top engineer

The Elomatic Magazine 2 · 2020

"High expectations have been placed on the hydrogen economy."
– Ted Bergman

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Decarbonisation a key weapon in fight against climate change

2020 has been overshadowed by the Corona virus epidemic, but news of successful vaccine trials has allowed us to image life as it was before. One of the major challenges of life long before Covid, was the threat of climate change and our unsustainable use of natural resources. These challenges will remain with us for many decades to come, even as our momentary challenges fade into history.

This battle against climate change will be fought on many fronts, but a key area is decarbonisation, which has received much global attention. In December 2019, EU leaders decided to set an ambitious goal of making the EU carbon neutral by 2050. Individual states have set their own goals, with Finland, for example, aiming to be carbon-neutral already by 2035. This ambitious goal will make Finland the world's first fossil-free welfare society.

The European Investment bank has pledged €1 trillion to fight climate action and environmental sustainability while the EU's so-called Green Deal has set aside €100 billion to help member countries that are dependent on carbon-intensive processes to move to more renewable energy sources. The Green Deal further proposes that greenhouse gas emissions be cut to 50% of 1990 levels by 2030, as opposed to the current 40% target, as well as the introduction of a law that will set the EU on an irreversible path to climate neutrality by 2050.

Being part of the solution

At Elomatic, a cornerstone of our reason to exist is our drive to assist our customers in their struggle against the most significant challenges of our time, including environmental wellbeing and resource sufficiency. As consultants and engineers, we can be part of the solution concretely assisting our customers with, for example, renewable energy sources and energy-efficient solutions, and smarter utilisation of raw materials.

It pleases me greatly that this edition of our magazine has a clear decarbonisation theme. All the articles are directly or indirectly related to it. We have top experts at Elomatic that are making a difference, they are part of the solution.

In this edition of the magazine, we have, among others, an article about sail-based/assisted vessels to achieve carbon neutral shipping, one about decreasing primary fuel consumption and CO_2 emissions in district heating solutions, and another on the implementation of the hydrogen future. We also look how we can manage the energy future and how online CO_2 calculation can assist in monitoring emissions at different stages of production.

I wish you happy reading and welcome your feedback.

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Content

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Is the hydrogen future here already?

Text: Ted Bergman

The world is in urgent need of fossil-free energy in order to abate global warming. There is no single solution available and it is likely that different applications with different solutions will need to be employed. In energy production, the first steps have already for been taken: in the last decades, wind and solar production have become economically viable even without subsidies. The drawback of especially these two production methods is that production cannot be scaled up and down according to demand. The need for energy storage is thus increasing, and a complete solution for this has not yet been found.

Green hydrogen has the potential to be a partial solution for energy storage, and high expectations have been placed on the hydrogen economy. For the time being, however, solutions on extensive energy storage for grid balancing (Ex Seasonal) with hydrogen are expensive and likely to be so for some time. The same applies to a large extent to other P2X (Power-to-X) solutions. The issue with hydrogen is that even though the energy content per kilogram is very large, the density is low even when pressurised to 350-700bar or when liquified, leading to costly energy storage for all solutions.

There is a vast amount of mobile applications (cars, trucks, busses, ferries, and industrial machines such as dumpers, excavators, etc.) in need of oil-based diesel replacement. They require a smaller amount of energy storage compared to grid balancing, and there is added value in storing energy in a moving application.

Key energy storage role for batteries — growth expected in hydrogen-based solutions

Batteries have already entered the market and the scale-up for cars, local distribution trucks, and even short-distance ferries have entered the market. Battery-based solutions will continue to grow rapidly but will not be the most viable solution for all applications. Bio-oil and biogas (methane) will have a share of the market.

In applications with slightly higher energy demand, such as medium-distance small-size ferries, trucks, and even airplanes, hydrogen-based solutions are expected to grow. The first steps are here; practically all major truck manufacturers (Ex. Volvo, MAN, Toyota, Scania, Daimler, Hyundai, etc.) have released timelines for fuel cell hydrogen operated trucks, and the first ones are already in operation. The first hydrogen ferries for public use are on the way in Norway and California, for example, while the first demonstration flights with hydrogen have also been performed.

"High expectations have been placed on the hydrogen economy."

Market entry hampered by the need to scale up both demand and supply

The difficulty of entering a market where both production and consumption need to be scaled up needs to be addressed. It is impossible to identify a business case to produce hydrogen without consumers, who, on the other hand, are not tempted to use hydrogen unless it produced. It is, therefore, crucial to identify business cases where both production and consumption can be agreed upon for more extended periods in the start-up phase. In the long term, business cases will become more diverse, but this will initially not be viable.

Heavy subsidisation can naturally support the production and distribution of hydrogen without fuel supply agreements (FSA). Germany, South Korea, and Japan are on a trajectory to make hydrogen available for the public. In Germany, there is already a good network of refuelling stations for passenger cars, which can be found on the Internet at *h2.live*. This can, however, be a costly method, especially in less densely populated areas. It may be of interest to search for solutions where the production investment is linked with FSAs, for instance, for ferries or a fleet of trucks. For such applications, the production can be somewhat oversized to accommodate the sale of green hydrogen on the free market, thereby achieving a stable basis for the business.

None of this will happen, however, with pure current business cases: the technology is still too expensive. There is significant interest in supporting these efforts, and the EU, for example, has sub-stantial funding in place for hydrogen. (See text box) Individual countries still must create their own paths. It could be said that the time for only planning has already passed; action is needed for the first pilots to achieve the set targets.

Reliance on batteries will not be enough. Now is the time for the implementation of hydrogen projects. Equipment suppliers of hydrolysers have already noted a rapid increase in demand in 2020. The start of the hydrogen economy is thus here as, without it, global warming targets are unlikely to be met. The only question now is when each country will adopt it. Some states have already started to lead the way in implementing hydrogen in the pursuit of decarbonisation.

A hydrogen strategy for a climate-neutral Europe

In an integrated energy system, hydrogen can support the decarbonisation of industry, transport, power generation and buildings across Europe…

This gradual transition will require a phased approach:

- From 2020 to 2024, we will support the installation of at least 6 gigawatts of renewable hydrogen electrolysers in the EU, and the production of up to one million tonnes of renewable hydrogen.
- From 2025 to 2030, hydrogen needs to become an intrinsic part of our integrated energy system, with at least 40 gigawatts of renewable hydrogen electrolysers and the production of up to ten million tonnes of renewable hydrogen in the EU.
- From 2030 to 2050, renewable hydrogen technologies should reach maturity and be deployed at large scale across all hard-to-decarbonise sectors.

(Extract from EU Communication COM/2020/301, publication 8.7.2020)

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Ted Bergman joined Elomatic in 2019 as Vice-President with a focus on developing international business. His professional experience dates back to 1995 and covers sales, design and commissioning tasks in e.g. the power industry, pulp & paper industry, and process industry.

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Getting rid of coal

Elomatic/TAMK proposal to Helsinki Energy Challenge

Text: Olli Peura and Pekka Koivukunnas

The phasing out of coal-fired powerplants by 2029 in Finland and the government's pledge to become carbon neutral by 2035 poses challenges to the district heating system, where the burning of fuels has been the core heat source for decades. It is essential to already look beyond the first deadline of 2029 and prepare for continued efforts between 2029 and 2035.

Elomatic joined forces with the Tampere University of Applied Sciences in submitting a proposal to the Helsinki Energy Challenge, a competition held by the City of Helsinki to find the best sustainable heating alternatives.

When creating visions of a future district heating system that does not burn fuels, one must answer two key questions: where do we get the required heat, and how do we manage the significant variation in demand between winter and summer? For the first question, a careful examination of available heat sources reveals that if burning is undesirable, what remains is either diluted heat sources (geothermal, seawater) or a few existing centralized waste heat sources.

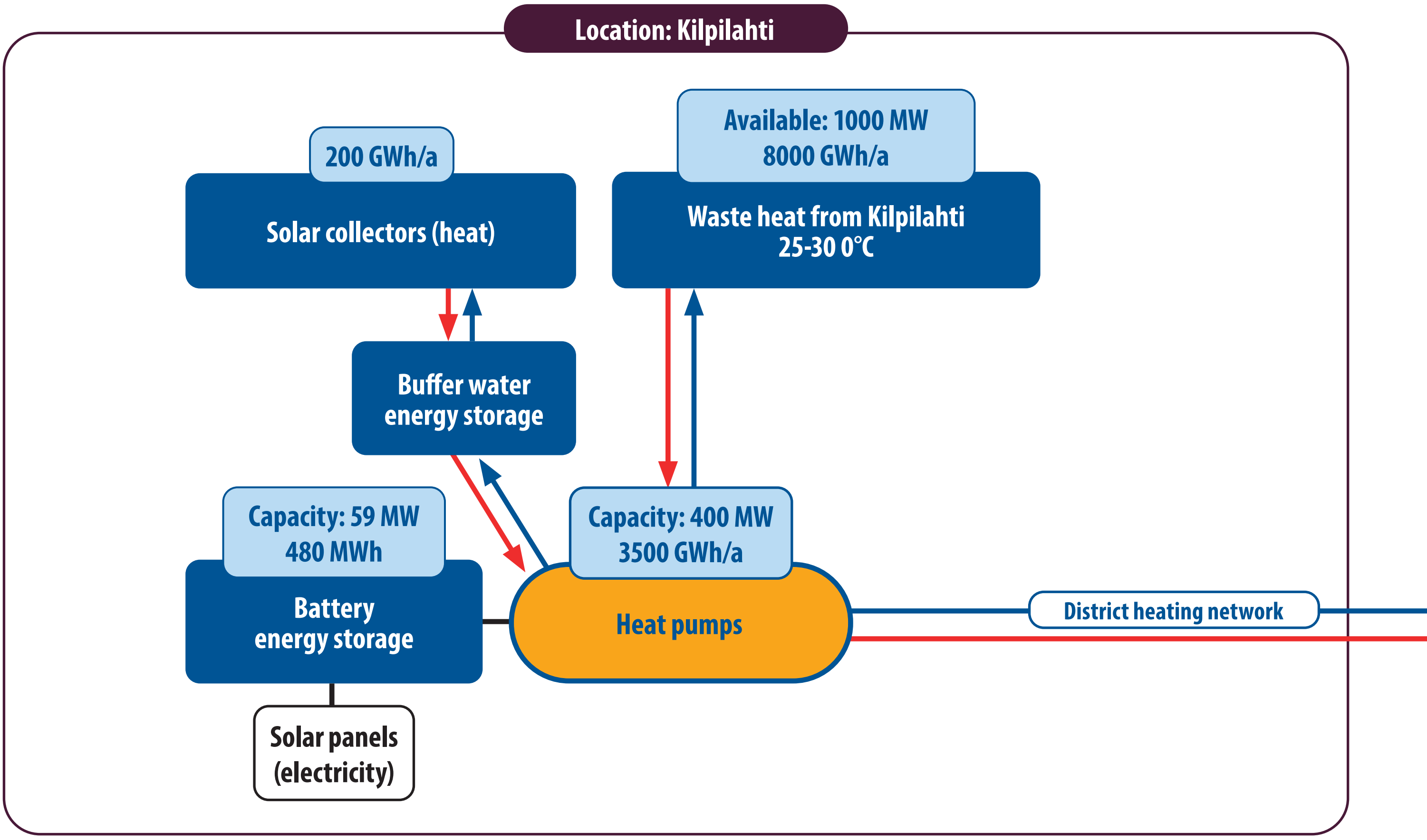
8 TWh of waste heat fed into the sea at Kilpilahti

Many studies have been conducted on the utilisation of waste heat from the Kilpilahti industrial site. It is estimated that a total of 8 TWh of waste heat is fed into the ocean there each year, more than the total district heat consumption of Helsinki. Due to the vast amount of available heat and the good technical feasibility, it was selected as the backbone of the Elomatic/TAMK heat generation proposal.

