solutions for the restoration of forests and seas, the protection of ecosystems, carbon-neutral industrial production, and sustainable food production. This increases the sequestration of carbon in the soil as well as reduces carbon emissions[2].

Food production must be optimized in order to increase production efficiency and to reduce carbon emissions. This can be achieved through, among other things, new technologies developed for more sustainable production of fertilizers, solutions for precision agriculture, improved feeding, and the creation of carbon-neutral food production systems[2].

In addition to minimizing emissions and increasing efficiency, technologies and methods for removing carbon dioxide from the atmosphere through industrial means, and sequestering carbon in soil and marine ecosystems (sequestration) are vital. Out of these developing NETs, that is, negative emissions technologies, the ones currently showing the most potential are bioenergy with carbon capture and storage (BECCS), biochar (PyCCS, pyrogenic carbon capture and storage) and direct air carbon capture and storage (DACCS). In Finland, BECCS and biochar offer the most potential for negative emissions[2,3].

Reducing harm from farming with new technologies

Optimizing the use of fertilizers and water on arable land can significantly reduce the greenhouse gas emissions in crop farming systems with the help of digital, drone, and sensor technologies. In addition, new synthetic nitrogen fertilizers which release nutrients in a slow and controlled manner are being developed, as are new varieties which use nitrogen more effectively and have characteristics which inhibit emissions[2]. As part of the solution, the production of biomass must be increased through the means of forestry, cultivation of meadows and carbon farming, among others. In addition, carbon dioxide must overall be removed and sequestered from the atmosphere through various methods and stored back in soil and marine ecosystems.

The manipulation of enteric fermentation in animal production is one of the key ways to reduce the methane emissions of ruminants. So-called methane inhibitors are being developed by affecting an animal's metabolism through precise nutrients and more easily digestible kinds of feed[2]. Also, new innovations and start-ups are popping up, such as Finnish Origin by Ocean. The company refines blue-green algae and bladderwrack into bio-based ingredient that is suitable, for example, for compound feed with significant lower animal emissions.

Manure processing practices could also significantly reduce indirect greenhouse gas emissions by optimizing the management of pastures and producing energy (biogas) and organic fertilizers at the farm, with low emission factors[2]. According to the research of the Natural Resources Institute Finland (2020), among others, in the field use of recycled fertilizers, organic fertilizers have lower nitrous oxide (N_2O) emissions when compared to the N_2O emissions of mineral fertilizers[4].

One new technology is the vertical plant factory, that is, a vertical indoor cultivation system, which enables continuous food production throughout the year regardless of the season or weather. All environmental parameters, such as lighting level, temperature, humidity, and air composition, are controlled in a smart, closed system. New testing facilities verify the viability of mass production, and full-scale factories have been built for the commercial production of fruits, vegetables, and medicinal plants.

Vertical indoor cultivation systems can help achieve very high productivity and low greenhouse gas emissions with small changes in land use when compared to traditional production systems. The environmental impacts of operations can be minimized by using renewable energy to run the factory.[2]

Transition to cellular agriculture leads to significant environmental benefits

There is demand for feeding a growing population with the help of innovative and low-emission technologies. The development of biotechnology, automatic control systems, and even artificial intelligence enables more sustainable primary production of food in a factory environment. This is cellular agriculture, where microbes and bioreactors replace fields and productive livestock.[5]

> **The development of biotechnology, automatic control systems, and even artificial intelligence enables more sustainable primary production of food in a factory environment.**

According to the surveys of Boston Consulting Group[6], the transition to edible plant, microbe, and animal cell-based protein products instead of beef, pork, chicken, and egg alternatives will save more than one gigaton of CO_2 equivalent by 2035, which is roughly equal to the annual emissions of Japan. In addition, there are potential savings in land use and water consumption: it is estimated that by 2035, they will equal the water consumption of London over a period of 40 years! This assumes that alternative proteins will represent an 11–22% share of the protein market in 2035, depending on the scenario.

Tempeh and tofu are traditional plant-based, meat-like proteins, which are made from soy, peas, and beans. During production, proteins are extracted and separated from the plants or fungus, which are then formulated and processed. The taste and structure of plant-based meat is improved through food additives and extrusion, as well as innovative technologies such as high-temperature shear cell technology and 3D printing.

Challenges in the further development of these protein products are caused by cultivar development with regards to taste and color, protein separation technologies, clear formulation, and expensive large-scale extrusion. There is also a need for efficiency when it comes to costs, as the prices of the products in question are nearly double that of traditional meat products[6].

Pioneers: nutrient protein can be produced from air

Bacteria, yeasts, molds, and single-celled algae also produce edible microbe-based proteins, as do certain aforementioned microbe populations, when proteins are fermented with cellular agriculture technology in a carbohydrate-rich solution. Depending on the method, the result is either a meat substitute – protein and biomass – or pure single-cell protein.

Quorn is one such microbe-based protein product, which was developed in England and has been commercially available since 1993. All in all, there is still plenty of development to be done with regards to these products. Their costs are three times that of traditional protein, particularly when it comes to the production of single-cell protein. Finding more cost-effective growth solutions and the development of separation technology are also highlighted in the further development of these protein products[6].

In addition, biotechnological pilot and demo facilities are already being built, where nutrient protein will be produced with the help of microbes and even the direct capture of carbon dioxide from the air. One of the most famous projects is SolarFoods' "Food without fields and food from thin air" project, which uses carbon dioxide as a raw material. The microbe is isolated from the sediment of Western Finland's seashore, which produces a soy protein-like powder for food products and nutrient supplements. All that is needed is electricity, carbon dioxide, and a source of nitrogen. According to the company, the pilot phase has shown that environmental impacts remain well under 10 per cent of that of traditionally produced plant or animal protein.[5]

A third alternative source of protein is animal and crustacean cell-based protein products, which are produced by directly growing animal cells in a nutrient-rich solution in tanks. According to surveys by the Boston Consulting Group[6], the development of these alternative proteins will still take time in order for growing proteins to become efficient, as well as for the taste and structure to match traditionally produced alternatives in the volumes needed for global consumption.

