TOP ENGINEER

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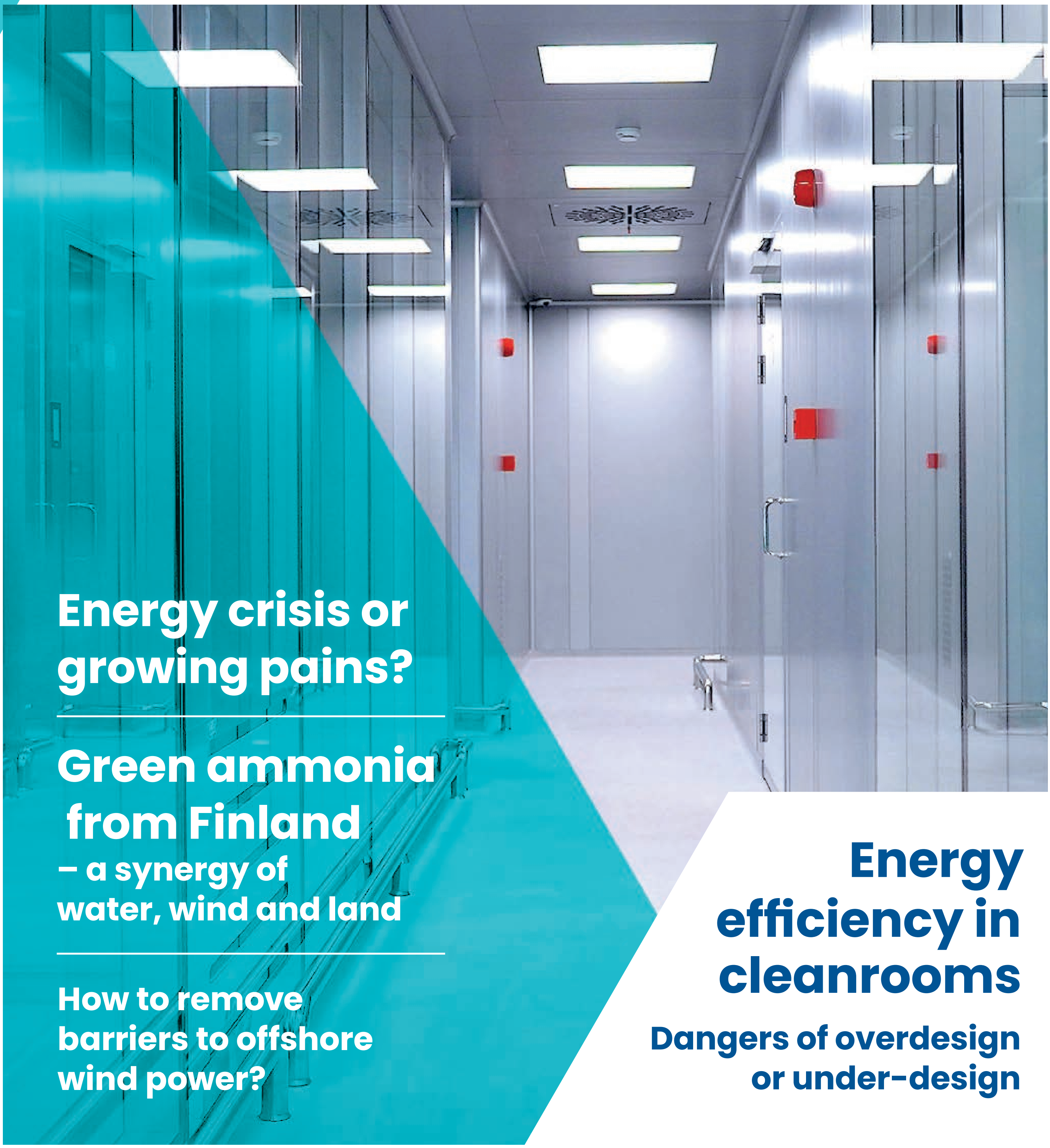

Energy crisis or growing pains?

Green ammonia from Finland – a synergy of water, wind and land

How to remove barriers to offshore wind power?

Energy efficiency in cleanrooms

Dangers of overdesign or under-design

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A silver lining to the energy crisis?

Limited energy availability, soaring energy prices and the urgent need to curb emissions have led to a perfect storm throughout Europe. Or is this an opportunity to speed up the replacement of carbon fuels with new technologies and cutting-edge solutions?

Finland's in a unique position because of its huge and continuing growth in wind power in the coming decades. Recently, wind power in Finland has been doubling every four years. Given plans in progress, wind will continue to double every four years. Also, a new nuclear power plant is soon coming on stream.

But the current energy situation demands rapid change and flexible energy solutions to replace carbon fuels, handle fluctuating energy production and provide cost efficiency. This is now a huge opportunity for us to unlock the valuable potential of wind power. Finland does not have many natural resources, but we have trees – and now wind to use to replace fossil fuels cost efficiently.

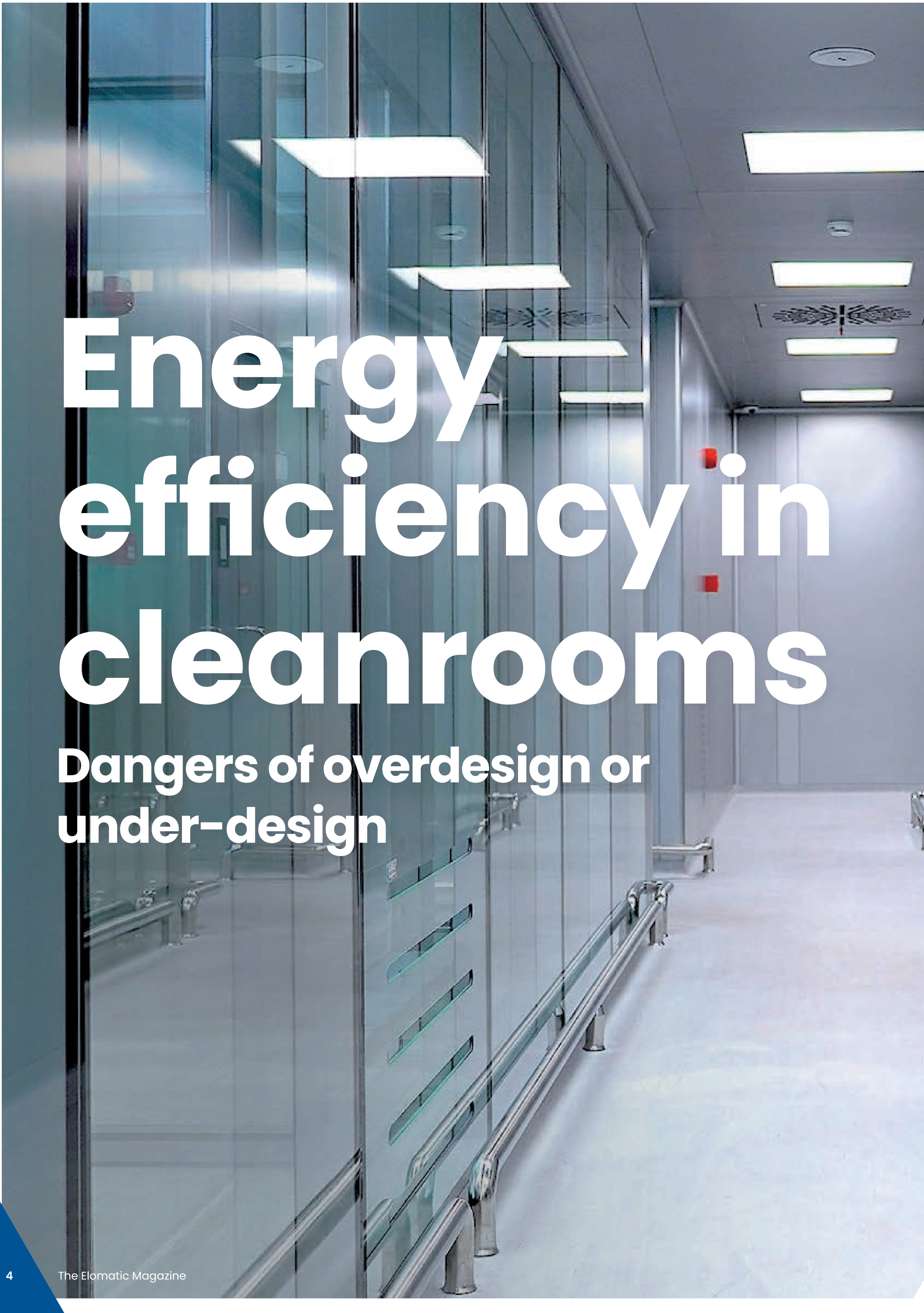
Finland already has experience improving energy efficiency. This gives us the skills to solve the challenges of energy flexibility. Heat storage and timing of industrial usage with energy availability are just some of the solutions already being developed.

Offshore wind power is another area being explored. Solutions already exist for building wind turbine foundations. Coming steps include solutions for efficient transfer stations and plan for new green fuel plants next to offshore turbines. Shipping, too, is rapidly becoming green with numerous new total system approaches being developed for carbon-neutral vessels.

As the crisis speeds up our energy transition, we at Elomatic are ready to help throughout the entire value chain. We're ready to take advantage of the natural resources we have available and make them energy flexible for new business opportunities.

I hope you enjoy reading our new issue!

Patrik Rautaheimo
Editor-in-Chief, CEO
patrik.rautaheimo@elomatic.com



Energy efficiency in cleanrooms

Dangers of overdesign or under-design

Since the global energy crisis hit, companies in pharmaceutical manufacturing started improving their energy efficiency to contribute to the economy as well as to their budget. Heating, ventilation, and air conditioning (HVAC) systems are typically the biggest energy consumers in pharmaceutical facilities, and design is the best stage at which to influence them.

Text: Gligor Mukaetov, Zarko Kostovski, Goran Serafimov
Images: NAYA Life Sciences

The energy efficiency of the system typically takes a backseat to the functionality of the system in the world of cleanrooms. These are controlled environments where particle concentration and its generation are the main criteria for performing sensitive pharma operations, in which good manufacturing practices (GMP) must be followed.

Increasing energy efficiency is crucial for both top-line growth and cost reductions. For it to be more successful, significant internal organizational cultural changes are required that demonstrate a desire to act on environmental issues.

The biggest energy-saving potential is usually found in HVAC

HVAC can be a crucial component that influences a facility's ability to provide safe and effective products when contamination control is desired. For most of these manufacturing plants, HVAC is typically the largest consumer of energy.

Many factors need to be considered when designing low-energy HVAC systems for pharmaceutical facilities, especially regarding maintaining a clean and safe operational environment. Environmental control systems that are properly planned, constructed, installed, configured, maintained, and operated can assist in ensuring the quality of goods produced at a facility. This increases dependability and lowers a facility's upfront and ongoing operating expenses.

The importance of design

It is hard and expensive to change a design during or after construction, and there is more impact on capital cost and schedule. As the design develops, input from all interested parties should be considered to avoid later changes.