The second fundamental question concerns overcoming the difference in consumption between summer and winter. Even though the industry in Kilpilahti produces 1000 MW of waste heat, it is nowhere near enough to cover the heat consumption on a cold winter day. In summer, however, the waste heat production is far more than the heat consumption. The solution to this mismatch is to construct a borehole thermal energy storage (BTES) system in Helsinki. Heat can be efficiently stored in the bedrock for long periods, and the bigger the storage is, the greater the overall efficiency is. BTES operation can be optimized with CFD simulations to minimize heat losses and to maximize the efficiency of heat pumps throughout the year.

Feeding waste heat via pipeline to Helsinki

In the Elomatic/TAMK proposal to the Helsinki Energy Challenge, the waste heat from Kilpilahti is primed with heat pumps and fed to Helsinki via a pipeline. The construction costs of the pipeline are estimated to be hundreds of millions of euros. To justify the high investment cost, the pipeline would have to be used at its maximum transfer capacity throughout the year. If a 400 MW pipeline were constructed, half of the transferred heat would be used to cover the district heating demand together with Katri Vala heat pumps during summer when demand is low. The rest of the transferred heat could be fed to BTES in Helsinki. In winter, all of the transferred heat and the stored heat in BTES would be used in the district heating network.



▲ *Operation scheme of Kilpilahti waste heat and BTES utilisation*

The pipeline and BTES, together with solar collectors and selected energy-saving measures, can fully compensate for the lost heat production due to the phasing out of coal-fired plants. The proposed solution would also more than halve the natural gas consumption and lower the fuel-based emissions of district heat production by 88%.

Overcoming the mismatch between energy production and consumption

There is a well-known mismatch between the consumption and production of renewable energy, both in terms of time and location. The sun does not shine in winter when a lot of energy is needed. Also, people do not want to have wind turbines in their backyards.

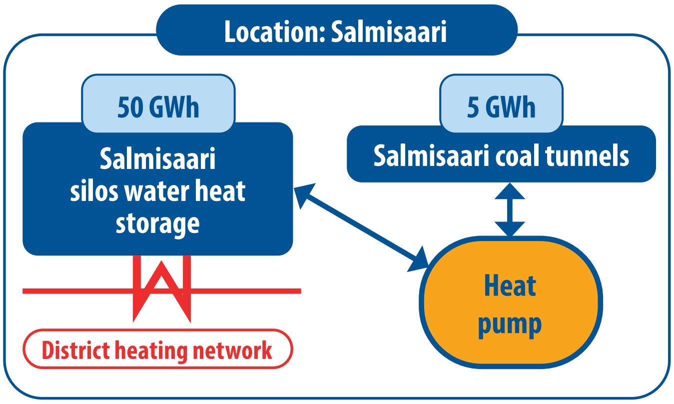
Some locations are known to be exceptionally sunny, windy, or to have strong wave action. A lot of renewable energy is available, if only the energy could be harvested, stored, and transferred to consumers. These energy-dense areas are typically located far away from densely populated ones.

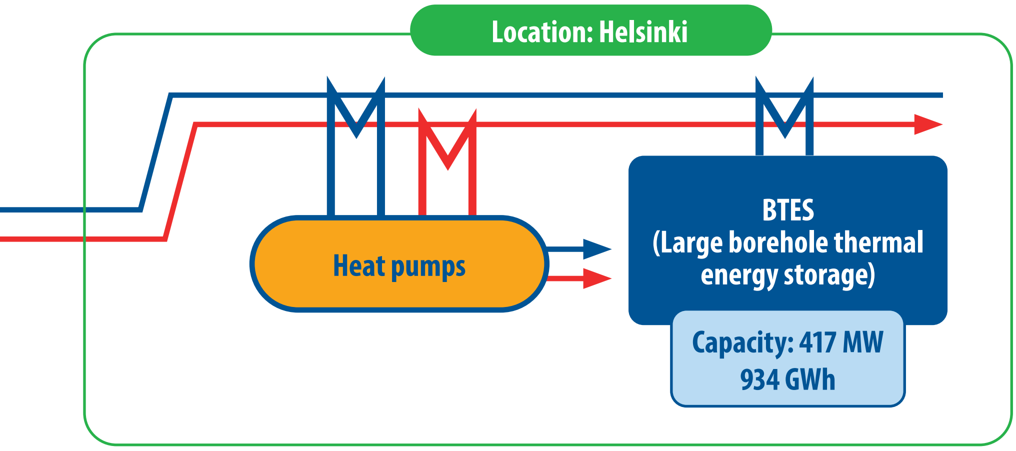
The technologies for harvesting renewable energy are developing fast. PV panels and wind generators can be considered to be mature technologies. According to the IEA, solar energy is already the cheapest electricity in history. Wave generators are perhaps the most challenging to develop. The idea to place solar energy collectors in the desert is decades old. In contrast, floating energy fields in international waters are new and exciting, at least for countries/cities that do not have energy-dense areas within their borders. A floating energy field could consist of a combination of wind, wave, and solar collectors.

Use of aluminium in energy storage and transfer

A novel solution for energy storage and transfer is aluminium. With the help of renewable energy, aluminium oxide can be converted into metallic aluminium. Aluminium ingots are easy to store and transport, and their high energy density means that fewer ships and trucks and smaller storage areas are required. Aluminium's energy content (roughly double that of diesel oil in the same volume) can be released by letting aluminium react with water, producing hydrogen gas, heat and aluminium oxide. The heat can be led to the district heating system and the hydrogen gas can be utilised, for instance, in public transportation.

Aluminium is not consumed in the process; it cycles in a closed loop. Aluminium oxide is transported back to the floating energy harvesting fields in international waters. All sea transportation is carried by emission-free cargo ships (see article on page 18). The aluminium oxide is converted back to aluminium on floating aluminium factories close to the energy fields with the well-known Hall-Herlout process using the harvested electricity. Inert





"Borehole thermal energy storage is utilised to overcome the mismatch between energy production and consumption."

electrodes or biochar electrodes are used to avoid carbon emissions from the aluminium conversion process. The same ships transport aluminium back to the point of use. No special infrastructure is needed to store aluminium. It is a well-known, safe and widely accepted material that does not induce any risks or environmental hazards. Also, aluminium is one of the most abundant elements in the crust of the earth.

Carbon-neutral district heating

Aluminium can be used as an energy storage method that enables the carbon neutrality of Helsinki's district heating. In the Elomatic/TAMK proposal to the Helsinki Energy Challenge, the City of Helsinki plays a key role in the development of Al-to-P technology. By acting early, Helsinki could become the hub of international Al-to-P research and development.

The combination of Katri Vala heat pumps, Kilpilahti waste heat, solar collectors, BTES and aluminium incineration can cover all of Helsinki's district heating consumption. To reach carbon neutrality by 2035, a 430 MW aluminium incineration plant would be constructed and a total of 2000 GWh of district heat produced annually from carbon neutral aluminium. This would, in addition, set in motion a new global energy system based on aluminium energy storage that would help other cities and nations to replace fossil fuels in their district heating systems.

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Olli Peura is a technically gifted designer with an analytical mindset. He is part of a generation of emerging engineering professionals that are guided by millennial values for a more sustainable society. Olli has worked at Elomatic since 2016 and acted as Team Leader of the Elomatic/TAMK team that participated in the Helsinki Energy Challenge.

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Determining the least-cost district heating alternatives

**Text: Jarkko Olkinuora,
Katazina Andrukonyte and Pasi Vesimäki**

International financial institutions (IFIs) play a major role in social and economic development programs in developing and transition economies such as Belarus, Kyrgyz Republic, Tajikistan and Uzbekistan. This role includes project development, project funding and assisting beneficiaries (e.g., energy companies) in project implementation.

Abbreviations

DH = District Heating
CHP = Combined Heat and Power
HOA = Homeowners' Association
MAB = Multi-Apartment Building
LCA = Least Cost Analysis
COP= Coefficient of Performance (efficiency) used for heat pumps
ToR = Terms of Reference
DHW = Domestic Hot Water
HOB = Heat Only Boiler
BAU = Business as Usual
Ariston = Electrical DHW heater

Such investments and funding are usually tied to specific projects that focus on sustainable development. Elomatic's IFI team provides technical and advisory assistance to IFIs and beneficiaries by conducting extensive technical studies on development issues.

The key task in large investment projects is determining project feasibility. This article focuses on the issues related to identifying which heating method would be the least costly solution for these countries at the city level. We call this analysis the Least-Cost Analysis (LCA), and it is essential for District Heating (DH) feasibility studies.

Conducting LCAs requires careful deliberation and a solid track-record of working in transition economies. On the one hand, holistic, multivariate analyses, like the LCA, form the basis of many IFI projects, because they can be used to determine the best ways to plan and to implement effective development.