Developing innovations for waste and packaging challenges as well

Solutions are also being created for the global waste problem. The thermochemical transformation of solid organic waste into porous biochar (300°C–900°C anaerobically) is part of circular economy and mitigating climate change, in addition to sequestering carbon. In soil improvement and composting use, biochar has been shown to reduce greenhouse gas emissions. Biochar is a natural adsorbent which binds free carbon and nitrogen compounds to itself, as well as different kinds of impurities. In addition, biochar has been shown to slow down and prevent erosion and even reduce the formation of methane in ruminants as part of animal feed.[2]

For an interesting case of current development investments, I highlight the production of products and raw materials of fossil origin using bio-based and renewable materials. For example, bacteria can use organic materials as a source of nutrients and change fatty acids, sugars, and proteins, among others, into different kinds of monomers and materials suitable for the production of biopolymers. These can be used as ingredients in food products, in packaging materials and, more broadly, in the industrial production of plastics, bio-based fuels, lubricants, medical equipment, and other valuable goods.[2]

Food industry roadmap to low carbon

SCENARIOS UNTIL 2035 and their central elements

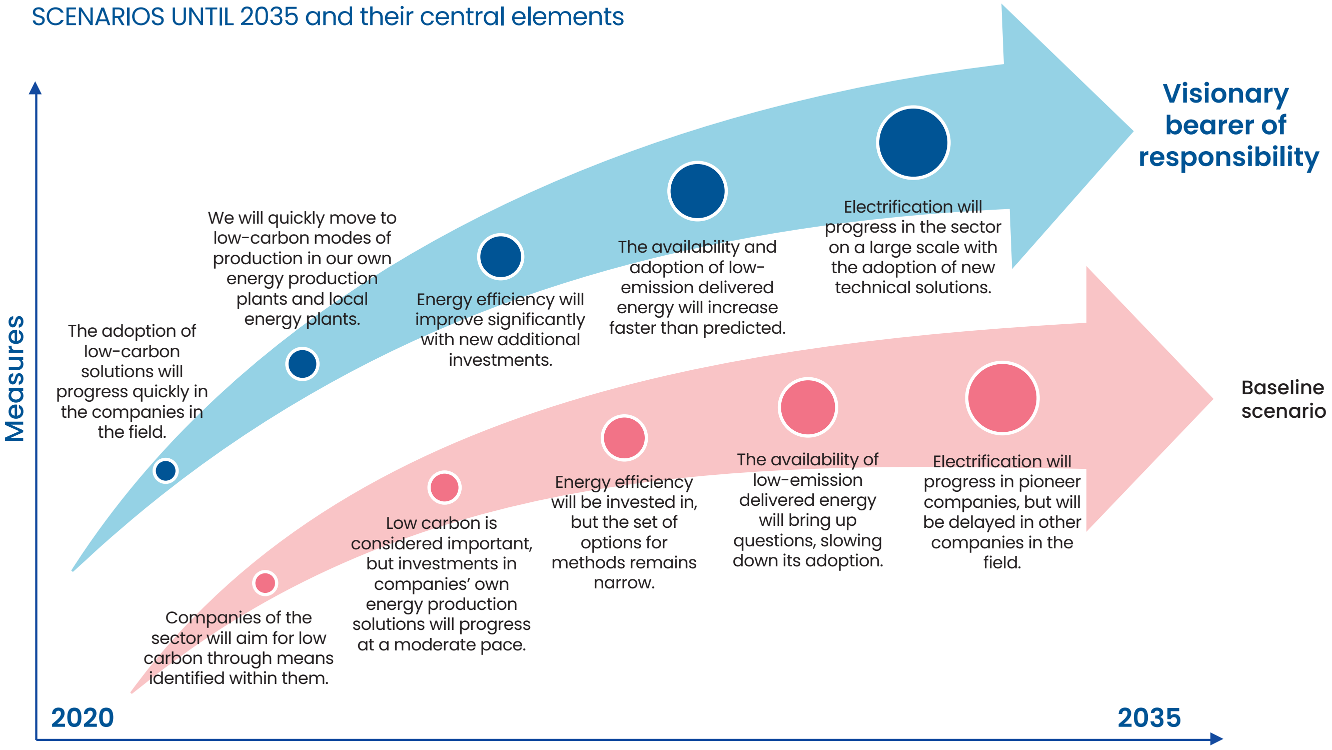


Image *Food industry roadmap to low carbon.*

Target of 75% reduction in greenhouse emissions

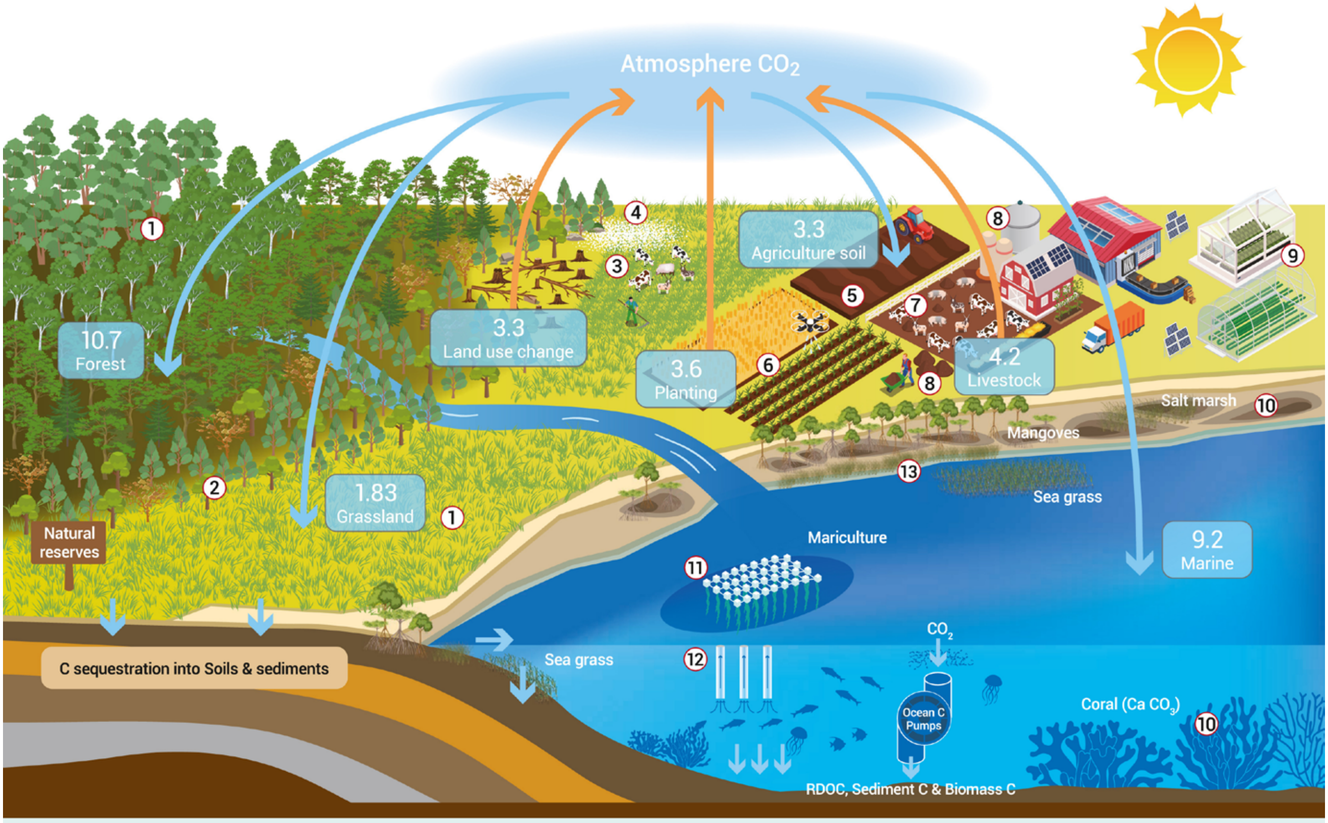
In the roadmap created by the Finnish Food and Drink Industries' Federation and coordinated by the Ministry of Economic Affairs and Employment in 2020, the readiness of the food production sector for carbon neutrality was mapped out. According to the surveys, Finland is well equipped to pursue carbon neutrality. National legislation, funding and incentive systems, and a high level of technology enable the majority of the viable technologies determined by the EU (BAT conclusions of the industrial emissions directive) to already be extensively in use in the businesses of the food industry, according to the roadmap work.

The roadmap's survey of the current situation ensures a clear basis for systematic and long-term work to promote the climate measures of the food industry by 2035. The aim of the roadmap is thus to achieve a 75% reduction in greenhouse gas emissions in proportion to sales at the industry level. In 2035, low-carbon solutions should be widely in use in the food production sector and climate impacts should be under control in the sector's value chain.

What does this mean in practice? The starting point for success is cooperation with other operators, such as primary production, logistics, and the energy and construction industries. In this value chain, the role of the food industry is:

1. to invest further in increasing energy efficiency (10–30% savings in energy consumption in several businesses are possible)
2. to look into and implement switching the mode of production of delivered energy to an alternative with lower emissions and/or plan the electrification of operations
3. to develop raw materials and packaging to reduce fossil emissions
4. to reduce loss and waste and use the side streams of own operations and value chain more efficiently.