Several goals are achieved through the process of assessing drawings and specifications, as a design progresses from concept to issued-for-construction status:

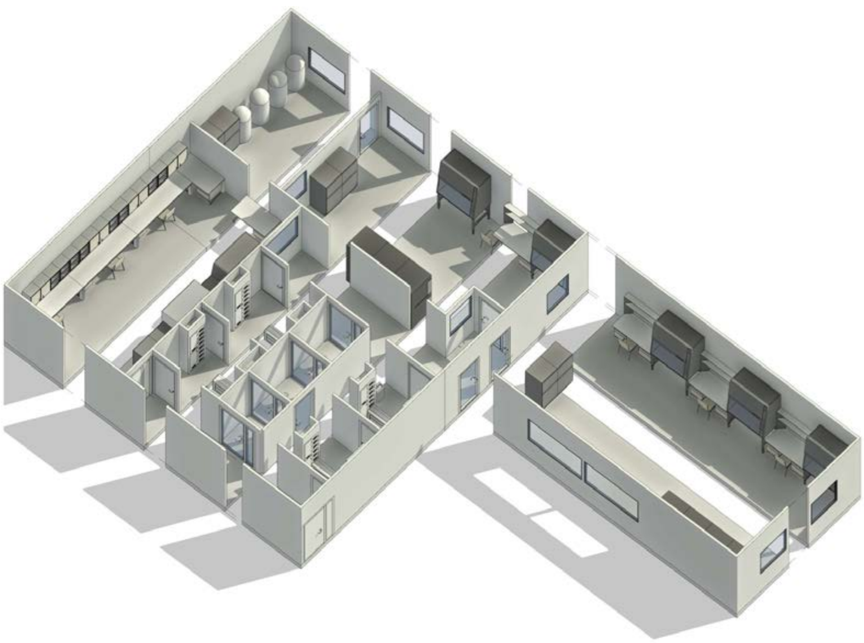
- Confirm that a design adheres to accepted tradition and practice
- Ensure that the concepts proposed are meeting user expectations
- Make sure a design reduces the risk to product quality or process safety
- Ensure that a design is reliable and that it performs as expected
- Validate that the hazards have been identified and considered while also ensuring that the suggested design is cost-effective.

A cost model helps to estimate the need for energy

An HVAC system's life-cycle cost is typically significantly higher than its initial cost. Hence, the overall cost is a key consideration when selecting HVAC systems.

It is customary to assess various design possibilities using techniques such as net present value or the rate of return. Engineers that aim for the most robust design regardless of cost frequently lack familiarity with these ideas. However, the layout of a manufacturing facility must be developed around the needs of that facility. Hence, separating "must" goals from "want" goals requires work, because each department must reassess its operations in relation to what is necessary for successful operations.

When working on the design, a cost model helps to determine the facility's final maintenance, consumables, and energy needs. Net present value and investment rate of return are common components of systems. Early on in a project, the cost model should serve as the benchmark for evaluating judgments about life-cycle costs, and it can be utilized to contest choices regarding user requirements.



Things to consider in design

The basis for all consumption estimations is the number of air changes per hour. If this is overdesigned, the air-handling units will have larger flows than necessary, necessitating larger fans and more cooling or heating loads. On the other hand, under-design would compromise the system's usability and dependability, which are critical factors in any facility where contamination control is required.

Furthermore, when designing the HVAC system of ductwork or pipework, it is not just important to ensure that all ducts reach their location, it is also important how they get there. Every elbow, bend, reducer, and transition contribute to a higher static pressure drop, which increases the capacity of the fans, which in turn consumes more energy.

As the technology is modernizing, good designers are considering implementing modern technologies in the design, to contribute to energy efficiency. Proper design tools (CADMATIC, REVIT, AUTO CAD MEP) help to superpose all the systems in the project, and to ensure that the best distribution routes for the energy in the system are considered.

"Increasing energy efficiency is crucial for both top-line growth and cost reductions. For it to be more successful, significant internal organizational cultural changes are required that demonstrate a desire to act on environmental issues.

> **The air-flow strategy used in the building layout, along with the analysis of the physical flows within the facility, is a key factor to consider.**

Automation helps especially in complex systems

Better automation of the facility can provide fine-tuning of the system, which will reduce unnecessary consumption. Some clients do not trust it, but the rule of thumb is that the more complex the system, the better the control of energy efficiency.

If the project has less than 24/7 working time, the building monitoring system can be programmed during the downtime to operate with minimal capacity. This ECO mode can be used on weekends or evenings when the process is not running. If the HVAC system is designed so that the amount of fresh air entering can be controlled through the building monitoring system, this can be a great asset at times when the outside air is within the required parameters.

The air-flow strategy used in the building layout, along with the analysis of the physical flows within the facility, is a key factor to consider. It is preferable to keep similarly classified areas physically close to one another as much as possible, so that they can be connected to the same air-handling system. Duct runs, energy distribution costs, and air system complexity will all be reduced as a result.

Energy consumption depends on the HVAC system

Once-through air systems provide the most acceptable form of preventing cross-contamination. Without any mixing or recirculation, the air leaving the supplied room or space is fully vented to the outside of the building. Therefore, potential contaminants from one space are not transferred to another through the return side of the air-handling system.

This strategy necessitates a lot of energy expenditure. However, a once-through system is recommended in locations where potent processes are handled and where the product is directly exposed to the environment.

Recirculated air systems increase the energy savings in the facility. This type of system circulates conditioned air into the room before returning it to the air-handling unit, where some of it is combined with fresh air and reconditioned, while the remainder is vented outside of the building. When using air recirculation technology, care should be taken to prevent the contaminated air from one location from contaminating the supply air for another.

Installing **a heat recovery unit** may be considered as a typical method in all HVAC systems in some parts of the world. Despite the high cost of the initial investment, this strategy offers effective energy savings. Some companies use constant recirculation of fluid through heat recovery units. However, at some time when the outside conditions are ideal, the design must ensure that the three-way valve may not transfer the additional loads.

There are several options for air drying

The best solution should be chosen based on the energy consumption or budget when determining how to dry the air required for process control.

1. **Cooling and drying.** Relative humidity is typically achieved by cooling the air as much as feasible, then heating it to the desired room temperature to meet design requirements. This can be done with a water system.

2. **Dehumidifiers with silica gel.** Drying a portion of the recirculated air to a very low relative humidity level before combining it with the remaining air. It is necessary to determine whether this design is suited to delivering greater energy efficiency throughout the design calculation.

3. **Devices for dehumidification.** Despite being the most expensive solution and providing the best control over low humidity, these units use the most energy, as they dehumidify all the air that has been prepared for the cleanrooms. Even when steam or electricity can be used, a significant amount is still needed.

The significance of training

Personnel involved in the manufacture and testing of GMP facilities must be sufficiently knowledgeable and trained for their role. At a minimum, personnel must understand the fundamental principles of GMP operations, as well as the critical documents specific to their area of work. For more important operations, employees may need to demonstrate operational skills, and operators may need to undergo formal qualification tests.

Training is a crucial component in developing skills, competence, and a high work performance culture, all of which are necessary to enhance maintenance performance. Lower operational energy costs could also come from properly implementing some well-known maintenance procedures, such as preventative maintenance and predictive maintenance. ◣

Elomatic has strengthened its expertise in cleanrooms

Elomatic has founded a new business unit, Pharma BU, to further develop our knowledge of engineering and design for our customers producing pharmaceuticals, and to grow internationally. To meet our customers' demands for fast design and delivery of new production facilities and containment, Elomatic has engaged with **NAYA Life Sciences**.

NAYA provides turnkey cleanroom deliveries to customers in Europe and other locations. Product safety, containment, usability and energy efficiency are key to the design of NAYA cleanrooms.

Gligor Mukaetov
Eng. Manager,
NAYA Life Sciences

Gligor has over 10 years of strong and diverse technical background in engineering and mechanical design. He has designed, supervised, and led projects on developing innovative solutions for many industry stakeholders.

Zarko Kostovski
Head of Design team,
NAYA Life Sciences

Zarko has comprehensive knowledge and experience in projects where contamination control is considered as an issue. He has been involved in every phase of NAYA's cleanroom projects.

Goran Serafimov
Designer,
NAYA Life Sciences

Goran is part of NAYA LS's Mechanical engineering team. He's a versatile member of the group, HVAC designer with focus on the practices, methods, materials, and equipment used in installation and exploitation of HVAC systems for the cleanroom projects.

Energy crisis or growing pains?

Text: Lari Heinonen
Images: Elomatic, iStock

The options for solving the energy crisis have been known for a long time – now the actual solving of the issues should take priority. In Finland, the forest industry produces a large portion of the renewable energy, but also uses a lot of energy just the same. Our special characteristics also include our district heating network that enables the large-scale distribution of heat from different sources. We need investments in things such as promotion of the circular economy and storing of energy.

In the last few months, the headlines have been dominated by the energy crisis. However, according to one definition, a crisis is a new situation or turning point encountered by a human or organization wherein the learned problem-solving skills may not work anymore. In the big picture, the situation in the energy market does not really correspond to this definition of a crisis.

The system built on fossil fuels is, despite everything, approaching the end of its life. The inevitable progress has just been forced to leap forward, which naturally causes more sudden growing pains than a controlled change would. However, the direction of the long-term development is not changing.

A clear consensus of needs and means has prevailed for a long time

Naturally, the price of energy is an issue for many households, companies and communities, to put it mildly. But the proposed solutions, such as investment in energy and resource efficiency and renewable energy, have been known to us for at least a decade. Ensuring our survival does not require doing anything new or surprising.

The private persons, communities, companies and states that have taken action in a frontloading manner may escape the crisis completely. The seed of a much more severe crisis lies in the continuous use of fossil fuels.

Finland has strived for a quick change

The path of the EU and Finland towards carbon neutrality has been presented in both the general roadmap of the EU and the roadmap of Finland. The EU strives to achieve carbon neutrality by 2050, whereas the objectives of Finland are considerably more ambitious: our country wants to be carbon neutral by 2035. Countries such as Japan and China have also presented their own targets.

In any scenario, achieving these targets would have required actions that would be painful to at least some parties. Now we have a taste of the things to come, because we have had to take action in one fell swoop. The list of necessary actions remains massively long, and implementing the plans will not be easy.

> **The seed of a much more severe crisis lies in the continuous use of fossil fuels.**

Long-term roadmaps often include perspective issues

When a target is set far enough into the future, there is no need to take unpleasant action in the current parliamentary term – in other words, now. The carbon neutrality of Finland or even the EU will not solve the global climate issues, if the additional production demanded by growth and the emissions related to it are outsourced. The bond between economic growth, consumption, and energy consumption is yet to be severed, which is part of the problem.

In addition to achieving zero-emission energy production, another essential task is building a circular economy that is both extensive and energy efficient. The benefits and disadvantages of the circular economy are largely determined through the energy consumption of the cycle processes and the disadvantages of the related energy production. Transparent and comprehensive lifecycle reporting must be developed to verify these factors and, of course, the benefits of a circular economy.

Finland currently utilizes wood-based biomass extensively

Every country and economic community has its own characteristics related to its regional energy systems. The special characteristics of Finland include the large amount of wood-based biomass it has in relation to its population, its forest industry that uses the biomass efficiently, and its district heating network to which I will return later.

The biomass reserves of Finland make the large-scale production of wood-based renewable energy possible. Of course, in political decision-making the degree of renewability depends on the agreed approaches and definitions. Biomass will possibly be defined in the EU region as renewable energy, which is an issue for the system in Finland.

Impact of forest industry is evident in both production and consumption

At the moment, the forest industry produces a considerable portion of the renewable energy in Finland, but the industry also uses a lot of energy. The forest industry participates in things such as frequency management and the reserve market, and is thus an essential operator in the Finnish energy system.

The processes and logistics that enable the efficient utilization of forest biomass have found their current forms through centuries of development. The forest industry has, throughout its history, survived many upheavals, such as the end of tar use and the crash in the demand for magazine paper. It will also survive the current crisis, and it will not only survive; it will be part of the fossil-free solution.

> The forest industry participates in things such as frequency management and the reserve market, and is thus an essential operator in the Finnish energy system.

Side streams will continue to have a key role

At the moment, the energy production of the forest industry is largely based on burning unutilized side streams, such as lignin. Therefore, the energy system of Finland is affected by whether the forest industry will start utilizing its side streams for purposes other than energy production, which will require compensatory energy production. For example, the demand for heat pump solutions that are based on the utilization of waste heat might increase. In the future, we may see solutions such as small nuclear power reactors to generate heat.

The interest in utilizing side streams in the manufacture of physical products may come, for example, through EU regulation or as new innovations and products of a better level of added value become viable options. This will make using biomass for energy less appealing.

However, it is unrealistic to assume that the burning of side streams would cease completely, at least in the near future. The products or markets in which these raw materials could be utilized do not exist on a large enough scale.