On the other hand, effective LCAs consider the often-complex local contexts for the IFI projects themselves. Positive economic development in transitional economies has been hampered by underdeveloped local infrastructure, small domestic markets, limited access to world markets and competition from more attractive destinations for foreign direct investments. These issues are exacerbated further by byzantine heat tariff regulations and a planned economy style of governance. Energy production solutions also have far-reaching social consequences, as a sizable part of the population of transition economies is affected by poverty.

A scarcity of available funding forces energy companies to continue their operations without substantial investments to outdated systems, which may cause wealthy customers to change to individual heating systems. In the long-term, this may eventually result in the defunding and closure of the more affordable centralised system.

Therefore, to support decision makers, an objective way of analysing the different options is needed. For such assignments, Elomatic uses its own LCA Method. This method follows the processes determined in the relevant standard (EN ISO 14066:2006) but has the added advantage of being fully targeted to the specific topic of

energy costs.

The LCA is a simplified and systematised way of comparing the socio-economic costs of different heat supply alternatives at multiple levels. The method has some limitations: The model considers the costs of the alternatives but not the revenues (except for the value of heat produced). Costs are also considered as evenly distributed over the lifetime of the system and do not include taxes, subsidies and project-specific financial costs. The LCA is therefore not a tool for assessing project viability.

The confidence level of the results of the analysis is directly dependent on the quality of the modelling inputs.

Topic	As of today	Target
Heating	• Under heating in winter • Temperature differences inside buildings • Availability low	• +20°C • Risers balanced to even temperatures • 99% availability
DHW	• Availability: 330/24 • Temperature: < +55°C, depending on the location of the building in the DH network • Waiting time: long, depending location of the apartment in the building	• Availability: 365/24 • Temperature: min +55°C • Waiting time: max 10 s
Pricing	• Below cost recovery	• Competitive, but cost recovery
Billing	• Normative in MABs	• Consumption Based Billing
Technical Support	• Reactive: response to complaints and alarms	• Proactive using data acquisition • Informative: about energy use
Risks	• Dependent connection = DH water in radiator • Open: improperly purified water	

▲ ***Table 1****. The goals for the best available technologies proposed by the LCA.*

"The best and first step should address low-hanging fruits, like system inefficiencies."

The variables, such as investment and fuel costs, wind and solar resources, environmental costs and so forth, are determined by the local or project specifics.

Service quality is an issue in transition economies and the goals for the Best Available Technologies proposed by the ***LCA are presented in Table 1.***

1st Question: The Point of view

An informed choice of perspective is essential for an effective LCA result. Depending on the point of view, the outcomes of the analysis may diverge or even be at odds between stakeholders. The stakeholders include the country, city, heating company, homeowners' association (HOA) and the tenant.

Typically, the analyses in IFI feasibility studies are made at two levels: the country and the tenant.

At the country level, stakeholders are mainly concerned with the benefits across the whole economy, like foreign trade balance (import/export of goods, energy), primary fuel consumption, investments, employment, living conditions of the population and the impact on health and social equality.

For example, when calculating the primary fuel consumption, the country level analysis also needs to take into consideration the whole electricity system.

The tenant, conversely, is interested in decreasing their payments for heat and electricity, in their own investments and their living conditions. Unlike in the Nordic countries, in the target countries an apartment, i.e., a tenant, is the direct customer of the DH company. Consequently, in some countries legislation allows individual apartments to disconnect from the heating system.

Transition economies often suffer from an electricity deficit; hence the model also considers the known benefits of Combined Heat and Power (CHP) production compared to heat-only production.

In Finland, Elomatic conducts similar studies, but mainly for different stakeholders. These might be cities aiming at carbon neutrality, DH companies planning their long-term investment/fuel sourcing, or homeowners' associations considering disconnecting from the DH system in favour of hybrid heating systems (e.g., ground heat pumps).

2nd Question: Centralisation

In densely populated cities, DH together with CHP production has been demonstrated to be the least costly heating option in the long run. The comparable benefits of centralized DH accrue from:

- high energy efficiency due to integrated systems,
- fuel type flexibility,
- effective flue gas cleaning benefiting from economies of scale

The design of the DH systems in transition economies is rather uniform and is based on old Soviet-era standards that are often inconsistent with modern international practices. In many instances, neglected maintenance has resulted in deterioration, which causes high operational losses, low availability and poor performance, particularly since the collapse of the Soviet Union.

DH is commercially viable and competitive compared with other heating methods in open markets where prices are not regulated and DH is produced with cheap fuel, and/or provided through efficient CHP production. For a centralised DH system, heat density is the benchmark value: the higher the density, the more efficient the system.

If, however, the population density of the area studied is not enough, the LCA model will recommend other solutions.

In each case, the technological heat supply alternatives vary. The number of alternatives may be high ***as shown in Figure 1.***

3rd Question: Method

It is ineffective to carry out an LCA for each individual building or for an entire city. The IFI team uses the following method:

- Calculations are made only for multi-apartment buildings, those that are standardized after the post-Soviet era
- Based on the inventory of the building stock in a city, 1-2 typical building-types are selected
- Heat demand (kW) and heat consumption (MWh per annum) are calculated based on real building data (building structures, U-values, number of apartments, number of tenants, specific water consumption per tenant, etc.)
- Specific consumption data is determined (W/m^3, kWh/m^3)
- Calculations are carried out for an imaginary area consisting of 200 buildings for the DH concept, respectively 10 buildings for the Area Heating concept
- Special attention is paid to network heat density (MW/km) as one of the most important parameters.

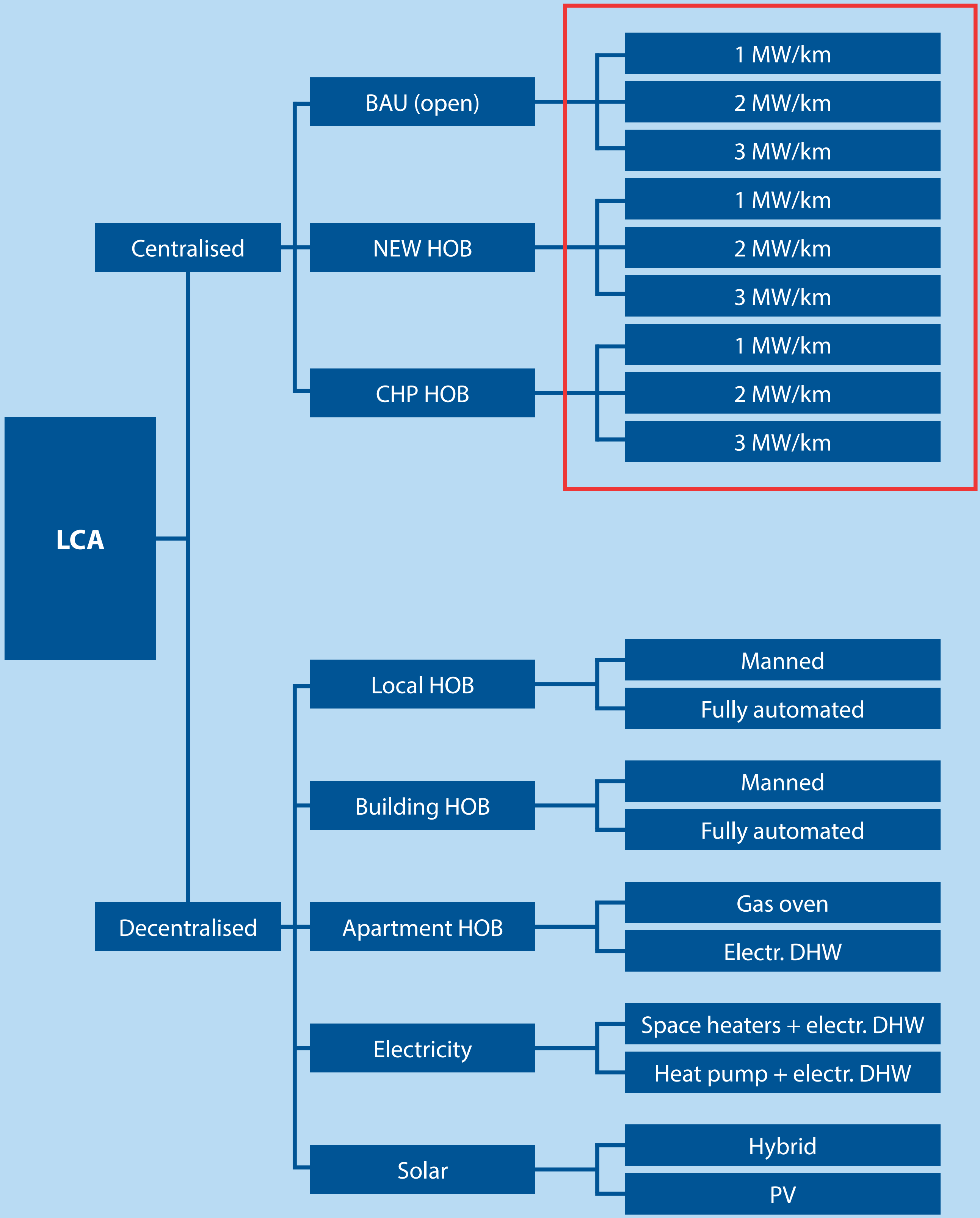
Normally, calculations are done using the business-as-usual baseline (BAU, current system). Due to the obsolescence of the existing system, all new alternatives might seem lucrative.

A full-scale least-cost analysis requires substantial information about all available systems. In transition economies, reliable metered information is often scarce and unreliable. Therefore, demonstrable previous experience of DH in transition economies is central to determining key values and performance indicators in an effective manner.

Typical Key Performance Indicators (benchmarks) for the DH system include, for instance:

- Efficiencies in general

▼ ***Figure 1.*** *Technological heat supply alternatives.*



- The sources of marginal electricity
- The specific CO_2 emission value for grid electricity
- Climatic conditions
- Current and future tariffs and prices
- Socio-economic aspects, like the availability of DHW during summer and affordability
- Investment costs for each possible component, for instance strengthening of the electrical networks in the buildings
- Necessary spare & peak capacity to be included
- O&M cost and staff costs
- Estimated lifetime for each component

4th Question: Analysis

The interpretation of LCA results is not a simple matter. The model does not provide absolute answers but offers a tool for unifying different alternatives for the purpose of comparison.

Figure 2 shows an example of country level results as relative annual heating costs compared to BAU. The second result at the country level is the primary fuel consumption and related CO_2 emissions.

Figure 3 shows an example of the results of the analysis at the tenant level as absolute annual heating costs including annualised investment costs.