In order for these objectives and measures to be fulfilled, more open sharing of information in cooperation with other operators in the value chain is necessary for the identification of key impacts on a value chain and product basis. In addition, the availability of carbon-neutral energy, the development of technologies and expertise, and sufficient forms of support and funding from the government in a predictable operating environment must be ensured. This in turn enables the necessary investments in the sector for carbon neutrality.



Strategies to promote GHG reduction & absorption

Forest, grassland & soil

1. Protection of existing forest & grassland
   Forest managements with biodiversity-carbon mutually benefit
2. Short-rotation young forest of fast-growing hardwood tree species
3. Sustainable grazing land management
4. Enhancement of rock weathering from basalt dust
5. Organic materials amendment

Crop production

6. Crop variety breeding
   Precision irrigation
   Improved efficiency of N fertilizers
   Inhibitors for CH_4 & N_2O emissions

Animal production

7. High-productive animal breeding
   Dietary nutritional management
   Methanogenesis inhibitor
8. Efficient manure management

Revolutionary technologies

9. Indoor vertical farming factory
   Microbial protein production
   Plant- & cell-based meat production

Ocean

10. Protection of existing coastal wetlands & oceans
11. Sustainable mariculture
12. Marine artificial upwellings
13. Land-sea integrated strategies

Image *The Innovation 2021. www.sciencedirect.com/science/article/pii/S2666675821001053*

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Ms Brade´s 20 years' experience covers competences spanning production process development, R&D management, B2B sales, and circular economy content marketing. In addition, she possesses a lead auditor qualification in QEHS management systems utilized in strategic business development. Riina joined Elomatic at the beginning of 2012 as Manager for Process Industry Sales. Over the last years, she has achieved a firm footing within industrial investment and revamp management supported by sustainability assignments, key customer management and project supervisory tasks.

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The end of combustion – a happy ending?

Text: Sebastian Kankkonen

We have many reasons to change our energy consumption behavior and replace fossil fuels. However, even alternative energy sources have their drawbacks. Hydrogen is a hot topic, but its large-scale production and storage pose challenges. That is why we must also consider the potential for energy savings. By optimizing any industrial process to be more efficient, it is possible to save both energy and costs.

For several centuries, centralized energy production has relied heavily on combustion alone. The heating of households has been done by means of combustion for thousands of years. One turning point for the combustion that we can remember was the oil crisis in the early 1970's when the world realized that the resources are not infinite, and the oil price soared.

There are several reasons to reconsider our energy use

Oil, along with other fossil fuels such as coal and gas, have been the cornerstone of energy production and transportation for all of us. Several mechanisms have been making us all rethink and change our energy consumption behavior.

Firstly, the cost mechanism with rising fuel prices made us start saving energy which decreased combustion. Then later, environmental regulations became more stringent and further decreased combustion of especially solid fuels. The advances in combustion technology have luckily compensated much.

In recent months, political unrest and the war in Ukraine have made us think about where the combustibles are coming from, and sanctions could be imposed to further decrease combustion of fossil fuels.