District heating network increases flexibility of energy system

The more urban Finland becomes, the larger is the part of the Finnish population living in an area covered by the district heating network. The district heating network enables the large-scale distribution and utilization of heat from multiple sources.
The already utilized sources of waste heat include

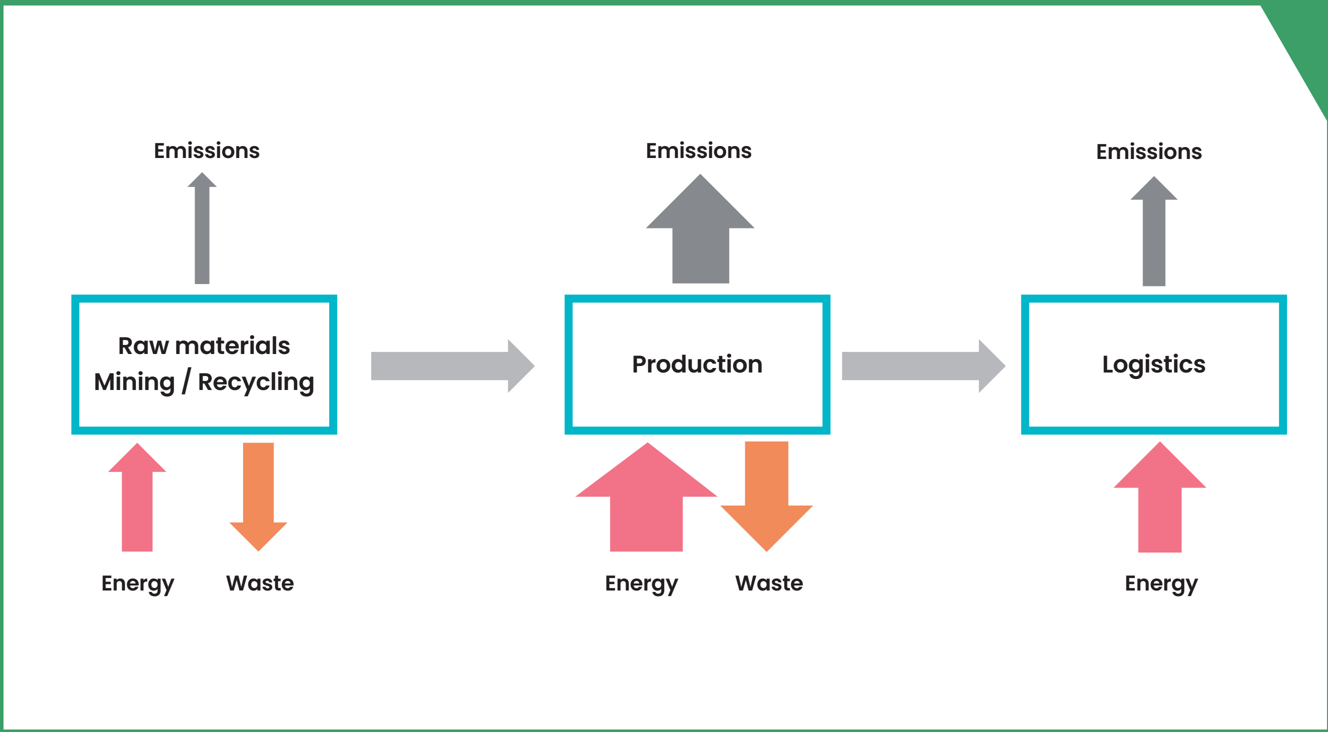
- waste heat of industry
- heat from wastewater
- waste heat of data centers.

The district heating network also enables things such as the production and distribution of geothermal energy, which is practical in comparison to individual geothermal wells. The benefits of a good network also include an increasingly flexible energy system, when energy can be stored cost-effectively on a large scale.

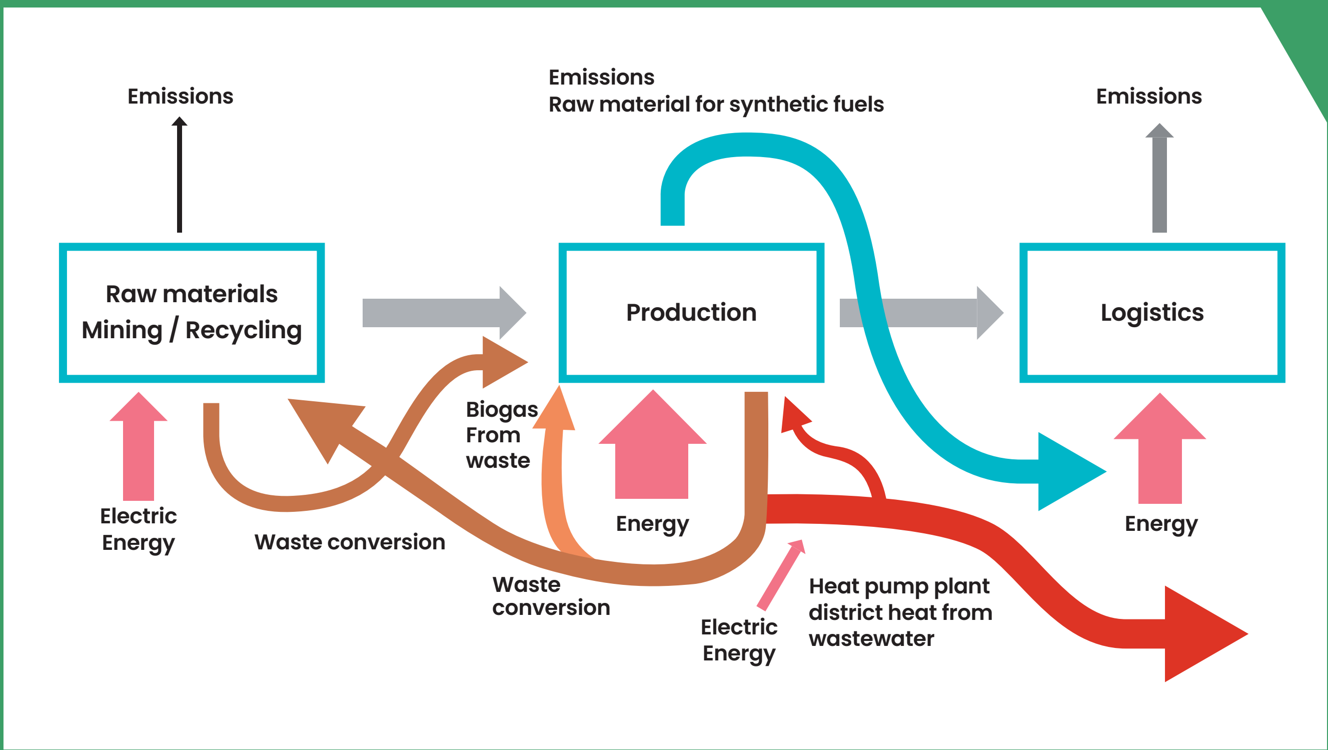
Storing of energy is worth the effort

Preparing for the increasing need to store energy is a smart move. As long as the production profile of the industrial plant allows, effort should be made to store energy or to direct the use to occur at night. Cheap electricity can also be stored in heat accumulators and discharged as process steam, for example.

The optimized storing and flexible use of energy require a good understanding of the future consumption in relation to the price of energy, now and in the following hours or days. The prediction of short-term consumption



A traditional system.



A re-thinked system

Finland can make the most of renewable electricity

Renewable electricity leads the way to a fossil-free economy. It enables things such as a green hydrogen economy, which in turn is the key to the flexibility of energy systems. A district heating network is an excellent way of distributing and utilizing the lost heat from the hydrogen economy processes.

In the Nordic countries, the carbon footprint of electricity is reasonably small, thanks to things such as hydropower. Therefore, replacing gas or other fossil fuels with electrification will create a real emission reduction in, for example, industrial processes.

Contrary to this, the energy systems in many other places in Europe are based on natural gas and other fossil fuels. For political reasons, natural gas has quite unscientifically been defined as a renewable source of energy. In its own way, this underlines how far the EU still is from an energy system based on actually renewable sources.

There are still places in Europe without a sufficiently extensive district heating network. Gas is used both for heating communities and in many industrial processes. Electricity production is also widely based on fossil fuels. Therefore, electrifying processes is not a solution as long as the carbon footprint of electricity is high.

Even though the EU on a general level requires massive investments in its production capacity for carbon-neutral energy, Finland has an excellent opportunity to utilize the head start it has in comparison to Central Europe, for example. We can now look beyond surviving the coming winter, because Finnish competence could be utilized elsewhere as well.

requires the process to have reliable energy indicators, and, furthermore, the data produced must be adjusted and utilized in energy price data and forecasts.

"Zero waste" thinking is also required

The introduction of the circular economy must be accelerated as part of sustainable economic growth. The investments to be made in it will bear fruit in the future, similar to the way the investments made in renewable energy and energy efficiency in the past are now being rewarded.

The lifecycle calculations striving to verify the benefits, such as carbon footprint analyses and carbon handprint analyses, will become mandatory, because the consumers and financiers know to demand them. This is why companies should immediately develop their calculation and reporting methods. The entity related to energy and material flows must be rethought, which will challenge the benefit and disadvantage assessments and business models and make them more complex.

Introduction of unimplemented energy efficiency actions

On reflection, the solution to the present problems is to take the same actions that were supposed to be taken before the crisis. It is crucial to utilize the opportunities to optimize energy use so that the specific energy consumption required by the growth is as small as possible, leading to the investments in carbon neutral energy production remaining similarly as light as possible.

As someone who has spent almost their entire career working with energy efficiency, I know that the world is lamentably full of energy efficiency actions that are clearly recommended but still unimplemented. It is certain that our current standard of well-being could also be achieved at reduced energy consumption. ◣

Lari Heinonen
Senior Manager, Energy Consulting

Lari works as a head of Elomatic's Energy Consulting function leading the world-class energy experts, process specialists and project managers. Lari has 15 years' experience in industry and technology supplier, mainly in the energy efficiency field. He've had responsibilities in R&D, solution sales, project management as well as leading the expert teams.

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Vaasan Sähkö is building a future heat pump plant

Images: Elomatic Visualization Solutions

Vaasan Sähkö will have a plant built at the Pått wastewater treatment plant to recover waste heat from treated wastewater. The heat will be fed into the district heating network, where it will be sufficient to meet the needs of almost 2,000 private homes. Elomatic is responsible for the entire project, from the planning and procurement phase to construction management and commissioning.

Vaasan Sähkö's heat pump plant is a great example of the circular economy: one investment that utilises waste heat equivalent to the annual heating energy of all the private homes in Vaasan Sähkö's district heating network.

Elomatic has designed heat pump plants before, especially for industrial applications. However, this is the largest overall project. Interest in similar projects has clearly increased, and Elomatic is currently working on the concept design of another similar solution.

"Heat pumps have developed so rapidly in recent years that this kind of heat recovery has become profitable," says **Anne Kujanpää**, Project Manager at Elomatic.

In cities, district heating is the fastest way to move to a zero-emission era

The Pått wastewater treatment plant treats wastewater from the entire city of Vaasa and part of the wastewater from the neighbouring municipalities of Mustasaari and Maalahti. The waste heat from the treated water is fed into the district heating network.

"It is better to invest in one efficient heat pump system instead of forcing a couple of thousand single-family home owners in our region to switch their heating to zero emissions themselves," says **Juha-Matti Karvala**, Project Manager at Vaasan Sähkö.

According to Karvala, the district heating network serves as a platform for a circular economy, and the Pått heat pump plant is a good example.

"Heat recovery is definitely the way of the future," Kujanpää adds.

The project requires a wide range of expertise

The project, which started in early 2022, is now well underway. Elomatic is the EPCM supplier for the project, which means that in addition to design and procurement, it is responsible for construction management and commissioning.

"This is a major project for Vaasan Sähkö and EPCM's implementation is a good fit, as we want to be involved in the project throughout its life cycle," says Karvala.

"In addition to extensive planning expertise, supervision and coordination, Elomatic will provide us with up-to-date reporting on the overall progress of the project, including forecasts and necessary decisions," he continues.