In transition economies, the first obvious step – to decrease primary fuel consumption and CO_2 emissions – would be an improvement of the efficiency of the whole value chain. Knowing their least-cost heating solution allows transitional economies to influence the future development of their energy sectors in meaningful ways.

A least-cost heating solution will also allow economies to ensure affordable and reliable energy. With salaries as low as 100 USD per month, an annual heating cost of 1000 USD equals 40% of the income of the society's poorest segments. A good quality of service will also deter wealthier customers from disconnecting from the DH system, which in turn allows DH companies to make enough revenue for continued production.

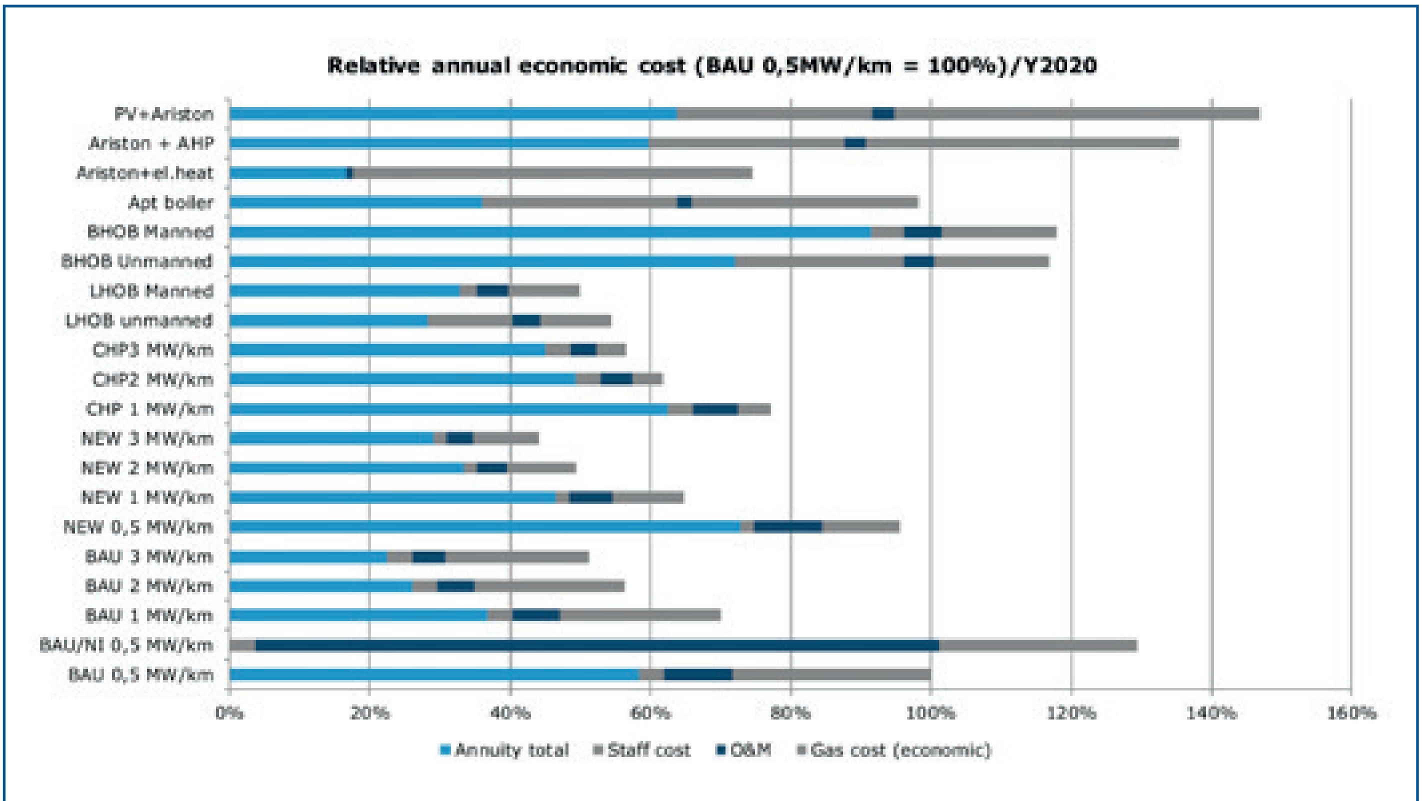
Conclusions and future trends

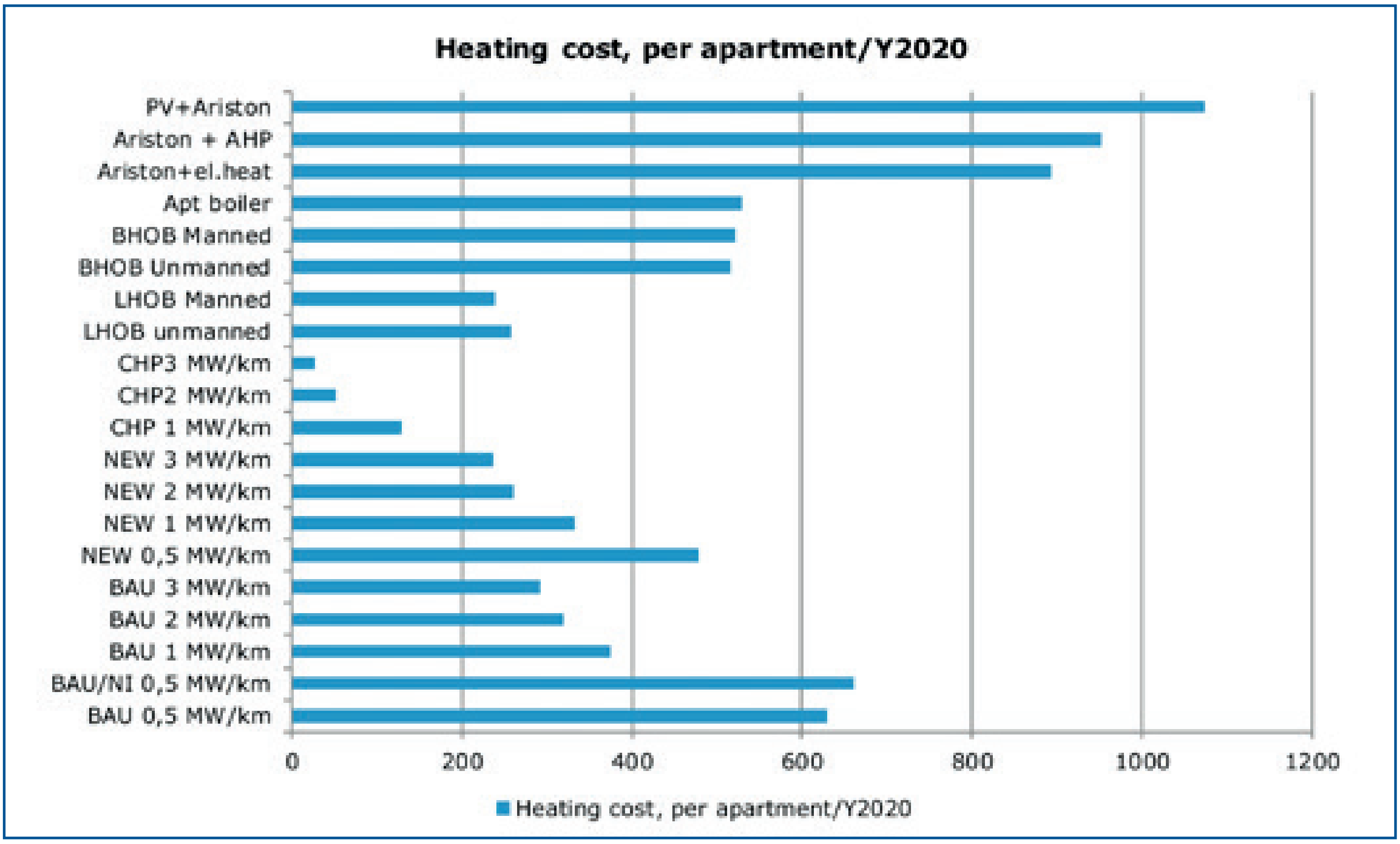
Transition economies are usually highly centrally governed. Many of them are currently developing their heating strategies. This work requires a good empirical understanding of different heating scenarios.

The best and first step should address the low-hanging fruits, like system inefficiencies. If the current centralised system is both inefficient (expensive) and unreliable, any new solution might seem better, at least from the tenant's point of view. The LCA is aimed at ensuring that heating solutions consider the prevailing situation in ways that minimize costs and maximize benefits.

A future application for the LCA is in forecasting future developments in energy production. The current trend of global warming indicates that summertime temperatures in some countries will become almost intolerable. A significant rise in demand for space cooling is therefore likely imminent. But why not pay the small marginal price and buy cooling devices that can also be used for heating purposes with high COP.

▼ ***Figure 2.*** *An example of country level results.*





▲ ***Figure 3.*** *An example of tenant level results.*

About the authors

The authors are members of the Elomatic IFI Team. The IFI team, based at Elomatic's Espoo office, is specialised in assignments financed by International Financial Institutions such as the World Bank or EBRD. Services include Feasibility studies, Corporate Development or Project Management services (design, procurement, site supervision, commissioning) during the project implementation.

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With wind power towards zero-emission maritime traffic

Text: Antti Yrjänäinen

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Ever-tightening environmental regulations, combined with the pressure to lower fuel costs, have made wind power an attractive option as transport energy for ships. Many sail applications have been developed, but no real breakthrough has been achieved. Suspected uncertainties have slowed the re-emergence of wind-based propulsion. However, there have been clear fuel economy benefits from the installations made. Emission reduction targets force the development and application of new environmentally friendly technologies, such as wind power in shipping.

Wind as a ship's propulsive force

Of the solar radiation energy that reaches the earth, 2–3% is released into the wind. It is completely pure, unpolluted energy that is freely available. Before the era of motor ships, shipping was based on wind power. 100 years ago, the last sailing ships in active service reached peak speeds of up to 17 knots when sailing from Australia to Europe – a speed that modern bulk carriers cannot reach. At the same time, the world's largest and fastest sailboats reached speeds of over 11 knots in yacht races. In cargo transportation, sail propulsion has been abandoned, while racing sailboats have developed tremendously, utilising advanced wing sails and light-weight structure technology. The most extreme reach top speeds of over 50 knots. The development of the use of wind power in ships was forgotten for 100 years, but interest in it has been revived.