We do have several alternatives

Some of our alternatives have more obvious downsides than others. The combustion of biomass is still considered to be approvable; the coal cycle of wood-based fuels just circulates faster. Still, we do have other pollutants to the air than CO_2, but they could to a certain degree be reduced by emission control equipment such as scrubbers and filters.

Nuclear energy is a source without CO_2 emissions and does not generate emissions to the air. However, various events and technical design flaws have shown us in the past that nuclear energy is not a problem-free solution. The latest nuclear power plants have much more intense safety protocols to prevent nuclear catastrophes from occurring.

Alternative energy sources also have their downsides

Renewables, like water, solar or wind power, are emission-free energy sources. Even they have downsides, since they do affect nature by causing obstacles or barriers for other animals like fish or birds.

Geothermal projects have in general been an environmentally friendly way of producing energy. On a larger scale, they have reportedly generated unrest of the bedrock. Heat pumps are not generating energy from nothing either. Both are a source of heat energy but are also consuming electrical energy of higher exergy.

The challenges of hydrogen are related to production scales and storage

Hydrogen is a very hot topic today. If you are starting to see the pattern of my article you might expect me to start talking about the Zeppelin Hindenburg now. You are wrong. The challenge with hydrogen lies with the large-scale production and storage facilities.

Traditionally hydrogen production and consumption have been smaller scale applications and have been operating without problems for more than a century. There is no sense in producing hydrogen from other viable energy sources just for the sake of hydrogen production. We need to see the big picture.

There is a unique solution for each process

The one alternative left is the most obvious one. Saving energy. By optimizing any industrial process to be more efficient, we can save energy and save costs. In some cases, we can generate heat and recover it in an efficient way.

There is no quick fix, nor is there a single solution. Every client has their unique processes and challenges, and our task at Elomatic is to understand our client and to give them the solution that is the best for them.

Only then can we justify our existence. And maybe save the planet as well. ◣

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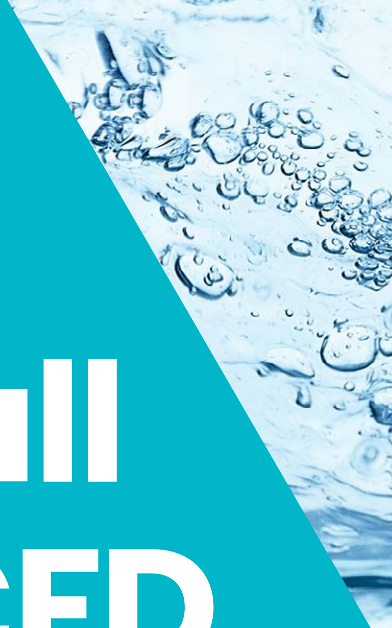

Finding the full potential of CFD

Accelerating and improving the quality of design and process modeling

CFD, or Computational Fluid Dynamics, is a method that is often utilized only for the post-design phase, although it is very well suited for wider and efficient use throughout the design process. Optimal use of CFD analysis generally shortens projects’ lead times and improves product assessment. It also provides an excellent basis for preparing digital twins. In process modeling tasks, CFD is an excellent tool for studying the components, for example.

Text: Hannu Karema

CFD is a branch of fluid mechanics that uses numerical analysis and data structures to analyze and solve problems that involve fluid flows. It uses computers to perform the calculations required to simulate the free-stream flow of liquids and gases, and their interaction with surfaces defined by boundary conditions.

The method is applied to a wide range of research and engineering problems in natural science and industry. The traditional, well-known fields are aerodynamics, aerospace analysis, marine engineering, weather simulation, environmental engineering, and industrial system and equipment design. However, CFD is not only a method of fluid flow, but all processes and equipment linked to flows through heat transfer, chemical and biological reactions or transport of particulate matter.

Therefore, CFD is suitable for many different types of design processes. In the following, I have tried to elucidate the optimal role and the most productive ways to utilize CFD as a part of the design process.

Benefits of CFD are lost if it is applied only in the post-design phase

Some 20–30 years ago, when CFD made its strong entry, it suffered from somewhat too long analysis times for efficient development work and, especially, for desired design process lead times. This major shortcoming appeared through several sources, like 2D design systems, forcing the creation of separate 3D models for analysis, the need to create structured element meshes for solutions, and insufficient solution power.

These shortages led to the application of CFD analysis mostly to check accepted designs. In this way, most of the benefits of CFD are lost since weaknesses or even inoperability of the design are found out far too late and lead to a repeated design process. Typically, related to the post-design analysis, the number of different analyzed model variations is also very low, leaving space for incorrect conclusions.

This approach, called the **traditional process**, has clear drawbacks. When

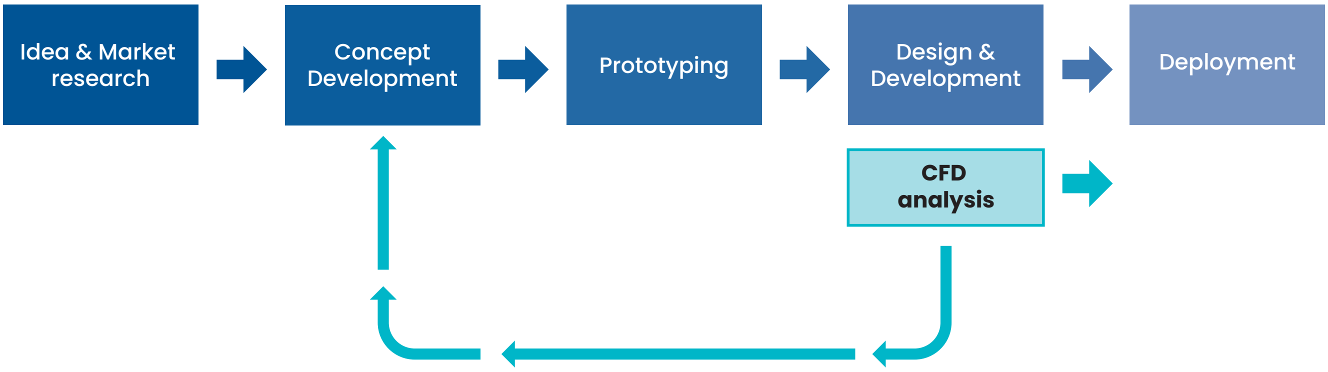

Figure 1 *The traditional process for CFD.*

modeling only serves to check design, knowledge is not created through modeling, and the information produced in the modeling phase is only partially utilized. Also, the accepted design can no longer be modified much. Changes and development ideas mean a return to the concept phase, resulting in slow and expensive changes. In addition, the modeling approach and sub-models do not improve in the process, but the same type of methods will be applied in later design.