The solid experience shows

At Elomatic, the aim is always to select the project team such a way that the expertise of each individual is utilized in the best possible way. Most of the designers involved in the project have experience in industrial projects over a longer period of time. Some have been involved in heat pump projects before.

"Yes, it shows that the designers are experienced. The most important thing is that they are able to carry out their work to a high standard within their own experience and that information is passed between different locations," Kujanpää says.

"When cooperation is smooth, the work is a pleasure"

The project is well on schedule, and earthworks have started in October 2022.

"Our cooperation has been great, and Elomatic has managed the whole thing smoothly," says Karvala.

"Vaasan Sähkö has a team of experts involved who have put a lot of effort into the project. We have managed to get things done together in a really good team spirit," says Kujanpää.

Kujanpää stresses the importance of people enjoying their work and a good and open atmosphere.

"Good communication, both within the project team and with the client, helps to achieve a good outcome in all respects," she says. ◣

About the project

What: Waste heat recovery from treated wastewater
Price: approx. EUR 11 million
Grant: EUR 1.9 million investment grant from the Ministry of Economic Affairs and Employment
Energy: 50–60 gigawatt hours (GWh) of heat/year
Planned commissioning: end of 2023

Green ammonia from Finland – a synergy of water, wind and land

Text: Jussi Ylinen
Images: Unsplash / Matt Hardy, Elomatic

A derivative of green hydrogen produced from renewable energy, green ammonia has the potential to become a new source of energy and revenue for the Finnish national economy. It allows the country to break its dependence on natural gas imports and provides self-sufficiency to secure agricultural production, power vessels in the future or to be a carrier of green hydrogen. Finland has the ideal mix of resources to produce green ammonia for both its own domestic use and for global distribution.

Throughout history, Finns have used their resourcefulness to survive some of the harshest circumstances. When life looked bleak, they turned to nature for sources of inspiration, sustenance and energy.

Only a few years ago, Finland was known mostly as a country living from the forests with its world-class pulp and paper manufacturing, machinery and wood-based products. Now facing climate change and the energy crisis, Finland is ready to leap ahead in another sector – producing green ammonia for its own self-sufficiency and to share with other markets globally.

The most critical resource needed is electricity from a renewable source

Finland has been lavishly endowed with all the natural resources it takes to produce carbon-free green ammonia that can be further used mainly as the essential ingredient in fertilizers, marine vessel fuel or a hydrogen carrier. The most important one is electricity from a renewable source.

Finland is currently in the process of building up its offshore and onshore wind power production in the region of North Ostrobothnia, thanks to the region's excellent wind conditions. Today, there are approximately 80 wind power projects at different planning and permitting stages in this area alone – with strong connections for transmitting electricity to the national grid.

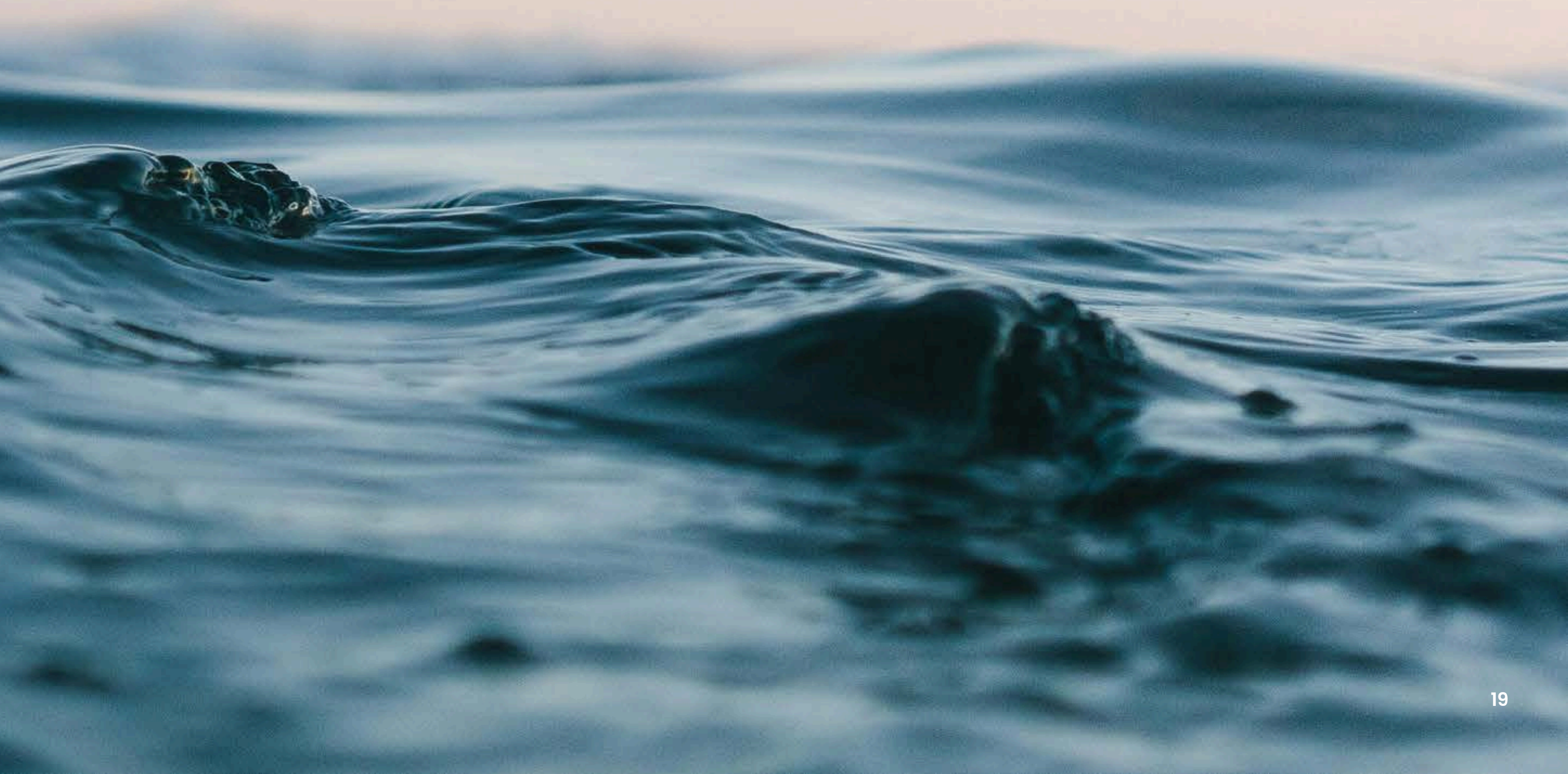
Onshore wind in Finland has been experiencing explosive growth in 2022, driving the green energy transition. In the coming years, wind power will more than double from the current 3.8 GW to 9 GW. By 2027, wind power will have even surpassed the amount of nuclear power produced in the country.

Finland also has plenty of water – another essential natural raw material for producing green hydrogen and green ammonia – and sufficient land for ports from which ships can be loaded and unloaded. From a logistics point of view, the country can be considered an island – fully dependent on exports and imports. Yet, that same reason makes Finland's use of shipping a key security factor for its national welfare.

Three growing ammonia markets

First, ammonia (NH_3) is used for agricultural food production. Ammonia has always had an essential role in the agricultural industry in the production of fertilizers. It releases nitrogen as a nutrient for plants, crops and lawns. At the moment, 80% of all ammonia is used to produce fertilizer.

Second, ammonia is expected to soon be used as marine fuel for deep-sea vessels, cargo ships and tankers. This may happen faster than expected



since Elomatic has already designed several ammonia-fueled ships destined for Japan. Such a green ammonia application also enables Finland to break away from its island-like status and become independent in the production of marine energy.

Third is to use ammonia as a hydrogen carrier. Combining hydrogen with nitrogen forms ammonia, which unlike hydrogen can be efficiently transported in large volumes over long distances, after which it can be returned to hydrogen gas again. For example, Central Europe has arranged to buy ammonia from Canada and the United States for this purpose.

Ammonia can also be used to produce industrial urea products, manufacture textile dyes and recover carbon dioxide. Forecasts in market demand for existing and new ammonia will double or even triple in the next few years. Fertilizer demand is estimated to grow fastest, but marine fuel demand will also grow roughly twofold. Demand for ammonia as an energy carrier is estimated to increase at a similar pace.

Zero CO_2 emissions – the great advantage of green ammonia

Surprisingly as it sounds, fetid ammonia is considered to be one of the fastest routes to a carbon-neutral Europe. Green ammonia is also the closest to compete pricewise with any synthetic fuel.

Grey ammonia production is based on natural gas, while future green ammonia production eliminates methane completely. The only inputs needed for ammonia synthesis are water and green electricity for electrolysis. And the only emission is excess heat, oxygen and clean water. Electrolyzing water dissociates H_2O molecules into hydrogen and oxygen. Once nitrogen is added to green hydrogen, it can then be converted into green ammonia, which is ready for further processing.

Green ammonia, like green hydrogen, emits no CO_2 in its production process. It is capable of storing energy economically for long periods without any energy losses. Its stored energy can be transported over long distances without significant losses. It is far cheaper to store than hydrogen and takes up about half the space.

Self-sufficiency for Finland

Finland now has the opportunity to proactively build a market for hydrogen as a raw material that can be further refined to create a Finnish gross domestic product. This is the start to a sustainable green transition that will increase the national economy and create new jobs.

The idea that Finland no longer needs to import ammonia from abroad but can instead produce sufficient amounts of ammonia from its own green resources is a promising opportunity to improve the reliability of food production.

The vision is to shift the industry from the countries that currently export natural gas, like Russia, China, the US and India, to countries where green electricity is available, so that green hydrogen or its derivative green ammonia can be produced from it. And Finland has what it takes for such a transition.

Finland’s abundance of clean water, favorable wind power conditions and an ambitious roadmap to build twice the total capacity of the country’s current electricity production make it eligible to spearhead the green hydrogen economy.

Putting potential electricity production capacity to good use

With Finland’s renewable energy resources and abundance of water, producing green hydrogen is one application that is worthwhile to pursue. The process of making green hydrogen needs a lot of electricity and can be flexibly operated within Finland’s strong and stable electricity market. In that sense, the most efficient is to situate production close to the wind power farms.

Areas such as North Ostrobothnia or the Åland Islands at the entrance to the Gulf of Bothnia in the Baltic Sea are interesting for hydrogen production where they can also take advantage of the natural cyclicality of wind power generation. Thus, hydrogen production increases when more wind blows and especially when the electricity is not needed elsewhere.

Finland’s advantages also include predictable regulations. To limit safety risks, a closed process is used to produce both green hydrogen and green ammonia. Environmental safety authorities in Finland issue permits, supervise operations and collaborate closely to ensure that green ammonia will be a safe and reliable source of carbon-free energy for the future.

As long as green hydrogen has good potential to replace natural gas applications, it is perfect timing for Finland to create a hydrogen market of its own.

Global green ammonia opportunities ahead

Finland’s green ammonia market can easily be made available to all other countries that need additional green ammonia resources. Most of the EU is already very familiar with the benefits of green ammonia. The EU aims to wean its demand off Russian natural gas and make the switch to green hydrogen, where the ammonia serves as its transport carrier between continents. So, why not consider green ammonia from Finland?

As ships power the Finnish market, they are ready to go. Offshore wind farm cables will come to shore close to production facilities and shipping ports. When the country’s first green ammonia facilities are ready in approximately four years, green ammonia can be shipped abroad.

Green ammonia can just as easily be shipped from the port of Naantali to Helsinki as it can across the Atlantic or to almost any other port, since shipping costs are a minor share of the total costs.

Start for two-way potential

To tackle climate change, break away from dependence on Russian natural gas and offer something of value to other countries globally, Finns can take pride of looking at their own natural resources as a starting point.