Today, consumers are aware of environmental issues, which makes even large global suppliers demand environmentally friendly activities throughout the whole transport chain. This universal attitude has materialised in IMO's (International Maritime Organization) target of halving maritime emissions by 2050. It drives the thinking of the whole maritime industry very strongly. Operators are looking for zero-emission solutions for propulsion power generation. This need is met by developers of wind energy-based equipment.

Conditions for wider deployment of wind power

Logistics chains are based on a precisely scheduled transport performance. On motor ships, this is easy to implement and achieve, although weather conditions can sometimes bring their own challenges. Sailing ships are completely dependent on favourable weather conditions. Instead of fully sail-powered propulsion, wind-assisted

propulsion permits keeping to schedules. Hybrid solutions make it possible to achieve significant savings in fuel consumption and thus also in emissions. In practice, such hybrid solutions have been able to verify annual fuel savings of around 10% (corresponding reduction in CO_2 emissions) cost-effectively, without reducing the service level of ship transportation.

If flexibility regarding schedule requirements can be introduced, the savings could be even greater. At its most extreme, all propulsion could be based on wind power – as it was before the era of steam engines and motor ships.

The most significant barriers to the uptake and wider use of wind propulsion are primarily related to various uncertainties. One is the price of fuel, i.e. the projected cost that needs to be reimbursed. In particular, the low price of fuel and its unforeseen fluctuations have dampened interest in the implementation of wind propulsion.

It is often questioned whether the proposed technology is at all suitable for ships and their operational profiles. Also, what is the usability of the devices, and how do they affect safety factors? These technical matters can be verified and tackled by accumulated information of every new pilot installation. Ultimately, investors require a "proven design" for a financially sound investment. The feasibility of proposed installations has to be carefully analysed and evaluated based on the vessels' operation and environmental circumstances.

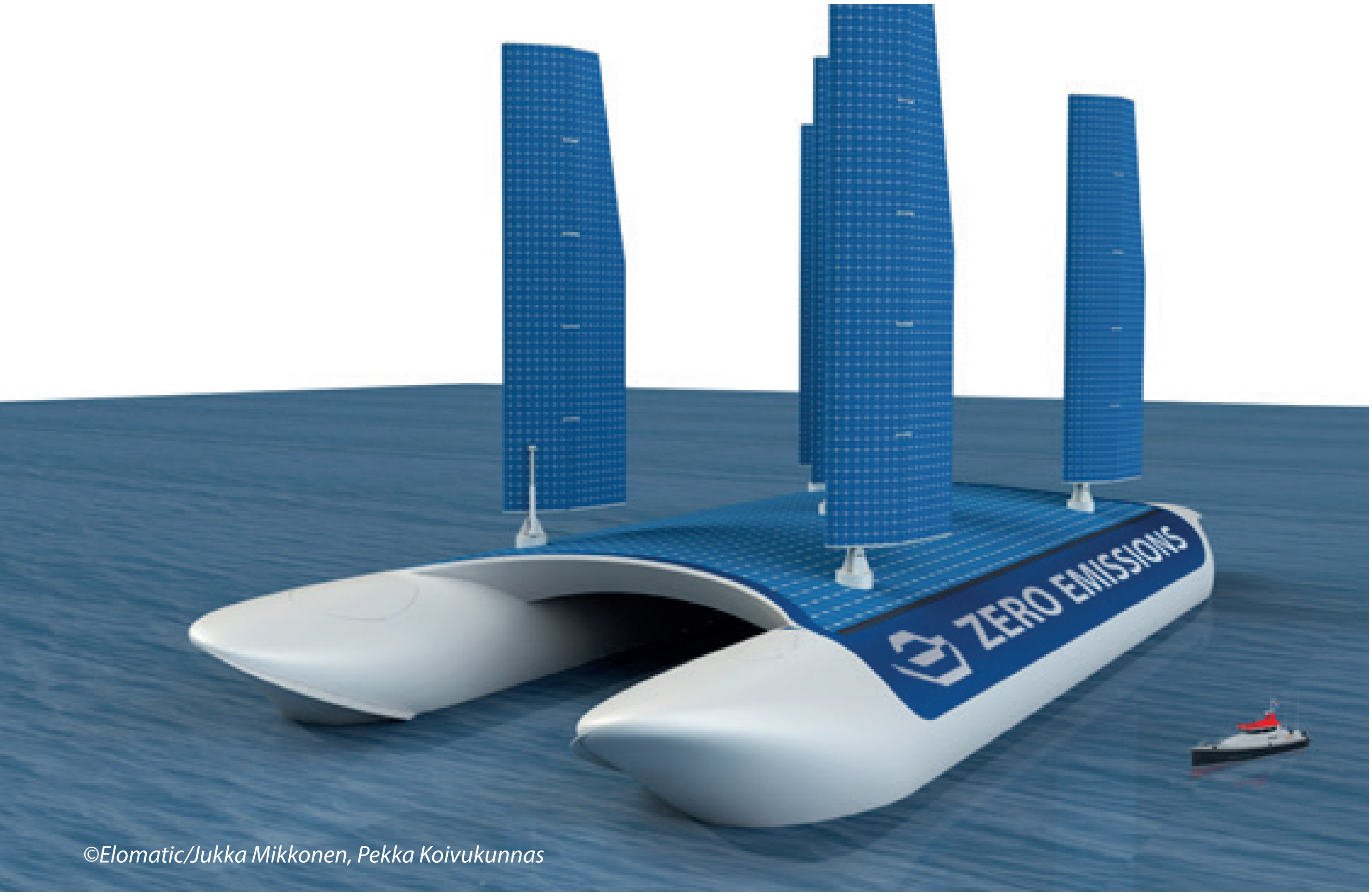
"Sail-based or sail-assisted propulsion is one way of achieving carbon-neutral shipping.

Wind energy solutions

Traditionally, wind has been used on ships directly for propulsion power. The wind can also be harnessed to produce electricity with a turbine. However, the dimensions of such a device and, consequently, the height of the centre of gravity and the movements of a ship, do not allow a working combination to produce the needed electricity for a propulsion motor.

There are more than 30 separate projects around the world studying or developing the use of wind power on ships. These projects are mostly being conducted by research institutes, but also by some commercial actors. Many of them are at a very low level of technological maturity. So far, there are hardly any commercially ready products on the market, besides sailing solutions derived from sail boats. One exception is Norsepower's rotor sail. Based on the activity of the cluster, new solutions will be coming onto the market in the years ahead.

▼ *A concept of wind powered handy size bulk carrier, 37 000 Dwt.*



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Classification societies have also done their work. The most significant classification societies have already published their guidelines and rules with respective notations for the classification of wind-assisted propulsion installations for different types of wind-assisted applications.

Assessing the benefits

Environmentally friendly technology creates benefits for society. However, wind power equipment must also be a commercially viable investment for the ship-owner, without reducing the level of ship performance. The payback time of the installation needs to be assessed. It, in turn, is heavily dependent on the price of fuel to be replaced by wind power. Unfortunately, fuel price fluctuations are large, making it challenging to predict future price levels reliably. In competition with fluctuating bunker prices, wind offers a more stable outlook, however, with uncertainties related to individual voyages.

Most wind-powered devices are currently at very early stages of development. The productization and series production of different types of equipment will create new opportunities and further improve their price competitiveness.

At the realised fuel cost levels, the payback times for the equipment have proven to be reasonable, but the value of the installation improves when the fuel price is high. Each case must be assessed individually, however, based on the ship's operational profile and

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◄ *A rotor sail installed on a Ro-Ro vessel.*

UTILISATION OF WIND POWER						
Means	Propulsive force				Electricity generation	
Type	Soft sail	Wing sail	Rotor sail	Kite	Axial turbine	Radial turbine
Application	Traditional sails	Hard sails, wing profiles	Flettner rotors	Towing kite systems	Windmill	Savonius wind turbine

▲ ***Table 1.*** *The different ways wind power can be utilised onboard.*

wind conditions in the operational area, in addition to the ship's characteristics.

Thoughts for the future

The paradigm of the whole current ship concept will change if the propulsive power of ships is produced only with wind power. The largest single component of operating expenses, i.e. fuel costs, will be excluded. On the other hand, compromising on speed raises the importance of capital costs as transportation performance declines. Achieving the maximum benefit affects the whole ship concept and its characteristics.

Based on the above, the thought can be taken even further. If a ship is rendered unmanned, another large item of operating expenses, i.e. the personnel costs, would be eliminated. At the same time, all facilities and systems related to living onboard and the ship's personal safety equipment become unnecessary, contributing to reduced capital costs. As a small concession, the ship would be equipped with solar cells, batteries and electric thrusters for port operations and occasional calm weather. Based on this philosophy, Elomatic developed the concept of a sail-bulker, pictured top left.

To achieve stability, the vessel is of the catamaran type. Both hulls are tubular and double hulled, with the second shell inside forming a cargo space. The bow and stern parts have a streamlined design for good seagoing characteristics. The deck and sails serve as a platform for solar cells. It is a futuristic concept study, which is important for testing and evaluating novel ideas and solutions. By testing ideas and calculating their feasibility, these now utopian concepts will be refined step by step into the workhorses of our seas, into emission-free means of transport. Although developments in the sector are swift, it seems that it takes very long for actual commercial installations to become widespread. The proposed emission reduction targets require faster development.

Sail-based or sail-assisted propulsion is one way to achieve carbon-neutral shipping. Various sail solutions are already a cost-effective way of producing part of the propulsion power. This share can be increased in the future, and in some cases wind power will undoubtedly be the main driving force again for some ships at least.

Every new sail-assisted propulsion installation paves the way for wind-assisted propulsion in general. The more data is gathered and knowledge of the use of such devices is gained in various sea and wind conditions, the better the benefits can be evaluated and verified. Technical barriers can be solved by researching, developing and testing.

The key element for wider utilisation of this pure energy is economic competitiveness. Some of today's solutions have generated a return on investment for the shipowner in less than 5 years, which simultaneously reduced CO_2 emissions by 10%. If the bunker price trends upwards and marine CO_2 emissions are part of any carbon tax instrument or carbon emission trading, such as the European emissions trading system (ETS), it will result in a lucrative market for wind assisted propulsion system suppliers. This will also assist shipowners to reduce fuel costs.

About the author

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Antti Yrjänäinen has extensive experience in ship design from concept design to life cycle related projects. He is particularly oriented towards concept design and novel marine solutions. He has held several managerial positions during his 20-year career at Elomatic, and currently works as Sales and Project Manager.