As a result, investment in modeling may fail due to an unsuitable approach. However, CFD is a tool that can be utilized at different levels of complexity and details, positioning it also in the concept phase. In addition, CFD has new roles as part of the design process.

"CFD is a tool that can be utilized at different levels of complexity and details, positioning it also in the concept phase. In addition, CFD has new roles as part of the design process.

Concept phase modeling takes product assessment to a new level

In the **early adaptors process**, the drawbacks of the traditional process are avoided by associating modeling with design already in the concept phase. The concept design models are much faster to create with CFD, which is applied with more approximate models and with lower local resolution (element mesh). Better screening in the concept phase also leads to better design and reduced risks. CFD can also provide improved information and indicate critical parts or components in design.

In the design and development phase, the base model can be utilized for parametric studies and small changes in design, providing wider gain of the base model. It also provides

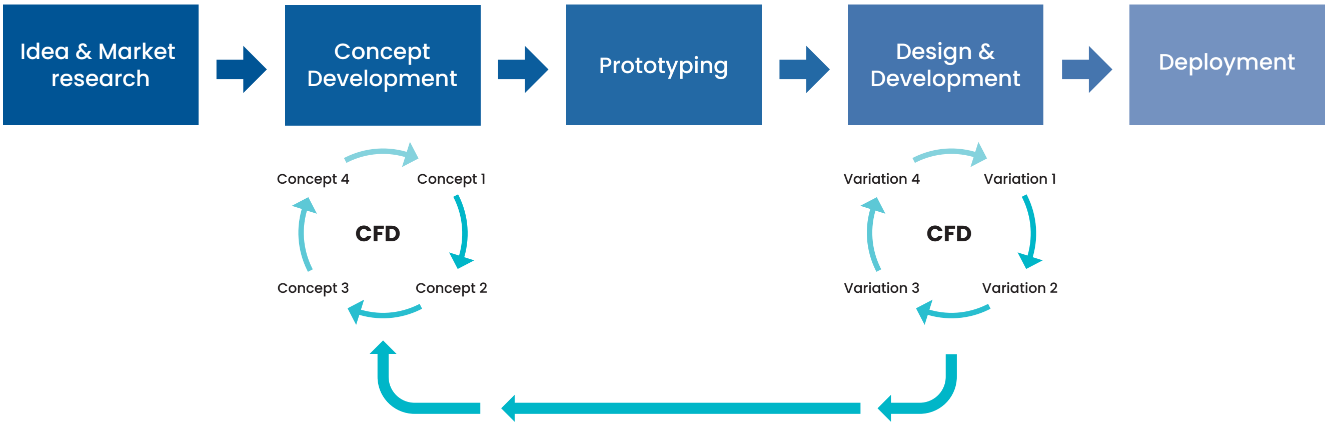

Figure 2 *The early adaptor process for CFD.*

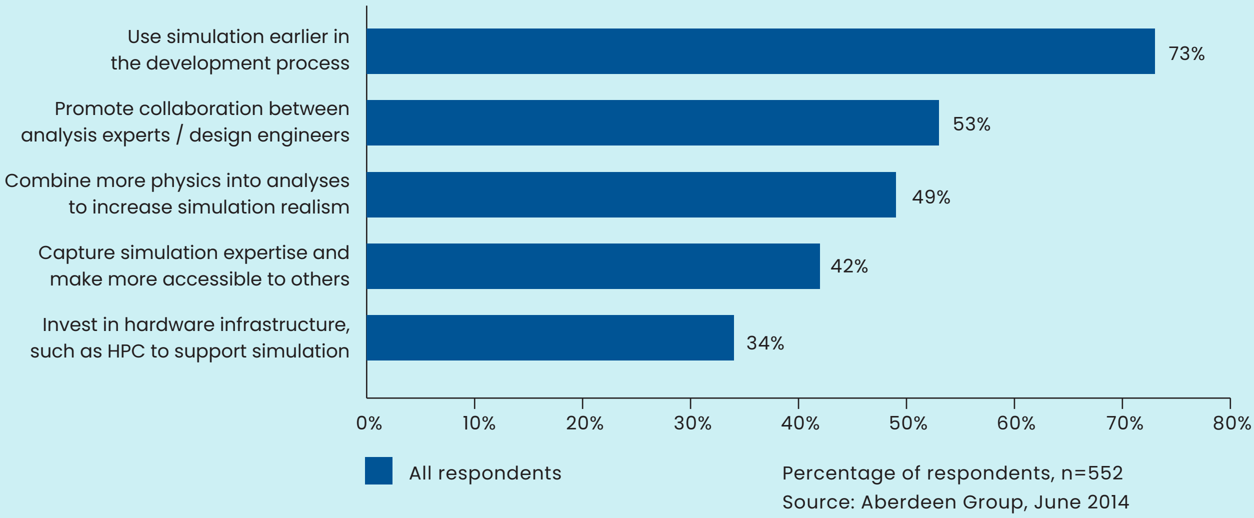

Figure 3 *Top actions to improve product assessment.*

Stages of modelling	Content	Phase of development process		
		Concept Time unit	Design & Dev Time unit	Design & Dev with preceding Concept Time unit
Preparations	Physics and data	5	15	10
Geometry	CAD modifications	5	15	10
Meshing	Discretization	10	25	20
Solution	Numerical solution	10	30	30
Post-processing	Solution analysis	5	15	10
		35	**100**	**80**