Finland’s abundance of clean water, favorable wind power conditions and an ambitious roadmap to build twice the total capacity of the country’s current electricity production make it eligible to spearhead the green hydrogen economy. Its further refining potential can bring huge benefits to Finland’s national economy, while simultaneously enables the country to spread the advantages of the green hydrogen economy to other regions.

Soon, the results of Finland’s natural resource synergies will be ready to roll out to the world. ◣

Jussi Ylinen
Master of Science (Tech.), CEO of Green NorthH2 Energy

Jussi has been working in the energy sector for more than 15 years, specializing in the electricity market. He is a true builder of new carbon-neutral business and projects: he leads the development of Elomatic’s subsidiary Green NorthH2 Energy, which aims accelerate the green transition with green hydrogen fuels and chemicals. Jussi’s expertise includes asset and investment portfolio management.

How to remove barriers to offshore wind power?

Text: Ted Bergman, Heikki Välitalo
Images: Elomatic

The Baltic Sea holds a substantial but largely untapped potential for offshore wind, which can accelerate the phase out of Russian energy by replacing fossil fuels. However, offshore wind projects often face big challenges. For example, their timetable often depends on the availability of expensive wind turbine installation vessels. To solve this, Elomatic has developed a solution that eliminates the need for offshore liftings.

Countries surrounding the Baltic Sea have announced that they will strengthen their energy cooperation and energy resilience as a response to Russian aggression in Ukraine. They see a huge potential for offshore wind, which can replace fossil fuels through for example electrification, increasing renewable fuels and a green hydrogen economy.

The countries have set combined ambitions for offshore wind in the Baltic Sea region of at least 19.6 GW by 2030, seven times the current capacity, and they recognize the substantial potential for offshore wind power in the Baltic Sea basin, reaching up to 93 GW. They will pursue faster permitting processes

and strive for a balanced coexistence of economic and ecological needs.

The availability of wind turbine installation vessels is a major limitation

Offshore wind turbine sizes are continuously growing and demanding bigger wind turbine installation vessels (WTIV), which cannot pass the waters between Sweden and Denmark due to either height or draft limitations. US waters also have local restrictions as there is a shortage of domestically built WTIVs as required by the Jones Act.

These challenges can be solved by eliminating offshore liftings.

A new gravity-based Float Foundation solution, developed by Elomatic, allows the foundation including the wind turbine to be floated and installed in the final location where it is lowered to the seabed. The solution is especially suitable for the Baltic Sea, where bed rock causes issues in many locations with traditional monopiles.

The Float Foundation solution is based on long-term offshore experience

The development of the Float Foundation solution started originally in Elomatic Pori office, where our experts have long offshore experience. The task was to protect the port quayside from ice. The work generated a pile solution with an innovative way to drive it into the seabed without using hammering. The concept was further used as a basis for different kinds of solutions in the shallow-water Caspian Sea oil and gas-related studies.

Development continued with the task of replacing artificial rock islands used in the oil and gas industry. Drawbacks with the rock islands include long construction times out at sea and the involvement of a lot of dredging, excavation, mass transportation for filling, and concrete works. On top of this, building up the topside equipment and systems is a costly offshore

A cost-efficient, environmentally friendly solution was born, which put the industry into change mode with the existing conventional execution plans.

operation. In harsh conditions, rock islands typically need to be ice barrier protected to minimize erosion and ice entering the island.

The goal was to enable local manufacturing

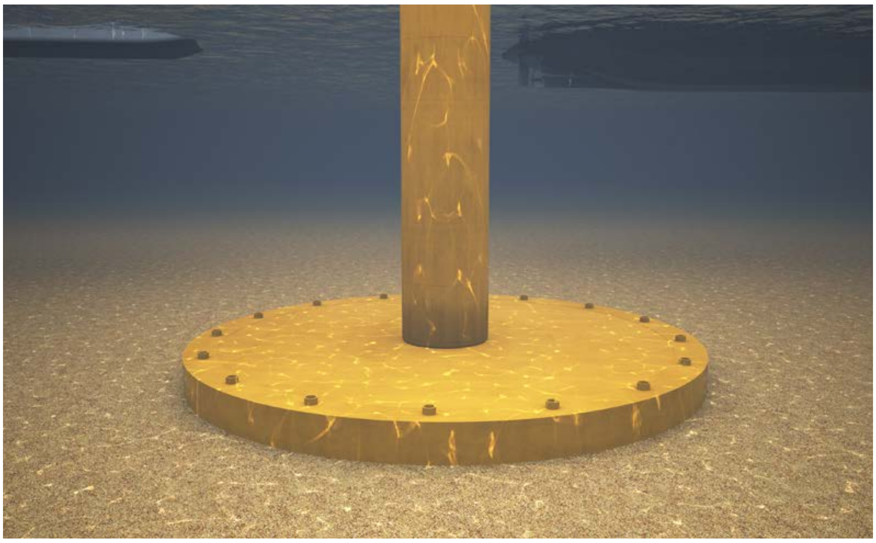
The solution selected was to go with a steel structure with patent pending outer skirt technology (pile concept) that can withstand environmental conditions without protection such as ice barriers. Instead of constructing the artificial island out at sea, the work was moved to a site located onshore. A method for floating the construction out and finally lowering it to the seabed was needed. All the top side equipment was designed to be installed already prior to floating out the island.

The design focused on keeping the steel structure as easy to manufacture as possible in order to be able to maximize local work in cases where it is seen as a social benefit. A cost-efficient, environmentally friendly solution was born, which put the industry into change mode with the existing conventional execution plans.

Heading towards wind energy

With the growing need in the offshore wind industry, our engineers continued to develop the solution. Once again, the target was to minimize offshore work and, in this case, eliminate the need for the special purpose WTIVs. These vessels are limited in number and the growth demand for renewable offshore wind energy will be limited by the lack of vessels for years to come. At the same time, already expensive offshore lifting is expected to continue to increase in cost.

A new challenge was that the artificial island needed to be made submergible for the final location. To solve this, installation barges were introduced for the lowering procedure. In the solution, strand jacks between barges and the foundation are used in combination with ballasting of the foundation.



Other benefits of Float Foundation

A complete Float Foundation solution utilizes the patent pending skirt solution that has many benefits, such as handling high side loads in ice conditions. A family of patents with innovations related to the solution have been internationally filed.

The structure of the Float Foundation is mainly designed in such a way that typical shipbuilding technology can be utilized. Manufacturing of the solution can thus be contracted to many suppliers in various parts of the world, enabling cost competitive construction also taking automated production lines into account.

Yet another feature no other design but Float Foundation has is the possibility to install wind turbines in ultra-shallow waters, 3–9m, enabling new potential wind harvesting areas. Current Float Foundation designs have been made for turbine sizes of 15MW and to water depth areas between 3–45m. In addition, sizing of the foundations can be altered easily. Thus, the solution can cope with any size of turbine now and in the future.

How does the Float Foundation solution work?

- First, foundations are launched to sea and towed from manufacturing sites to the wind turbine assembly site near the final wind turbine farm location. The wind turbines are assembled by an onshore crane on a quayside on top of the foundation.
- Next, the foundations are towed to the final location out at sea. Using ballasting and strand jacks on installation barges, the lowering to the seabed is done. The skirt technology is used to self-dredge the foundations securely in place. After that, the gravity-based foundations enhanced with the wind-turbine-equipped skirts are ready for fossil-free production for years to come.
- At the end of its lifespan, the foundations can be refloated, leaving no material behind, and the steel can be recirculated.

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How to benefit from a digital twin – real-life cases

Text: Valerius Yläjoki
Images: iStock

Digital twin technology can bring great benefits to manufacturing or processing industries, starting with saving resources. You can already find several documented cases of smaller successful adoptions of a digital twin, and larger scale utilization looms on the horizon. In the ever-growing need for greener solutions and resource-saving adaptations, digital twins will certainly find their place in industry.

The digital twin has been named as one of the driving forces in the industry 4.0 transition. It is no wonder, because its benefits range from saving resources by optimizing processes, to improving the training of personnel. Thus, an understanding of the concept is crucial to success in the changing business environment.

However, you could ask what exactly is a digital twin? One way to think of it is as a counterpart to a physical world machine or cog, or even to a whole factory with its workers. The key aspect of a digital twin is the bidirectional data exchange between the twins, where data flows between the physical and digital twin in real time. Another key element is the lifecycle management of the whole interaction between the twins.

Next, several real-life cases are presented, where the adoption of a digital twin has been documented and the benefits of the implementation listed.

Case 1 – The potential of a digital twin in the district heating of cities

A digital twin provides value, for example, in the simulation of district heating services by utilizing the vast amounts of data the physical network creates and has created in the past. By simulating the future needs of the network's heating power using the digital twin, models can be created for foreseeable needs.

In the simulation based on the data from the physical twin's history, a digital twin provides a platform where the simulation can happen. By getting knowledge from the simulation, the physical district heating network's load can be optimized. This optimization saves resources in the long run by cutting wasted energy.

Silo AI has implemented a digital twin-like solution in the district heating services of Helen. This "intelligent solution" provides better estimates of the district heating networks' future energy needs based on the historical data of the physical district heating network[1]. Another case where machine learning has been adapted for district heating is Ensense's software solution. According to the company, their solution has saved hundreds of thousands of euros for their customers, as well as natural resources[2].

If a digital twin were built as an exact digital counterpart of the physical network for district heating, it could be used to simulate the physical network in all its parts. The simulation would consist of the whole network's status, down to even the tiniest single apartment inside a block of flats. All this simulation could be done with the digital twin.

Case 2 – A digital twin in optimizing plant maintenance

Plant maintenance, also called industrial maintenance, is a process in which the goal is to reduce breakdowns, promote reliability, and increase uptime in the assets of the plant. One of the strategies in plant maintenance is called reliability-centered maintenance (RCM). RCM requires a lot of information on the assets, and especially on the critical equipment that is necessary for the plant to continue its daily operations. The aim is to allocate resources more efficiently depending on the needs of the plant.[3]

Critical parts may be serviced every three years, regardless of their performance or condition. The plant must keep operations ongoing, and these parts cannot fail or break during operation. If a critical part fails or breaks down suddenly, it will lead to long operational downtimes, which come at an enormous cost.

To benefit from a digital twin, these crucial parts could be simulated based on their historical data, and the parts' vibrations[4] could be monitored via different sensors and probes in the process, called condition monitoring, which produces information on parts' movement and patterns. By having the data about the behavior of the parts, it is possible to simulate the parts' lifecycle in the digital twin. The data could indicate, for example, that critical parts have a longer lifecycle than the three years after which they are serviced.

Based on this finding, the plant could service these crucial parts at the corresponding time, when they are in actual need of service. By prolonging the life of the parts, maintenance costs can be cut, and the plant can operate longer without a service or a halt in production. This also saves resources and the environment in the long term.

Case 3 – Using a digital twin as a learning tool

If you have a digital counterpart to the actual machine, you can multiply the machine's digital twin to your liking in virtual reality. Having the same effect that you see in the movie Matrix, you can use virtual reality for training in the operation and servicing of the digital twin's real-life counterpart.

Think of a complex physical factory machine, for which only one person can be physically present in the maintenance environment. This environment can be easily recreated via virtual reality in a completely different location from the factory where the machine itself operates. The key benefit is having all the digital twin's elements in virtual reality, where you can simulate the physical twin wherever you need to, in whatever scenario you want to.

Elomatic has produced for Valmet the Virtual Mill[5], which is a digital design twin of the customer's machinery and surrounding facilities. It can be used for training operators and maintenance personnel before start-ups and major shutdowns.

Wider adoption of digital twins looms on the horizon

You can see many of the advantages that a digital twin creates. The described case examples are just the start. However, many challenges

Definition of digital twin

Originally, the term "digital twin" was used in a presentation by **Dr Michael Grieves** in a product-lifecycle management conference held in 2004 at the University of Michigan. Since then, the term has been characterized in multiple different ways, both in academia and in industry. The easiest and simplest definition in research and industry was found to be the following: **"A Digital Twin is a virtual dynamic representation of a physical system, which is connected to it over the entire lifecycle for bidirectional data exchange."** [7]

remain that are preventing the wider adoption of digital twins. Data, privacy, security, trust, expectations, and IT infrastructure are listed as challenges for both data analysis and the industrial Internet of Things[6].