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Tool for developing the operations of industry and energy companies — Managing the energy future™

Text: Teemu Turunen

The energy market is currently experiencing a major transformation that will have a significant impact on both the energy industry and industrial business operations in the future. In the future, an industrial operator may be a producer of electricity and heat and, correspondingly, an energy company can be a major player in the circular economy. In addition, cooperation with different actors will become more pronounced. Although it will be a big challenge for everyone, it is possible to respond with a systematic approach.

A crisis can be an opportunity

At the time of writing, we are living in autumn 2020 and surviving the first wave of COVID-19, and the supposed second wave is currently reaching Finland. Although there are dark clouds in the sky for Finnish industry, COVID-19 has not, at least so far, changed the prevailing megatrends. Climate change and the quest for carbon neutrality are still here. Throughout history, crises have created space for something new and have contributed to accelerating development. For example, all the conditions for effective remote work have been available

for some years, but now, thanks to the crisis, we took a huge leap in just a few months.

Examining the current situation in the industrial and the energy sector, it is likely that, in the post-crisis world, energy prices, carbon neutrality and the functioning of energy supply will be key sustaining factors. Energy security will also be one of the key factors in maintaining social peace.

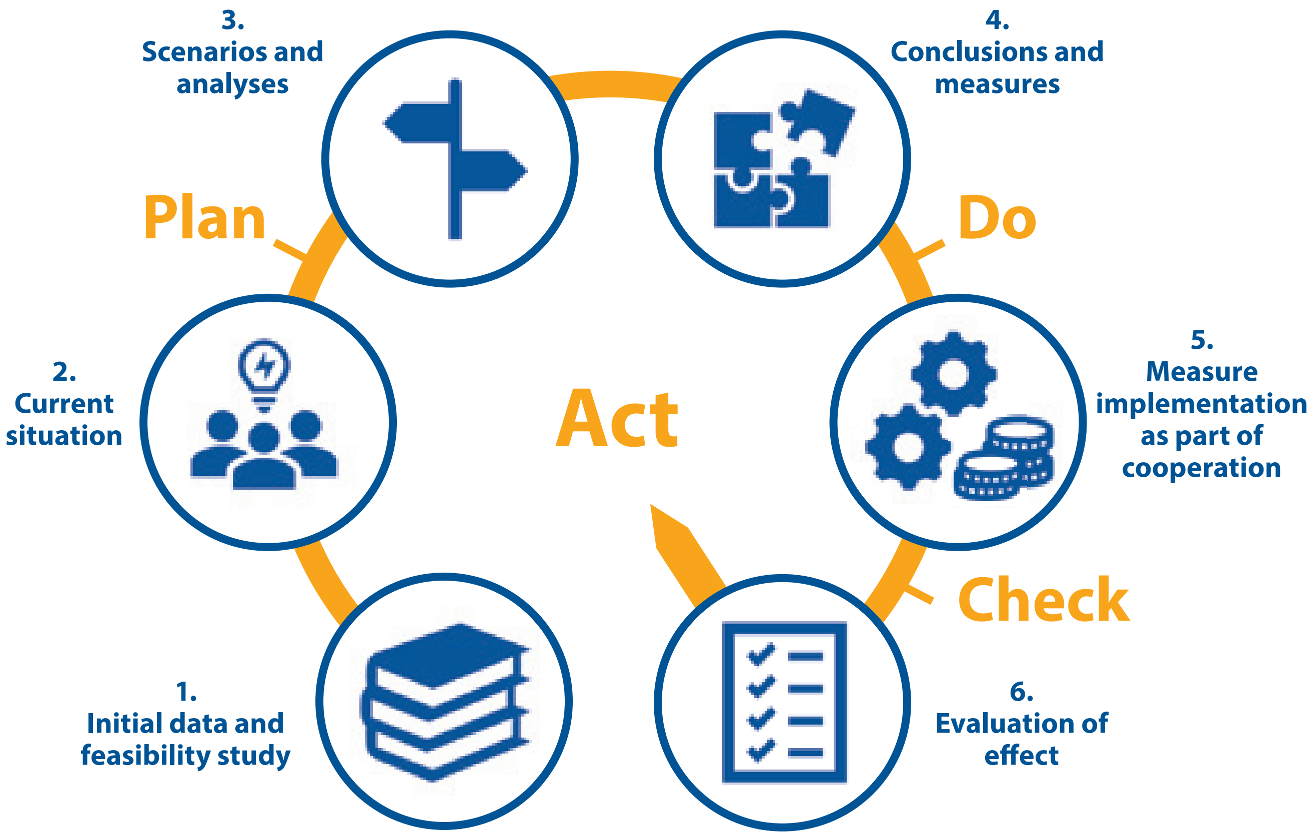
The ongoing development is also likely to be boosted by COVID-19-related economic recovery measures. Directing these recovery measures towards the so-called green recovery, is much talked about at the EU level. This would fit in well with the EU's pre-COVID-19 Green Deal programme, which aims to allocate a total of EUR 750 billion by 2027 to projects aimed at the efficient use of resources, a clean circular economy, emission reduction, or biodiversity conservation. The energy sector will be a key player in promoting these projects, but industry will also play an important role. The background to this work is the very ambitious carbon neutrality targets set by the EU for 2030, and in the long term, for 2050.

Sector integration is a key tool on the road to carbon neutrality

In 2020, the EU published a so-called sector integration strategy, which is one of the key tools in the fight against climate change. Sector integration describes the cooperation between different energy systems, technologies and carriers. It aims to reduce emissions in a wide range of sectors of the economy in a cost-effective manner and to enable renewable forms of electricity production to be integrated into the energy system without problems for the security of supply.

In practice, this means that the activities of energy companies, industry, and different service providers, for example, are converging, making it possible to find new and effective tools for climate work. This, of course, opens up completely new business opportunities and possibly also disrupts the traditional approach in different industries. In the future, an energy company can be a major

▼ ***Diagram 1.*** *The Plan – Do – Check – Act cooperation model*



circular economy operator or, for example, a technology supplier in heat recovery solutions. On the other hand, in the future, an industrial operator can generate heat for the municipal district heating network, trade electricity in the reserve market and be part of an industrial park's resource pool. Properties and consumers also have their own role. Depending on the situation, properties may be both energy producers and cooling system users. Consumer data will also play an increasingly important role as energy networks are driven more comprehensively and efficiently.

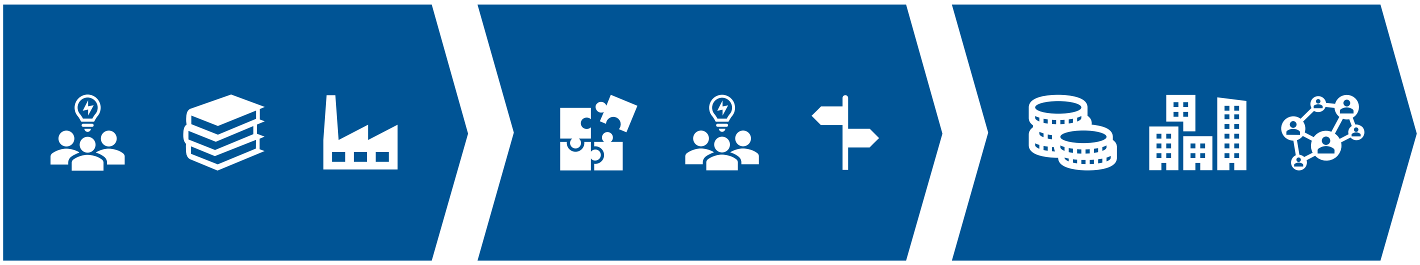
Managing the energy future – what is it?

The energy future is a very new concept and there is no unambiguous definition of it. However, it can be seen as a future space for energy production, distribution and use, where a significant part of energy is increasingly produced, used more efficiently and recycled in an increasingly holistic way. There are several factors influencing this development and if you look at it from the point of view of industry and energy companies, the following influential themes are:

1. Global megatrends
2. Energy policy and its predictability
3. Social change and changes in consumption habits
4. Change in energy business models and financing needs
5. Decentralisation of energy production and new forms of energy production
6. Electrification of society
7. Threats and opportunities of the data economy
8. Ensuring critical resources and skills
9. Energy efficiency
10. Demand response
11. Industrial circular economy and carbon neutrality

The aforementioned list points to a challenging and complex issue. When

▼ ***Diagram 2.*** *A three-step operating model for managing the energy future*



Current status of company

- History
- KPI metrics
- Organisation
- Established operating models and processes
- Production machinery
- Distribution networks
- Customers
- Partners
- Contract management
- Procurement of raw materials
- Competitors
- Environment (physical and mental)
- OUTPUT: Current status description report

Creating and maintaining future vision

- Maintaining / increasing market position
- Production cost management
- Boundary conditions and restrictions for business
- Necessary resources and measures
- Timetables
- OUTPUT: Creating and maintaining alternatives and scenarios

Implementation phase

- Implementation, start-up and change support
- Workshops according to the annual clock
- Interviews with different functions
- Management Team Advisor
- OUTPUT: Concrete development activities and return expectations

an entity of this scale needs to be managed in a controlled manner, it is easy to understand that without a systematic approach, as well as extensive cooperation and know-how, the task would easily become impossible.

How can the energy future be managed?

Therefore, the objective of managing the energy future is to form an individual development path for each company and to start implementing it purposefully. It is essential that the actions are extended to daily operations, with a Plan-Do-Check-Act operating model, familiar in the corporate world in the management of operations ***(See Diagram 1).***

When you look at the big picture from the point of view of an energy company or a production plant, you can start to work together on the definition and management of the future model using a three-step operating model ***(See Diagram 2).***

The first step is to define the current state providing a realistic picture of the present condition of the company's business. The next step is to create a vision for the future and possible scenarios. It is essential to identify opportunities and risks at this stage. At the end of the scenario task, the company's future objectives and measures (strategy) are created to achieve the objectives. Then we move on to the operational step, which includes taking concrete actions towards the vision of the future. The final step is the impact assessment (act) also used in corporate management, which verifies the effects and determines the necessary corrective measures.

Concrete approach leads to results

Creating a future vision and forming a scenario always begins with a comprehensive study of the baseline. In practice, the issues to be reviewed vary as to whether it is an energy company or an industrial operator, but the issues important for an industrial company, for example, are at least the following:

"Energy needs to be more efficiently produced, used, and recycled in a holistic way."