Table 1 *Estimates on duration of modeling stages based on my own experience.*

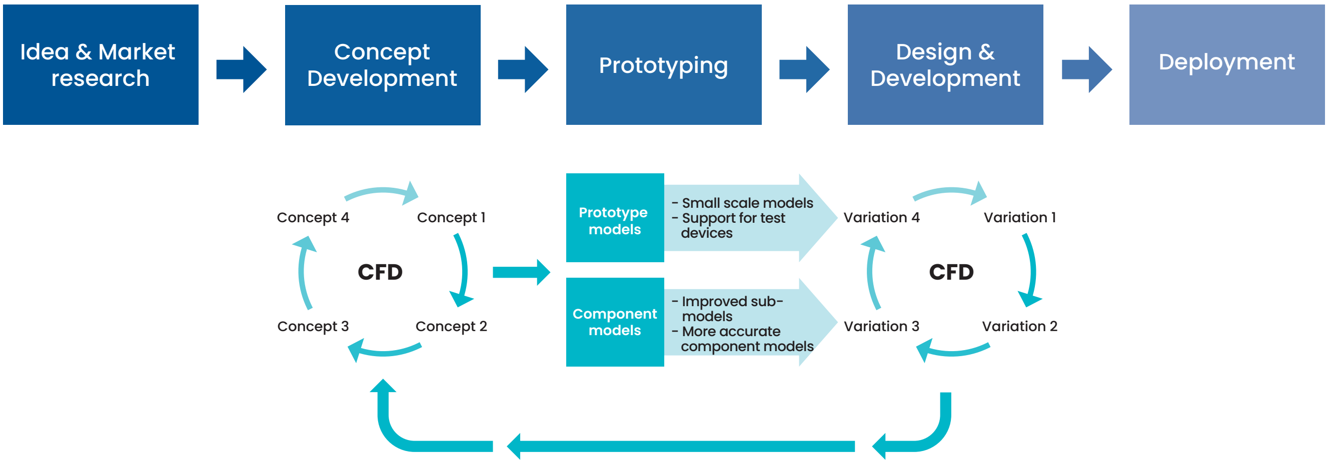

Figure 4 *The parallel modeling process for CFD.*

information on the sensitivity and features of design.

Accomplished studies confirm that there are clear advantages to this type of design process. Concept phase modeling improves most product assessments and leads to even more than collaboration between CFD experts and design, since concept-stage modeling focuses participants on key design areas. Already approximate modeling of concepts and ideas early in the process are very important for success. In addition, more expensive models in the design and development phase can be varied (parametric geometry, coverage of operational range) to improve utilization of later phase investment.

To further motivate the early adaption in the concept phase, estimates on the stages of a typical CFD modeling task are shown in Table 1. It can be stated that concept stage models are faster to perform. Time is estimated to be only one third of the duration of design and development phase. The models have impact over the whole process and even reduce time spent in later phases.

However, it is still obvious that there is a notable difference between the concept phase and the design and development phase, as the target and methods are different. Concept phase models do not directly support those later phases in the design process.

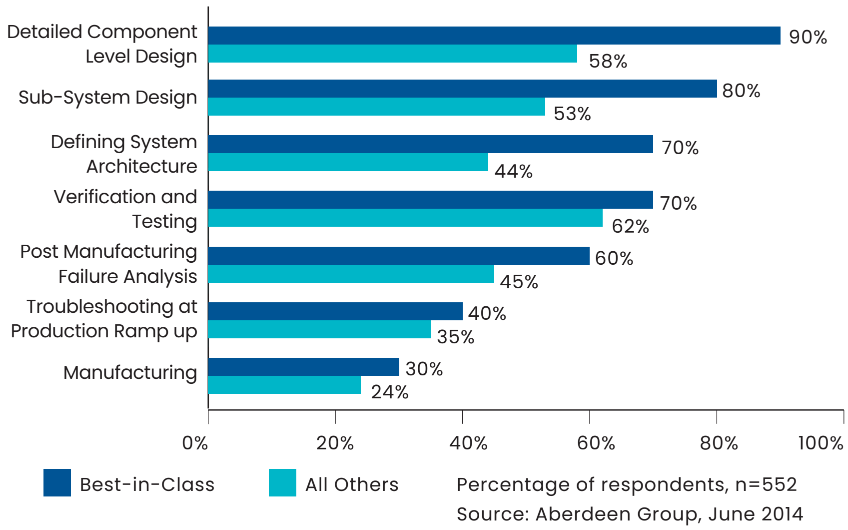

Figure 5 *Reduced development cycle by modeling.*

The development cycle can be considerably reduced

The basic idea behind the **parallel modeling approach** is quite straightforward. To enable design support at all stages, also modeling needs to develop along the process. In the regular design process, there is a notable time interval between the concept phase and the design and development phase. Often a prototype precedes the final design. This time slot is available for multiple supporting tasks like building prototype models for the planning of reliable and correct tests, a more profound interpretation of test results, developing concept phase models to cover challenges of the design and development phase, as well as conducting improved studies of critical components.

It is easy to see the benefits of this process. The development cycle is most reduced if concept phase modeling is supplemented by component models. This way, improved understanding of the selected concept can be achieved. The method also allows more profound analysis of selected components. In addition, verification and tests of critical components of the concept can be carried out before the final design.

In the typical process design, the notable difference is that CFD is not the natural tool of choice for full scope.