To implement a properly functioning digital twin that truly provides value, it is crucial to understand the different factors at play in the model and in the environment in which the digital twin is applied. The benefits must also outweigh the costs of the implementation of the digital twin for the investment to pay for itself.

The fourth industrial revolution is happening now, and even though the technology has not yet been adopted in the everyday manufacturing and processing industries, it surely will find its footing in the future. Currently, there are many documented cases of smaller successful adoptions of a digital twin in practice, but multilayered digital twins for whole manufacturing facilities and large-scale adaptations are lacking. Domain knowledge has been mentioned as one of the reasons for this.[6]

For now, the digital twin is gaining traction in the academic world, and more and more companies across various industries and domains are starting to see its potential as a component in their processes. Since the digital twin is all about saving resources and optimizing current operations, it will be relevant in the future to come. Even though the digital twin is still in its infancy, when more solutions start to emerge, it will certainly start being more widely adopted. ◣

For now, the digital twin is gaining traction in the academic world, and more and more companies across various industries and domains are starting to see its potential as a component in their processes.

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Valerius is part of the newly formed Digital Business Development team at Elomatic. He is currently writing his Master's Thesis at Elomatic on digital twins and finishing his studies in University of Jyväskylä. Valerius aims to become an enterprise architect in the future.

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References:

1. Tekniikka & Talous, (2020). Tekoäly suitsii hukkakaukolämpöä - ennusteet paranevat jopa yli 30 %. *https://www.tekniikkatalous.fi/uutiset/tekoaly-suitsii-hukkakaukolampoa-ennusteet-paranevat-jopa-yli-30-/e08b625e-5a0b-4c9e-b5cf-6257e083fe03*
2. Tekniikka & Talous, (2022). Säästö jopa satojatuhansia euroja vuodessa – Suomessa kehitettiin uusi ratkaisu kaukolämmön energiatehokkuuden parantamiseen. *https://www.tekniikkatalous.fi/uutiset/saasto-jopa-satojatuhansia-euroja-vuodessa-suomessa-kehitettiin-uusi-ratkaisu-kaukolammon-energiatehokkuuden-parantamiseen/*
3. Upkeep, Industrial Maintenance | What is Industrial Maintenance, *https://www.upkeep.com/learning/industrial-maintenance*
4. Valmet Oy, Portable condition monitoring, *https://www.valmet.com/automation/asset-performance-management/condition-monitoring/portable/*
5. Elomatic Oy, (2021). Immersive virtual learning experiences! *https://www.youtube.com/watch?v=uE1XmuwrNGo*
6. Fuller, A., Fan, Z., Day, C., & Barlow, C. (2020). Digital Twin: Enabling Technologies, Challenges and Open Research. IEEE Access, 8, 108952–108971. *https://doi.org/10.1109/access.2020.2998358*
7. Trauer, J., Schweigert-Recksiek, S., Engel, C., Spreitzer, K., & Zimmermann, M. (2020). WHAT IS A DIGITAL TWIN? – DEFINITIONS AND INSIGHTS FROM AN INDUSTRIAL CASE STUDY IN TECHNICAL PRODUCT DEVELOPMENT. Proceedings of the Design Society: DESIGN Conference, 1, 757–766. *https://doi.org/10.1017/dsd.2020.15*

Saving energy by reducing weight

— advantages of structural analysis using modeling

Text: Johanna Sjölund
Images: Elomatic, iStock

As the price of energy is rising, so is the price of materials. That is why it is now worth reducing the weight of structures to save energy and money. Structural analysis using modeling offers great opportunities here: the models give better results on the details of the structure, and thus the material can be used where it is needed. In addition, models help in choosing the right materials and in extending the service life of structures.

Recently, there has been a lot of talk about the CO_2 emissions of different materials and applications and how to reduce them. Lately, the discussion has shifted more to energy consumption and how it could be reduced.

This article concentrates on the possibilities of reducing energy consumption using structural analysis, especially the finite element method (FEM). With possibilities to save not only energy, but also time and money, structural analysis should not be ignored at any design stage.

Benefits of modeling are undeniable

Over the years, structural analysis has moved from using purely manual calculations to more and more sophisticated models. Analytical models are fast and reliable but cover only specific cases and thus restrict the design.

As computational power has increased and modeling tools have become more advanced, making complex models has become more common for different applications. These models can be used to analyze the strength and behavior of a structure.

FE models give better results on the details of the structure, and thus the material can be used where it is needed. For example, instead of making the whole bulkhead of a boat thicker, the thickness can be added to specific locations, and fatigue can be prevented with some carefully placed brackets in the corners. Another benefit is the possibility to change the thickness or material parameters easily.

The right materials offer a huge reduction in weight

Weight saving is not achieved only by optimizing the amount of material used or the type of steel, but also the material itself. Frequently used alternatives to steel are aluminum and composites. Aluminum is three times lighter than steel, although its strength, fatigue life, and weldability properties are poorer. Composites are also very light and can offer a huge reduction in weight, up to 50–70%[1]. One of the problems with composites is manufacturing quality.

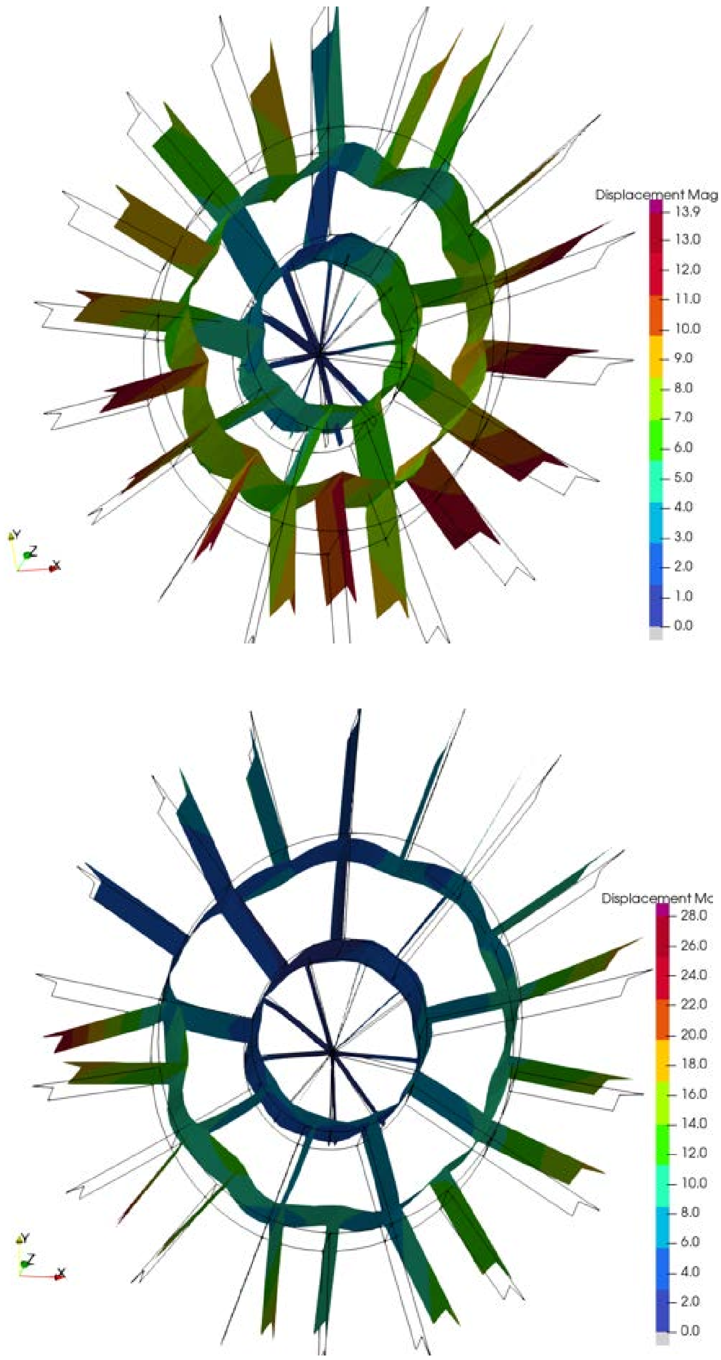
Modern modeling tools give the possibility either to model composites as layers or to estimate the properties of a relevant corresponding heterogenous material. The latter makes it possible to have approximate estimates of the suitability of the composite.

Significance of structural analysis is emphasized in moving machines

In moving machines, such as cars or elevated work platforms, conserving energy by conserving weight has been an industry practice for a long time. For example, the automobile industry uses composites for many parts to reduce weight. A 10% mass reduction results in approximately a 6–7% energy reduction when moving the vehicle[1].

High-strength steels with tensile strength even over 1000 MPa are also

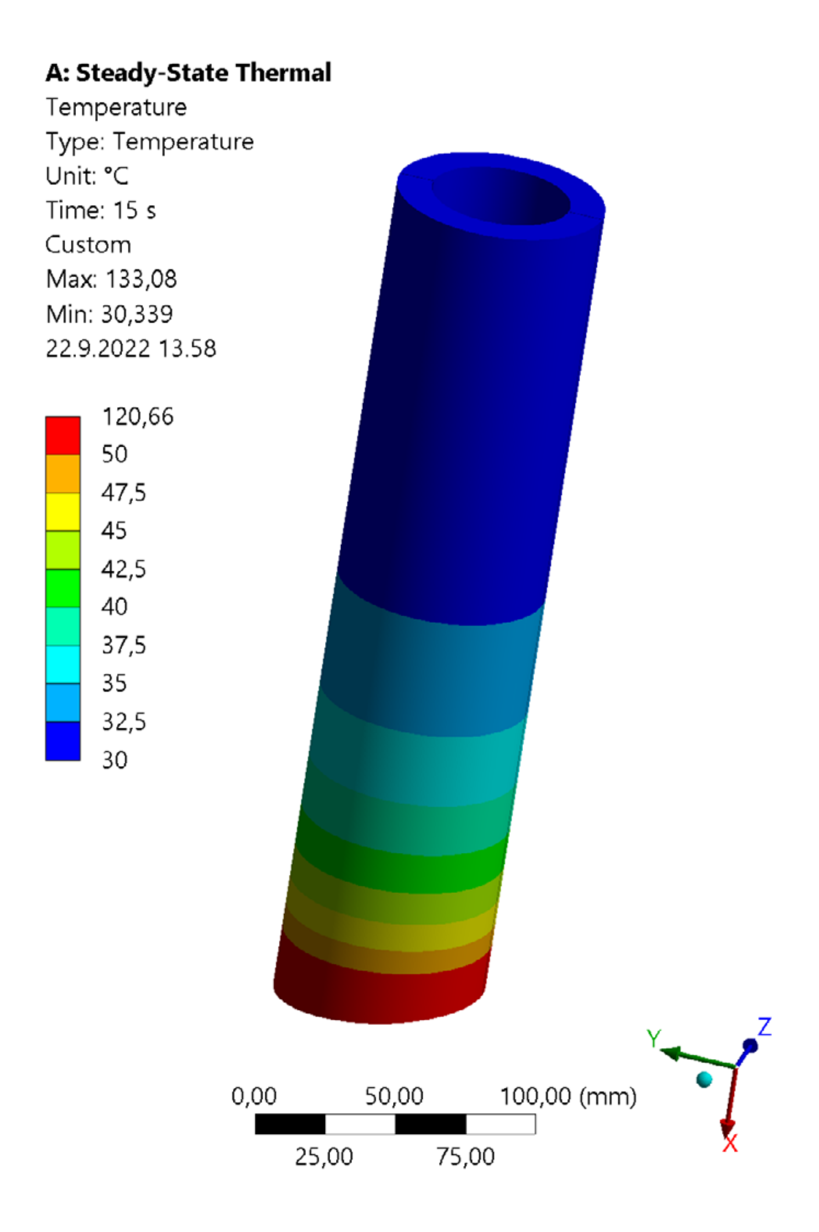
"Instead of making the whole bulkhead of a boat thicker, the thickness can be added to specific locations, and fatigue can be prevented with some carefully placed brackets in the corners."