- Energy consumption data and prices, by energy fraction
- Energy balances
- Energy efficiency activities
- Future plans and investments with an impact on future energy use
- Fuels used, their availability, price development, etc.
- Documentation of the most significant energy uses/processes
- Documentation of factory area transmission networks

The gathered information is specified with fieldwork, where interviews and scenario workshops are conducted as part of getting to know the site's activities. The aim is to have the widest possible representation at the workshops, in order to consider the perspectives of the various activities.

The information gathered is then analysed in relation to development trends at the societal and global levels. A scenario of the energy use of the operations is produced, strategic goals/measures related to energy use are formed, and a concrete list of measures is defined. Typical measures may include:

- Development of energy efficiency activities
- Alternative fuels towards carbon neutrality
- Utilisation of heat pumps as part of heating and cooling
- Investment in energy storage capacity
- Development needs of transmission networks
- Development of communications related to energy issues

After the analysis, the measures are summarised in two parts: an extensive technical report and a summary for management use. The broader part of the report includes comprehensive descriptions of operations, techno-economic reviews, CO_2 calculations, concrete recommendations for action, and the necessary energy scenarios. In many cases, an essential part of the work is also creating future development paths, political priorities and estimates of the future price development of energy fractions and technologies.

Summary

Energy will continue to be one of the most important factors in maintaining social peace. At the same time, it should be produced more cleanly and efficiently. The challenge will affect our entire society, and there are not many individual "easy" solutions. In order to make the foggy future even a little clearer now, it is important to start systematically forming an understanding of the situation and implementing the identified measures consistently.

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Teemu Turunen has extensive experience in energy consultancy across a wide range of industrial areas. He currently works as the Design Manager of Elomatic's Energy Consulting team, which develops and implements sustainable solutions for future energy needs.

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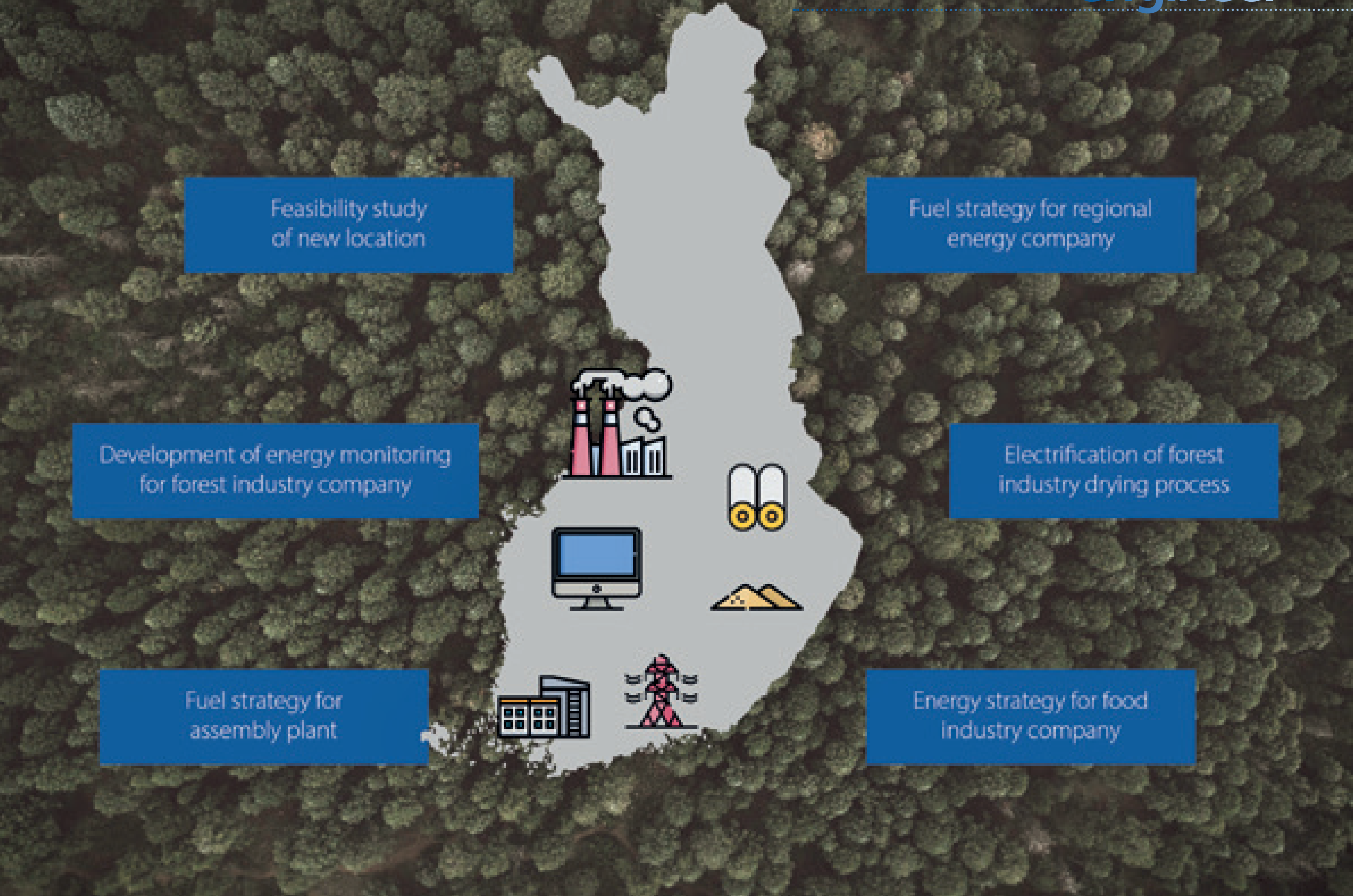


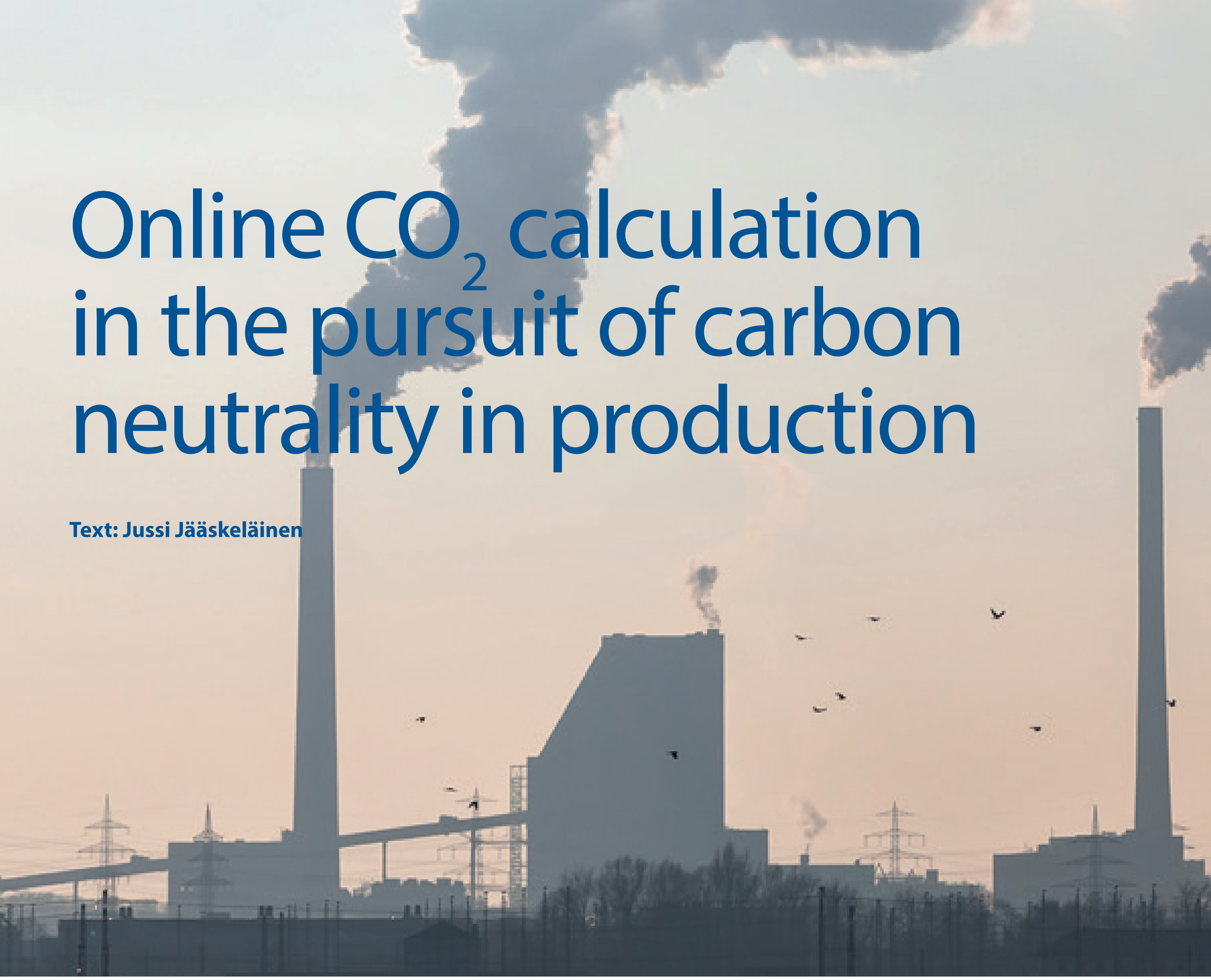
***Figure 1.** Recent collaborative projects related to managing the energy future*

Applying the operating model to different needs

The approach presented in this article can be applied to very different needs. ***Figure 1 shows*** our recent customer relationships on energy future topics.

As noted, before, the energy future is broadly relevant to energy companies as well as industry, and the developed operating model can be applied to different needs. The most extensive cooperation models have been the formation of an energy strategy for an entire plant, which has delved into the area's availability of electricity, CO_2-free heat production, and the development of energy-efficient operations in the area. Correspondingly, an example of an operating model for energy companies is the implementation of a fuel strategy for a regional energy company. The work examined the current state of fuel use and formed a view of the future, how the company will be able to meet future challenges and changes in the field of operation.

Some of the cooperation projects have been very specific, such as focusing on electrifying an energy-intensive process or consulting on the location of a plant, taking into account the energy infrastructure and consumables available in the area.



Online CO_2 calculation in the pursuit of carbon neutrality in production

Text: Jussi Jääskeläinen

Assessing the environmental impact of a product during its life cycle is often a laborious process that is done on a one-off basis, averaging the effects of production and raw materials. In the future, it will be possible to carry out CO_2 monitoring and analysis as an online calculation based on process data by production grades and for each production batch. This helps to analyse emissions at different stages of production and to develop processes in a carbon-neutral direction.