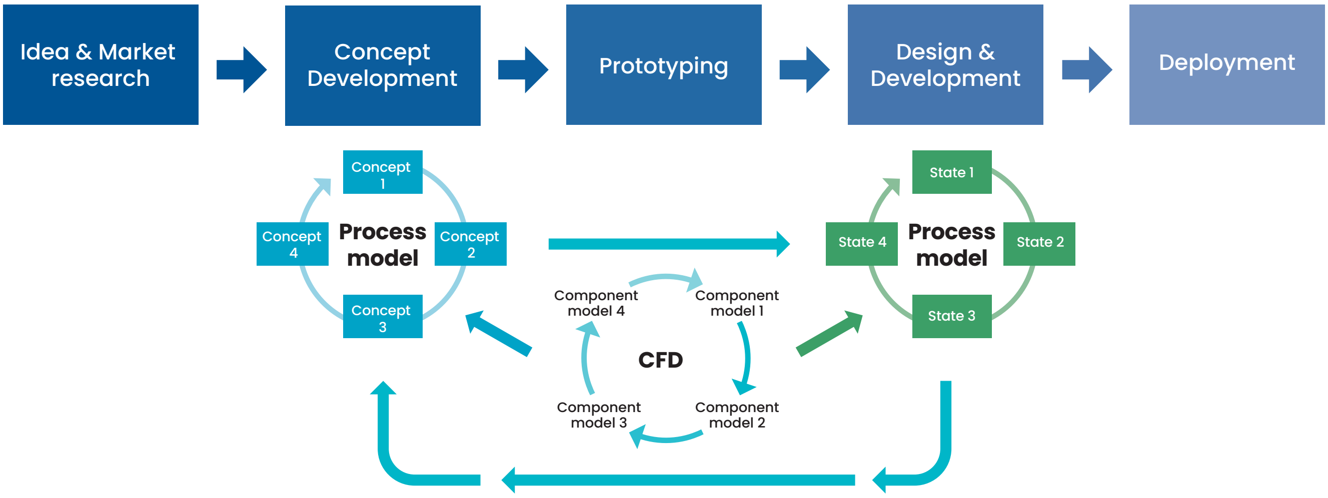

Figure 6 *The parallel modeling approach for processes' design.*

This role is then addressed to the process modeling tool, which provides the framework for design. However, CFD is an excellent tool to support components of process modeling.

Also, the parallel modeling process produces a digital representation of the functionality of design as a natural outcome. This is as an additional deliverable of notable value since the applicability extends to later studies on process parameters and easy access to further development.

The parallel modeling process can also be applied to designs that are tailored with each delivery. The concept phase can be thought of as serving the offer stage, for example the modifications and context for which the design is intended. This can be handled with quick and more approximate models.

CFD even supports the creation of digital twins

A digital twin is a digital representation of an active unique product or unique product-service system that comprises its selected characteristics, properties, conditions, and behaviors by means of models, information, and data within a single or even across multiple life cycle phases.

Covering the full essence of a digital twin is highly demanding and takes a long development time. Therefore, only a few real digital twins exist. Most of them are targeted to improve design based on the collected sensor data. Accordingly, digital twins are regularly built for existing designs but seldom during a design process.

Of the covered design process types, the parallel modeling process provides the best way to underlay digital twins. Improved component models are built during the process, which leads to better description in the design and development phase and serves as an excellent model base for the post-inclusion of the control system. Also, it provides additional confidence for the design process if sensor data from earlier designs can be utilized.

Companies may worry that a parallel modeling process will lead to a complicated design process and organizational changes. It is also often heard that designers are not capable of handling such specialized modeling tasks as CFD. However, questionnaires addressed to successful industry in the field reveal that the best outcome is achieved when modeling tasks are kept separate from design.

Most of the benefits related to a parallel modeling process can be achieved by organizing tasks in the design process differently: although a separate group of specialists is needed, they should not be a separate group in the process. ◣

The parallel modeling process can also be applied to designs that are tailored with each delivery. The concept phase can be thought of as serving the offer stage, for example the modifications and context for which the design is intended.

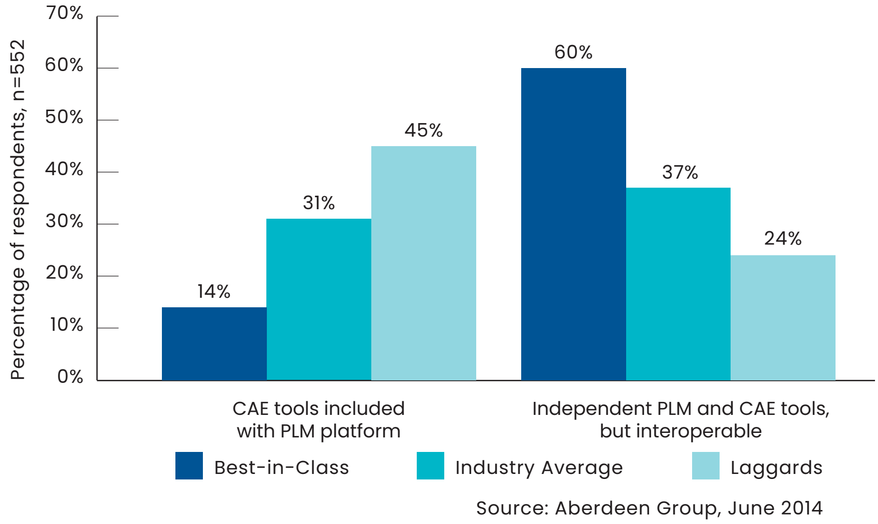

Figure 7 *CAE tools considered as independent tools.*

Hannu Karema
Dr. Tech. (Fluid dynamics and Thermal power Eng.)

Hannu Karema graduated from Tampere University of Technology in 1987. He worked 10 years as a researcher at the Tampere University of Technology and the Academy of Finland in the field of modeling of fluidized beds in combustion and multi-phase numerics. This was followed by a five-year senior researcher position at VTT, in the flow modeling group of Forest Industry. He focused on the research of the approach system and the wet end of paper machines.

After this research-oriented time, he has applied his profound knowledge on CFD modeling and industrial processes as a consultant. His special interests have been in combustion, energy production and, multi-phase flows, covering various specialist and R&D manager positions. Currently he is working as the Lead Consulting Specialist in the Technical Analysis group.

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The parallel process with machinery

In the design processes related to machinery, the general diagram in Figure 4 can be followed quite straightforwardly. The tasks in different phases could be:

The concept phase – multiple concepts modeled

- Short lead time, enabled by simplified geometry/models
- Guidelines and answers to select the right development direction

The prototyping phase

- Targeted prototype models to support tests, both planning and analysis
- More detailed models for key components, and at the same time, serving modeling for the next phase
- Both prototype models and component models are active while concepts are brought to design

The design and development phase

- Modeling supported by both preceding phases
- Reduced lead time and better accuracy/reliability
- Provide excellent bases for further development

The parallel approach with process modeling

Features of this approach are:

- The process model applied as a framework for the full scope
- Different concepts (process connections) studied with available basic components like PFR (Plug Flow Reactor) and CMFR (Completely Mixed Flow Reactor)
- Component descriptions improved with CFD during the process
  - o In the concept phase these are adjustments of basic components
  - o Critical components studied after selection of the concept serve in the analysis of both pilot projects and the final design
  - o For the design and development phase, more advanced components can be created – still, CFD models are usually not directly coupled to the process model

Fast developing 3D printing is one solution to component shortage

Text: Teemu Launis, Martti Tryyki
Images: ANDRITZ Savonlinna Works Oy

3D printing as technology is young and relatively unknown, which is why it isn't yet fully utilized. The method is, however, developing at a fast pace and should not be ignored, even in the light of component shortage. The biggest challenge we see is that the potential of the method is not yet sufficiently understood. At its best, 3D printing can reform your entire business, when you can print products and spare parts fast and near the user.