A simulation result for two different welding sequences for the same structure. Displacement can be reduced by 50% by optimizing the welding sequence.

Material	Energy intensity
Steel[4]	31–34 MJ/kg
Carbon fiber[5]	198–595 MJ/kg
Aluminum[4]	200–220 MJ/kg
Steel recycled[4]	7.7–9.5 MJ/kg
Aluminum recycled[4]	22–30 MJ/kg

The amount of energy required to manufacture different materials



Example of steady state thermal analysis.

becoming a more and more frequently used solution when trying to save weight. Using structural analysis, it is easy to find the minimum sheet thickness needed, depending on the strength of the steel used. This makes it easy to estimate both financial and energy savings when changing the material.

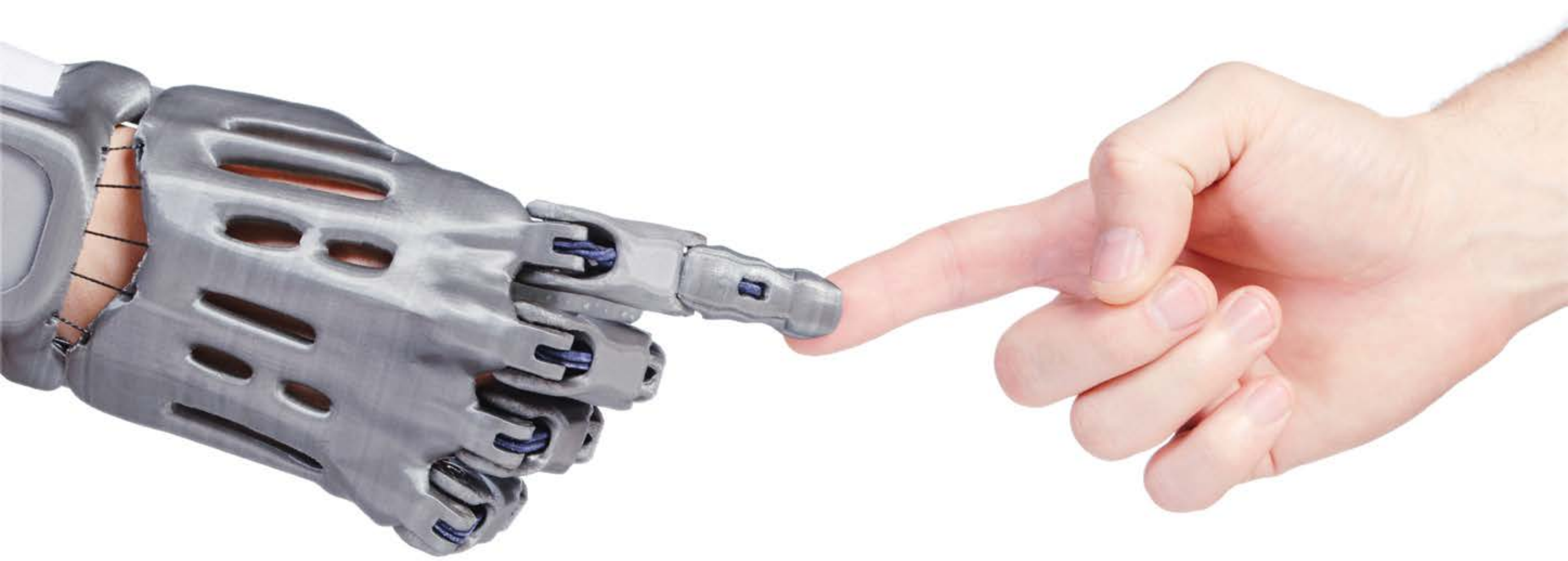
Welding these high-strength steels is more challenging, as the risk of distortion is larger than for conventional steels. This risk can be reduced through modeling the welding process, for example to optimize the welding sequence.

The energy used by material manufacturing also matters

Material manufacturing plays a big role in the energy consumption of structures, especially for stationary solutions, where weight has not traditionally played a big part. In Finland alone, the metal manufacturing and refining industry uses 13% of the energy consumption of the whole industry sector, which amounts to 17 TWh a year[2]. Energy consumption accounted for 10–40% of the manufacturing costs of the metal industry in 2017[2].

As the price of energy is rising, the prices of metals are fluctuating, depending on demand. The price of steel in the US grew by 200% between March 2020 and July 2021. Estimating the future price is difficult, but this risk can be reduced if less material is needed. Globally, the steel and iron manufacturing industries use 98 000 TWh in a single year[3]. Even a small reduction in the amount of steel and iron needed would mean a huge amount of saved energy.

However, composites or aluminum are not the solution to this problem, either: the energy consumption required to manufacture carbon fibers is even greater than for metals. Therefore, substituting steel with carbon fiber or aluminum as a means of saving energy is valid only when the



energy saving takes place throughout the entire life cycle of the structure, as with moving machines, not just during the manufacturing phase.

Modeling also helps in extending lifetime and reducing energy loss

As manufacturing new products takes a lot of resources and energy, extending the lifetime of existing structures is important. The models and methods available today for structural analysis are more sophisticated and can give more precise predictions for fatigue life. Combined with 3D scanning, this enables the assessment of the factory's remaining lifetime to be extended from the original estimate.

Yet another way to utilize modeling is to reduce direct energy loss with it, for example by modeling heat transfer problems. Optimizing the amount of insulation needed can reduce both the amount of material needed and the energy loss experienced.

Sometimes the best option is to start with novel concepts

Although energy is just one parameter, finding the best ways to save it is a complex multiple parameter problem. It is not a simple task to find out where energy consumption occurs and where the greatest opportunities for savings are. Structural analysis and modeling can help with identifying some of the parameters and estimating where the biggest savings can be found.

One method is to test completely new concepts that can perform better or that are significantly lighter than other currently used structures. This is where structural analysis and models bring a huge advantage: models make it easy to test different ideas and to compare varying concepts with each other. In this way, the best ideas can be found early in the design process. ◣

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Design Manager, PhD

Johanna graduated in nanophysics from the University of Turku in 2008, after which she worked as a researcher at Aalto University. There she produced a doctoral thesis on the modeling of wood, which she defended in 2015. After the PhD, she moved on to consulting, first at Process Flow and since 2017 at Elomatic. She has worked with different types of projects in structural analysis, ranging from marine applications to cranes, and from high-strength steel to soft soil. Since 2021, she has been the manager of the structural analysis team in Turku and Espoo.

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References

1 Vehicle Technologies Office, "Lightweight Materials for Cars and Trucks," Office of Energy Effeciency and Renewable Energy, [Online]. Available: *https://www.energy.gov/eere/vehicles/lightweight-materials-cars-and-trucks. [Retrieved September 2022].*

2 Työ- ja elinkeinoministeriö, "Energian kulutus ja sähkön hinta metallinjalostusteollisuudessa," Työ- ja elinkeinoministeriön julkaisuja, osa/vuosik. 15, 2017.

3 IAE, "Energy consumption in the iron and steel sector by scenario," October 2020. [Online]. Available: *https://www.iea.org/data-and-statistics/charts/energy-consumption-in-the-iron-and-steel-sector-by-scenario. [Retrieved September 2022].*

4 D. Cooper and T. Gutowski, "The Environmental Impacts of Reuse, a review," Journal of Industrial Ecology, osa/vuosik. 00, 2015.

5 J. Zhang, V. S. Chevali, H. Wang and C.-H. Wang, "Current status of carbon fibre and carbon fibre composites recycling," Composites Part B: Engineering, osa/vuosik. 193, 2020.

Electrification of industry is necessary for reducing carbon dioxide emissions

The electrification of industry will play a key role in the pursuit of carbon neutrality at the EU level and soon also globally. Electrification provides opportunities for industrial operators at many levels. In order to realize their full potential, a strategy and roadmap to promote electrification need to be established.

Text: Teemu Turunen
Images: Elomatic, iStock

The increased price of natural gas as a result of the Russian war of aggression against Ukraine has prompted many operators to consider abandoning natural gas, and one potential option is to replace it with electrical solutions. In general terms, electrification refers to increasing the use of electricity and electric applications in different areas. In the longer term, electrification is one of the key elements of the green transition.

From the consumer´s point of view, the development of electrification can be best seen in how cars are powered. In 2021, of the nearly 100,000 first-time registered passenger cars, 10% were electric cars and 20% were plug-in hybrid cars. Some of the passenger cars recorded as petrol- and diesel-powered cars were light hybrids and non-rechargeable hybrid passenger cars.[1]

Electrification can also be seen in industry

The electrification of industry can be divided into three trends[2]:

1. direct electrification,
2. electrification solutions that involve heat pumps, and
3. indirect electrification involving the production of electricity such as hydrogen and synthetic fuels.

In industrial environments, direct electrification refers to converting an activity that currently uses fossil fuels into an electric-powered activity. Practical examples include the replacement of gas trucks with electric forklifts, using electric furnaces instead of natural gas-powered furnaces and favoring electric boilers over oil boilers in district heating. Potential applications can be found in a wide range of industrial sectors.

Heat pumps provide the best energy savings

Electrification solutions that involve heat pumps differ from direct electrification in terms of efficiency. Heat pumps can replace fossil energy sources in the same way as in direct electrification while creating energy savings.

Direct electrification also provides the potential to save energy by eliminating the proportion of flue gas loss, but in general, more significant energy and cost savings can be achieved with the help of heat pumps. However, heat pumps have their own technical limitations, and are not suitable for all applications. For example, sometimes the process requires a temperature that is too high for heat pumps.

Modern heat pumps can already profitably produce temperatures over 100 °C. Technically, the potential is currently around 150 °C. Heat pumps typically require buffer capacity to provide stability, good control as well as backup energy systems to ensure the continuity of activities in all conditions.

Electrical energy is also used to convert water into hydrogen

The basic principle of indirect electrification is that electrical energy is used to decompose water into hydrogen and oxygen through electrolysis. Hydrogen can be used either directly as a source of energy, for example in ship engines, or as an energy carrier, in which case the bound energy is converted back into electricity with fuel cells.

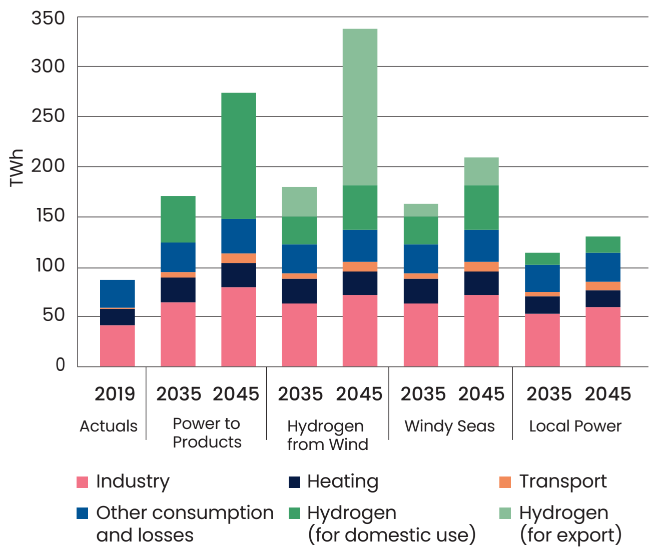
Hydrogen can also serve as a raw material for synthetic production processes, for example, when producing methanol or green ammonia as a replacement for fossil fuel. Today, ammonia is mainly produced from natural gas by means of steam reforming.

The use of electricity and how it is timed will be key elements in all hydrogen economy solutions. However, it is good to remember that one of the most important short-term development areas of the hydrogen economy is the efficiency of the production chain.