Determining the carbon footprint

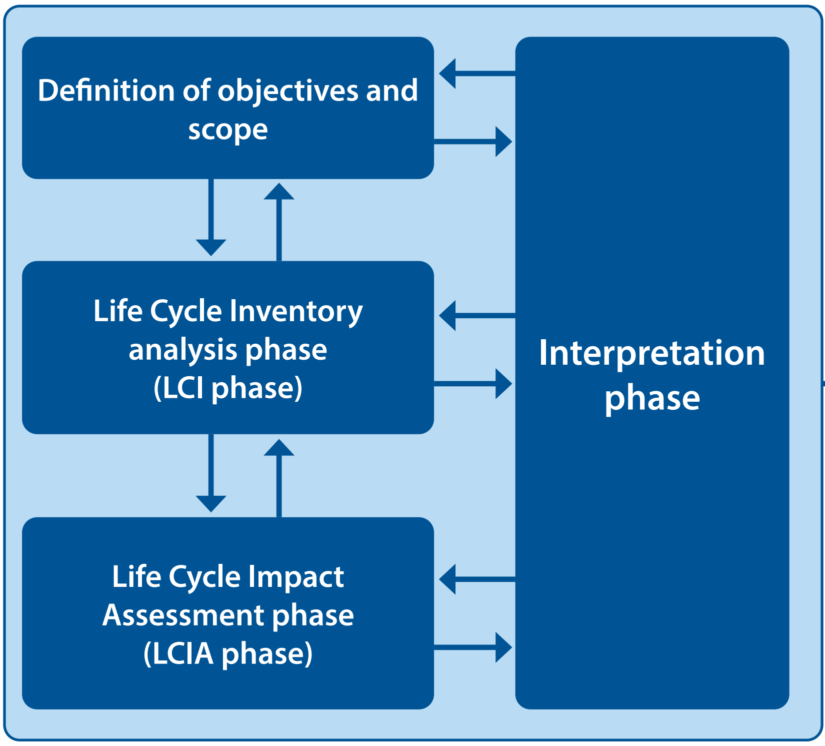
Carbon footprint calculation or life cycle analysis (LCA) is based on the ISO 14044 standard. The method allows the resources and environmental impact of a product or service to be analysed and assessed. Life cycle assessment can be applied, for example, to the following:

- Supporting decision making
- Identifying opportunities to improve the environmental performance of products at different stages of their life cycle
- Selecting relevant environmental performance indicators and measurement methods
- Marketing (e.g. eco-labelling)

The life cycle assessment includes the following steps ***(See Diagram 1):***

- Definition of objectives and scope
- Life Cycle Inventory analysis phase (LCI phase)
- Life Cycle Impact Assessment phase (LCIA phase)
- Interpretation phase

In order to implement the carbon footprint, several emission factor libraries have been produced for the needs of different industries. These can be used to estimate CO_2 emissions from different materials. Life cycle assessment is an iterative process, in which, as the assessment progresses, it is possible to return to modifying the phases already performed. Based on the results of the LCA analysis, it should be possible to draw conclusions as well as to identify limitations and make recommendations for



◀ ***Diagram 1.*** Phases in life cycle analysis, interpretation of results and applications (source: Standard ISO 14044)

"The traceability of materials and more accurate reporting of emissions will become increasingly important."

measures to reduce the environmental impact.

The life cycle assessment must consider all stages of the life cycle of the product and service:

- Manufacturing (raw materials, energy and water use, assembly, etc.)
- Use (treatment related to use, use of energy and water, etc.)
- Disposal (dismantling, recycling, waste, etc.)

Development of life cycle assessment monitoring and analytics

Typically, a life cycle analysis is performed on a one-time basis. However, by utilizing process data, it is possible to perform the calculation at least partially continuously, in which case it is possible to verify CO_2 emissions also under different production conditions, different production grades, or in case of changes in different raw material fractions..

In the future, the traceability of production and its materials will be emphasized as there are temporary changes in energy fractions. These can be, for example, energy demand-elasticity situations, where the use of electricity in manufacturing can vary according to the price of electricity. This also has implications for the carbon footprint of the product or service being manufactured. Changes may also occur in raw material sources if different CO_2 emissions have been identified in different batches of raw materials due to, for example, a different raw material supplier or a different manufacturing process. Grade-specific CO_2 calculation is also possible if the analytics platform supports the monitoring of different ranges of production grades.

For LCA life cycle assessment, the above entities allow for online monitoring of the inventory analysis phase (LCI) and if the CO_2 factors of different raw materials and energy fractions can be combined in this context, online emission calculation (LCIA phase) can be produced for the production phase.

Objectives in carbon neutrality and its continuous monitoring

Overall, the objective is for the CO_2 calculation to be easily implementable for selected time periods and production batches. This is the aim of Elomatic's development project, which is part of the Technical Research Centre of Finland's (VTT) SEED research project. The objective is to make an application for material traceability that calculates product manufacturing phases and instantaneous material flows by mirroring the process model. This can be used to verify which raw material

▲ Example of an energy consumption and CO_2 dashboard.

fractions and batches have been in use and when. This way, the CO_2 calculation can also be specified for each batch and species. At the same time, energy consumption volumes and how energy is produced or purchased at certain points in production can be combined. This can be converted to specific energy consumption, so that the CO_2 effect per quantity produced can also be determined. See below for more details about the SEED project.

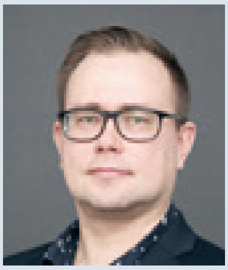
The application utilises time-stamped measurement data collected from the process, as well as process connections/design data for different phases of the process, statistical process control (SPC) and possible time delay models. Once material flows and their fractions can be traced, this information can also be used to calculate the carbon footprint and further determine carbon neutrality targets. It will also be easier to assess the effectiveness of the measures taken.

A prerequisite for the operation of the system are the adequate measurements used to assess material and energy flows. Solutions can be found for this, if necessary. Elomatic has extensive experience in increasing measurement instrumentation and building measurement data collection, so we are able to help customers with this challenge as well.

At the beginning of the development work, the aspect of product use and disposal and the environmental impact are not included in the traceability application. However, these phases can be examined on a one-off basis and assigned a fixed impact assessment. This can be linked to traceability application reporting, allowing the entire LCA analysis to be performed according to the requirements of the standard.

The traceability of materials and more accurate reporting of emissions will play an important role in the future as the carbon neutrality requirements of operations increase. Is it even possible that, in the future, CO_2 emissions from products will be controlled in the same way as emissions from cars?

About the author



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SEED Project – Traceability and improvement of process efficiency and predictability

Elomatic is participating in the SEED research project by developing digital services to improve production efficiency and material traceability in the forest industry.

An ecosystem is formed in the SEED project where forest industry companies, engineering companies, technology suppliers and IT companies together develop, test and pilot solutions over the life cycles of production lines from design to operation and asset management.

The SEED co-innovation is comprised of three research facilities (VTT, Jyväskylä University and Aalto University), the projects of seven corporate partners, as well as 11 companies participating in the ecosystem. The SEED project is based on a unique approach where forest companies offer an innovation platform for research, piloting and testing at their plants. The cornerstones of the new SEED model are co-innovation and learning.

Elomatic's goal in the SEED ecosystem is to research and develop digital business opportunities that support business growth and know-how development, and provide customers with traceability, production process efficiency and forward-looking solutions. This strengthens Elomatic's competitiveness in a dynamically changing market.

Finland is a digitalisation pioneer in the EU. We have strong digital know-how and the forest industry is one of the cornerstones of the Finnish economy. Combining these competencies creates significant opportunities for business growth and internationalisation.

Ways to decarbonise shipping – webinar materials available for download on demand

In November 2020, Elomatic arranged an online webinar where experts discussed ways to decarbonize shipping. The event report and recording are available behind the link provided.

Experts from Elomatic, ABB Marine & Ports, NESTE, Wärtsilä, Auramarine, The Finnish Shipowners' Association and the Ministry of Transport and Communications gave presentations or were involved in the panel discussion.

Ways to decarbonize shipping

Changes in the marine industry are today faster and more visible than ever before. A business that has faced almost no environmental regulations before this century and utilised cheap fuels, which were considered as waste in most other industries, has had few incentives to pursue any developments by itself.

Regulations in shipping

According to the third IMO GHG study (released in 2014), it is estimated that shipping emitted approximately 938 million tonnes of CO_2 in 2012, accounting for 2.6% of the global anthropogenic CO_2 emissions that year.

This is a reduction compared to the 1100 Mt CO_2 emitted in 2007 (3.5% of global emissions), however, the increase in vessel size and lower operational speeds are the main reasons behind this reduction (Bouman, et al., 2017).

Ship emissions are expected to increase in this growing industry. Depending on future economic and energy developments, shipping emissions may increase by 50% to 250% in the period to 2050. The continued growth of the industry is a concern if no significant gains in energy efficiency are achieved and alternative low-carbon fuels are introduced.

Go to event page to download report and recording.

https://resources.elomatic.com/ways-to-decarbonize-shipping-te

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CONSULTING & ENGINEERING

Scientia vires est

At Elomatic we believe that our human capital is our most precious asset. With knowledge comes the power to shape the future.

We continuously develop our employees' know-how and strive to be leaders in our respective technical fields. We focus on packaging and delivering this know-how to ensure that our customers stay ahead of their competition.

The Top Engineer magazine offers our experts the opportunity to share their expertise and knowledge and to engage other technical experts with their writing. It is a publication by engineers, for engineers, and other technically-minded readers.

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Elomatic is supporting mental health work of children and young people

Elomatic is providing support for the State of Mind Campaign organised by the Association of Friends of the University Children's Hospitals to raise funds for the mental health work of children and young people.

The funds raised will be used for the Cool Kids treatment program for children and young people with anxiety disorders in Finland and to support the accessibility of other evidence-based methods and the mental health work of children and young people throughout Finland. The project is being implemented by HUS child and adolescent psychiatry experts

As many as 20% of Finnish children and young people have mental health challenges. Anxiety disorder is one of the most common mental health challenges. As many as 100,000 children and young people suffer from anxiety. Elomatic is proud to be investing in the mental health of our future generations.