Mass production of 3D prints is already an everyday thing. However, the technology is hampered by the lack of standardization and different manufacturing process compared to traditional manufacturing methods. The biggest challenge for the widespread usage of 3D printing is that people don't quite understand what kind of possibilities the manufacturing method can offer.

When you can print objects easily and take the product lifecycle into account from the design stage, your entire business will revolutionize – All of a sudden, you can manufacture locally the parts that used to be transported from further away. Additionally, the maintenance and delivery of spare parts becomes faster,

and they can even be carried out on site. And this will naturally affect your whole business logic.

3D printing makes objects lighter and brings savings

One of the great things about 3D printing is that it gives you the freedom to determine the exact location of the material used. This saves material compared to machining or casting, as you can optimize the 3D printable parts to best suit the application. The method also makes it possible to combine multiple parts into a single object, which reduces the need for assembly and the number of items.

The more you simulate the object and understand the potential of the manufacturing process, the more you reduce material consumption and the more cost-effective manufacturing becomes. The key is to make use of the possibilities that 3D printing can provide you in designing.

Best of all, when the object becomes lighter, it usually brings savings to your customer as well. For example, the lighter you can make the boom of a forestry machine, the less energy it takes to move it. Alternatively, they can use this saved energy to increase capacity. It's also easier to control the movements of a lightweight structure.

Towards more energy efficient solutions

3D printing also allows the optimization of objects that have internal flow systems. This is very useful, for example, in designing cooling and heating, when you can optimize heat transfer by using Computational Fluid Dynamics (CFD).

Additionally, you can manufacture even more challenging objects. For example, you can create holes and channels inside an object that cannot be made by drilling or casting.

By first defining the interfaces, the required materials, and their mechanical properties, you can then print the optimized object.

Batch production of 3D printing is also suitable for small parts, which can be produced in dozens or even hundreds in a single run. However, the object must always be designed for printing, the same way you design an object to be casted.

Even large objects can be printed

In Finland, a project called DREAMS, led by DIMECC, was launched this spring to create an open material database for 3D metal printing. The database will make up for the lack of industry standards and facilitate the use of 3D printing for the most demanding applications. The DREAMS

project is financed by Business Finland and it is part of the FAME ecosystem.

The project involves a large number of Finnish research institutes and companies, and Elomatic is also participating in the development of WAAM printing (Wire and Arc Additive Manufacturing). In WAAM printing, a robot welds structures layer by layer. This way it is possible to print even large metal objects, and the size is not a restraint unlike when printing with an AM machine. The method can even be used to manufacture rocket fuel tanks!

3D printing methods can bring relief, especially in times of crisis when importing parts becomes a bottleneck: when it is enough that information is moving, objects can be quickly sub-manufactured domestically. Another advantage of WAAM printing is that the material used is welding wire, which is easier to import to Finland than, for example, steel sheets. ◣

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M.Sc. (Mechanical Engineering)

Teemu Launis graduated from the Tampere University of Technology in 1999 and has worked in mechanical engineering projects in various positions from designer to project manager. Teemu is one of Elomatic's representatives in the Finnish Additive Manufacturing Ecosystem, which aims to increase the role of additive manufacturing in Finland and unleash business potential in AM capabilities. In 2010, Teemu set up Elomatic's Tampere office. He is currently working in sales of Elomatic's mechanical engineering services.

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Martti Tryyki
M.Sc. (Engineering Mechanics)

Martti Tryyki started his career in 2000 at the University of Oulu in the Mechanical Engineering department. In 2012, Martti graduated with an M.Sc. in Engineering Mechanics, and right after graduation, he seized the opportunity to gain international experience as Design Manager at Elomatic's Shanghai office for two years. In 2014, Martti returned to Elomatic as Design Manager of machinery & equipment engineering. His main interests are tailor-made test machine projects, vast utilization of Elomatic's R&D services, and development of the engineering skills of his group.

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DREAMS project creates excellence in 3D technologies in Finland

6-million-euro DREAMS-project, led by DIMECC and funded by companies and Business Finland, will create a material database for 3D metal printing. The project involves leading companies and research institutes of the industry.

The knowledge and use of 3D printing, also known as Additive Manufacturing (AM), is still fragmented and small in Finland. Companies research and develop the issue on their own so that information will not become accumulated. AM technologies are used increasingly more year by year and the field is developing quickly around the world.

DREAMS project to build an open material database

In order to fix the issue, the FAME ecosystem (Finnish Additive Manufacturing Ecosystem) has started the DREAMS project (Database for Radically Enhancing Additive Manufacturing and Standardization) that aims to bring domestic 3D printing skills to the international forefront by 2024.

The project helps to build a comprehensive material database by researching about 10,000 metallic test objects, which are made from various materials and made by using different devices and printing methods. The research is based in particular on fatigue properties of materials.

The project aims to accelerate the progress of standardization in the industry and develop domestic expertise in all aspects of 3D printing, from research to cost management. The database will also facilitate the use of 3D printing of metals for the most demanding applications.

The basis for collaboration already exists in the FAME ecosystem

In the FAME ecosystem, companies can share information and create knowledge about AM technologies. At the same time, it creates conditions for cooperation between companies. In addition to the DREAMS project, other development projects are launched in the ecosystem, focusing on a specific area of expertise.

The aim of the ecosystem is to increase the use of and investment in AM technologies in Finland. Ecosystem involves nearly 30 Finnish companies and is run by DIMECC.

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