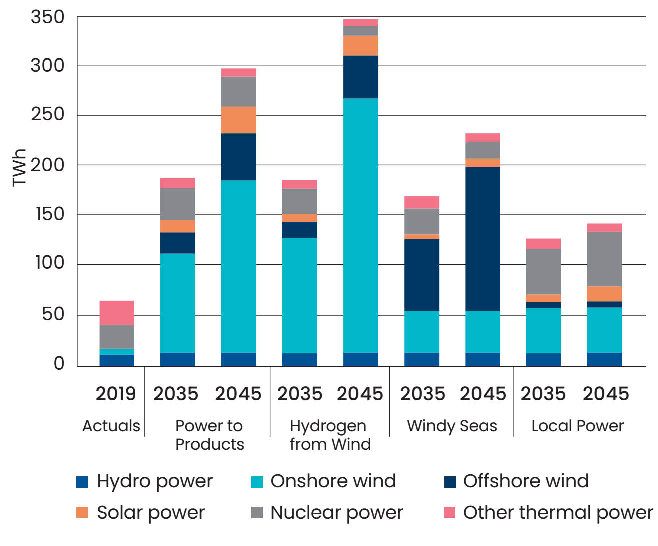
At worst, the efficiency may be as low as 25–50%, which is why direct electrification can be the most cost-effective way to promote low-carbon energy in certain settings. Likewise, in the long term, hydrogen economy solutions will play a key role in our energy system.

> **Practical examples include the replacement of gas trucks with electric forklifts and using electric furnaces instead of natural gas-powered furnaces.**

Electricity consumption in the different scenarios



Electricity production in the different scenarios



Fingrid's future system scenario outlines

EU emission targets guide electrification

According to the EU's emission targets, 55% emission reductions will be achieved by 2030 and carbon neutrality will be a reality by 2050. The EU also considers the promotion of sector coupling, in which electrification plays a key role, as one of the concrete actions.[3]

Previous targets were set at the national level with some variation. Finland's goal is to increase wind power capacity, which opens up more opportunities for market-based industrial electrification solutions. However, it is important to ensure, for example, the effective authorization of projects at the national level.

Industrial projects will also be supported with the electrification subsidy for energy-intensive industries, which was introduced in 2022. The aim of the subsidy system, which is in place for a limited time, is to prevent the risk of carbon leakage, safeguard the cost competitiveness of industry and guide operators to develop more carbon-neutral industrial production methods. Operators must use at least 50% of the subsidy in development efforts to reduce emissions, improve energy efficiency or increase the share of renewable energy in energy consumption.[4]

What are the forecasts for Finnish industry?

Several scenarios for the development of electrification have been prepared, for example, by the Finnish Climate Change Panel, the Finnish Energy, Sitra and Fingrid. Most recently, Fingrid prepared four different scenarios for the future of electricity consumption and production[5].

All Fingrid's scenarios highlight the growth of electricity consumption and production by 2035 and 2045. It should also be noted that in all scenarios, Finland produces more electricity than it uses, i.e. on an annual basis, self-sufficiency of electricity is exceeded. The main differences between the scenarios can be seen in production in wind power growth scenarios and in usage in hydrogen economy solutions.

It is important to understand that electrification takes place at several levels, using both direct and indirect electrification as well as hydrogen economy solutions. We need all of them, along with an understanding of which solutions are best suited for each application. In order to promote the hydrogen economy, every effort must be made to promote wind energy projects, and projects related to the production and use of hydrogen must be started as soon as possible.

Risks and opportunities abound

The electrification of industry involves both challenges and opportunities, which significantly affect the magnitude and speed of change. Energy is, and always will be, a strongly political issue. This creates risks, especially for a small country that does not have significant geopolitical influence. That is why unity within the EU in energy matters is important for Finland. On the other hand, appropriate political decisions allow us to support companies in implementing climate projects to an increasing extent.

> **In order to promote the hydrogen economy, every effort must be made to promote wind energy projects, and projects related to the production and use of hydrogen must be started as soon as possible.**

The development of electricity prices has a significant impact on the electrification of industry, both in terms of the average price level and price volatility. Profits from high electricity prices should therefore be invested in increasing clean energy production and promoting the green transition. Fluctuating electricity prices may make it more difficult for electricity companies to manage their cash flow and, on the other hand, create more financial risks.

Energy users may benefit from fluctuating electricity prices if it is possible to save on consumption volumes or to reschedule periods of high electricity consumption. Therefore, more alternative forms of energy production may be available for production facilities in the future, and in addition, reserve capacities will increase.

Room for improvement in technology

Technologically, we already have a working technology, but its efficiency still needs to be improved, which in turn will have a direct impact on the profitability of projects. It is also important to start green hydrogen projects as the proliferation of these projects will certainly also open up new financial channels.

In particular, the new connection possibilities of heat pump technology and the higher temperatures produced will create new potential applications. Heat pump applications as part of district heating is a strong, growing trend[6]. Hydrogen economy projects have also been announced to an increasing extent and suitable application concepts are being explored extensively. In addition, the development and application of digital solutions open up new opportunities for electrification[7].

However, as indicated above in the Fingrid scenarios, electricity networks and transmission links need to be developed in order to transmit the increasing generation of electricity to operating sites. This will also require the development of regional electricity networks and networks within industrial areas, which will require significant investments. Improved networks will also allow us to make even more efficient use of electricity while improving security of use and supply.

There is also another missing piece: the storage of electricity. There is no efficient and profitable solution for long-term storage of electricity in addition to hydropower, the capacity of which is nearly impossible to be increased in Finland. Hydrogen is a potential solution, but the current challenge is the profitability and financing of projects.

Electrification of Finnish industry is in its early days

Electrification is not always technically or economically feasible, especially when it comes to processes already in place. But when completely new processes are planned, electronic processes and solutions offer a very high potential.

The electrification of Finnish industry can be summarized as follows:

1. Electrification will be one of the tools for achieving the carbon neutrality targets of Finnish industry. We also need many other technologies and solutions, but electrification has a very important role to play.
2. Electrification partially enables the utilization of waste heat, for example with heat pumps, but on the other hand, we are facing a shift towards forms of energy production that do not involve combustion. Efforts should be made to examine the attainable benefits as comprehensively as possible.
3. In the long term, electrification is related to the hydrogen economy. It is good to outline a roadmap for the 2030s, when solutions will start to play an important role.
4. The extent and timing of electrification will be significantly influenced by future political decisions, the level of technology and the development of electricity prices.

In order to promote electrification, a strategy and a roadmap should be established to fully utilize its potential and minimize the risks involved. ◣

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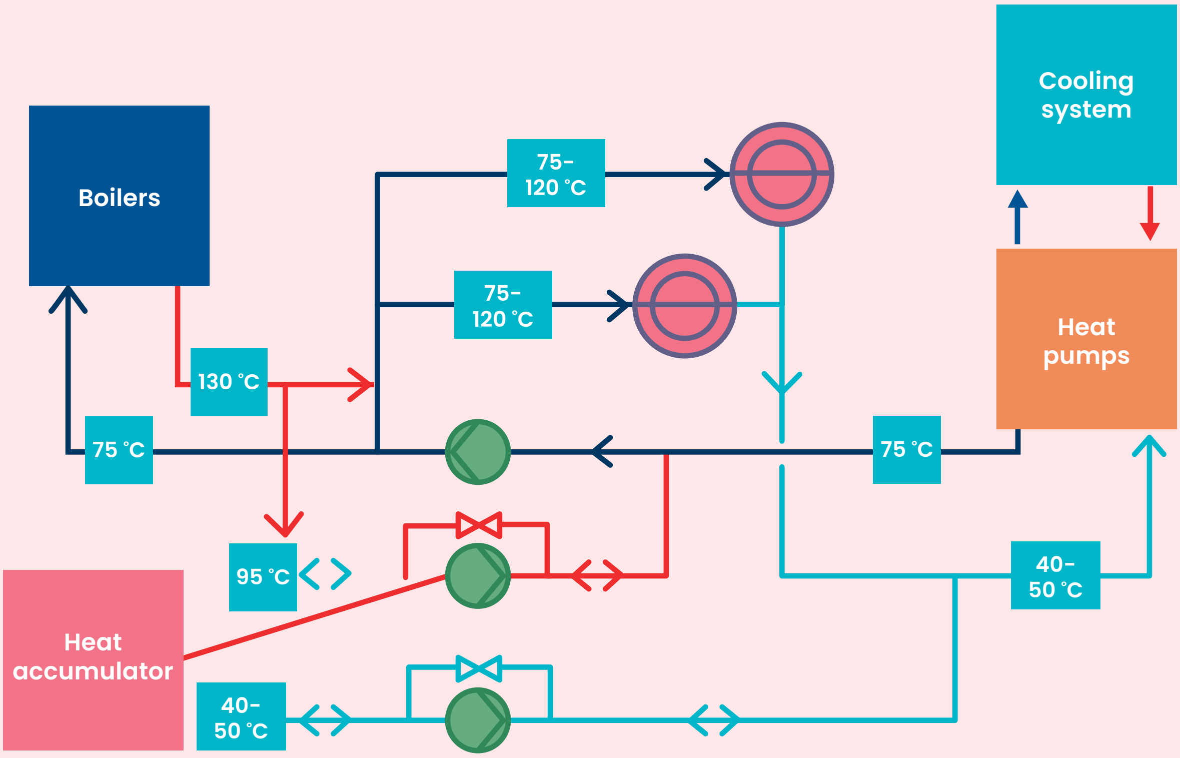
References

1. Stat 2022, Sähköautojen ensirekisteröinnit kasvussa, mutta sähköautoja vielä harvoilla | Tieto&trendit (stat.fi)
2. Motiva 2021, Suomen_teollisuuden_sahkoistyminen_ja_sen_vaikutus_energiatehokkuuteen_ja_hukkalampojen_hyodyntamiseen_-raportti_2021.pdf (motiva.fi)
3. Council of Europe, Clean energy – Consilium (europa.eu)
4. Energy Authority 2022, *https://energiavirasto.fi/teollisuuden-sahkoistamistuki*
5. Fingrid 2022, Fingridin sähköjärjestelmävisio 2022 – tulevaisuuden järjestelmän skenaarioluonnokset
6. STT 2022, *https://www.sttinfo.fi/tiedote/paljon-parjattu-kaukolampo-on-paras-tapa-saada-energianhintoihin-joustoa-20-000-euron-maalampoinvestoinnilla-voisi-ostaa-kaukolampoa-meilta-kahdeksaksi-vuodeksi-avaimet-kateen?publisherId=69819473&releaseId=69945631*
7. The Finnish Climate Change Panel 2021, PowerPoint Presentation (*ilmastopaneeli.fi*)



Example of a complex energy production system in industry

Special characteristics of industrial electrification projects

When considering electrification solutions for industry, the baseline is that effective production is always a priority. If electronic solutions have a negative impact on production, for example in terms of production volumes, quality or availability, electrification is very difficult to justify. It is therefore important to clarify the possible constraints comprehensively so that decisions are not based on individual opinions.

1. Reliability plays an important role in industrial environments.
For example, a heat pump solution that uses waste heat always needs a back-up form of production. The resilience of the systems will play an increasingly important role in the planning of future energy systems.

2. One factor to consider in an industrial environment is the large scale of solutions.
In practice this causes, for example, a need for space and significant investments. It is therefore important that sufficient investments are made in the planning phase to ensure, for example, that the cost estimate is sufficiently exhaustive and that there are no unwanted surprises during the actual project.

3. Projects typically require comprehensive competence.
Industrial projects can roughly be divided into two categories: replicable solutions (e.g. container solutions) and unique process-specific solutions. Replicable solutions are particularly suited for SMEs, while heavy and energy-intensive industries often involve highly customized concepts. In custom projects, holistic competence is important as investments are often made in the middle of existing industrial processes or as part of one. In the case of replicable solutions, it is important to ensure the ease of use and cost-effectiveness of the project to achieve wide-ranging effectiveness.

In an industrial environment, the operation of processes and production equipment is a routine, which can contribute to the introduction of complex concepts. The goal must be to make the operation as consistent as possible with the existing concept to ensure that the control is efficient and user-friendly.

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