TOP ENGINEER

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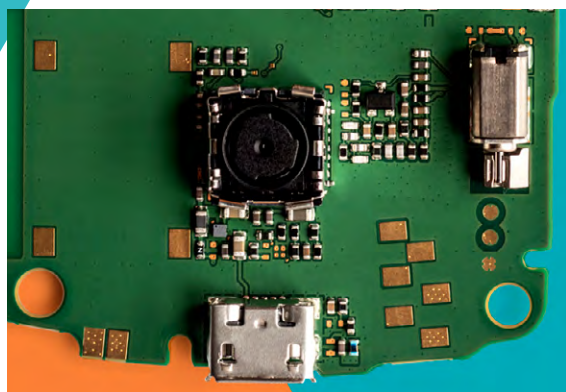

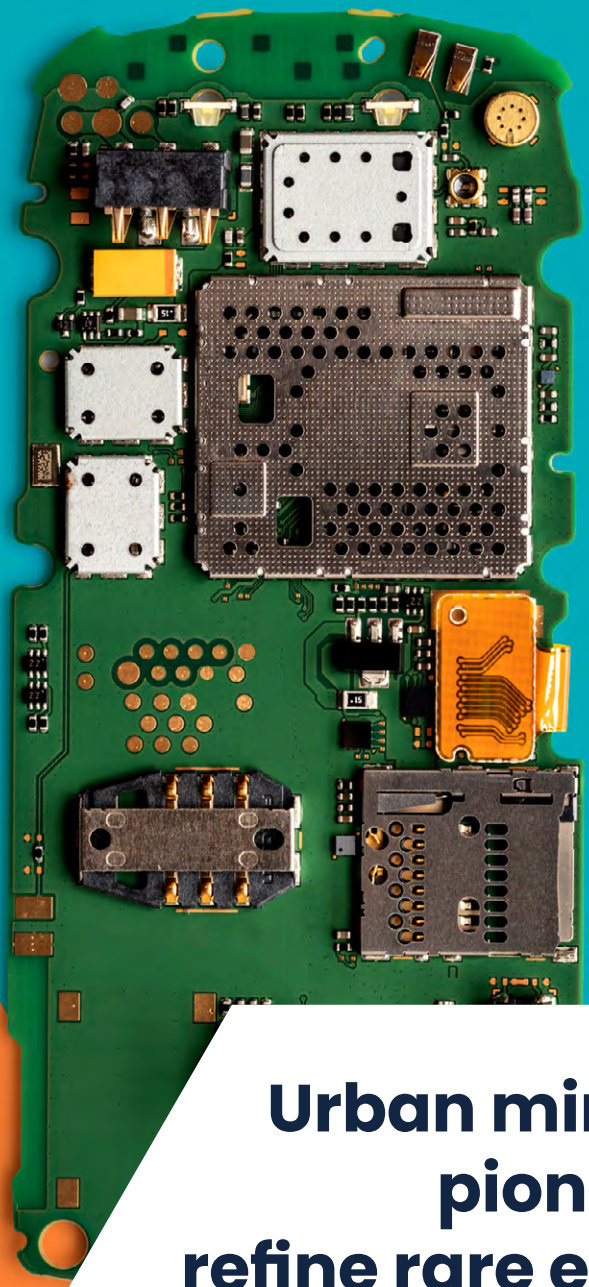

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The many benefits of resource efficiency

In today's industrial landscape, there is a growing impetus for actors to enhance resource efficiency, with some pioneers already formulating responses. Heightened awareness of the environmental impacts of resource depletion, pollution, and waste generation is driving this shift, while many also see opportunities for improved competitiveness.

As engineers, we hold a pivotal role in advancing resource efficiency. But how do we achieve this? One crucial avenue is learning from the past. When I entered the engineering scene over 20 years ago, the thumb rule was to over-dimension everything as "that is how we normally do it, and it is good to overdimension for future needs". This often led to unnecessary oversizing of systems and excessive consumption of materials without clear justification.

Another effective approach is optimizing operations. Finely tuned processes not only yield higher outputs but also produce fewer emissions with reduced toxicity. This optimization is intricately linked to ongoing learning and skill development and efficient utilization of modern control systems.

In this issue, we highlight an intriguing "urban mining" initiative. Finnish pioneers have developed an innovative method to promote resource efficiency through the recovery of metals classified as critical raw materials from electronic waste. Overall, technologies aimed at reclaiming valuable resources from waste streams and repurposing them for various applications are crucial in addressing global resource consumption. Extracting energy from organic waste through anaerobic digestion, as well as repurposing waste materials in construction projects, represents highly responsible examples of engineering fundamentals.

Recently, when a lock on my trusty old luggage broke, I chose to repair it for €40 instead of investing €500 in a new one. While the replacement lock may look different, it serves its purpose perfectly. This small decision reflects a broader mindset of resourcefulness and cost savings.

By adopting such resource-wise practices, we not only contribute to sustainability but also save significant resources and money in the process!

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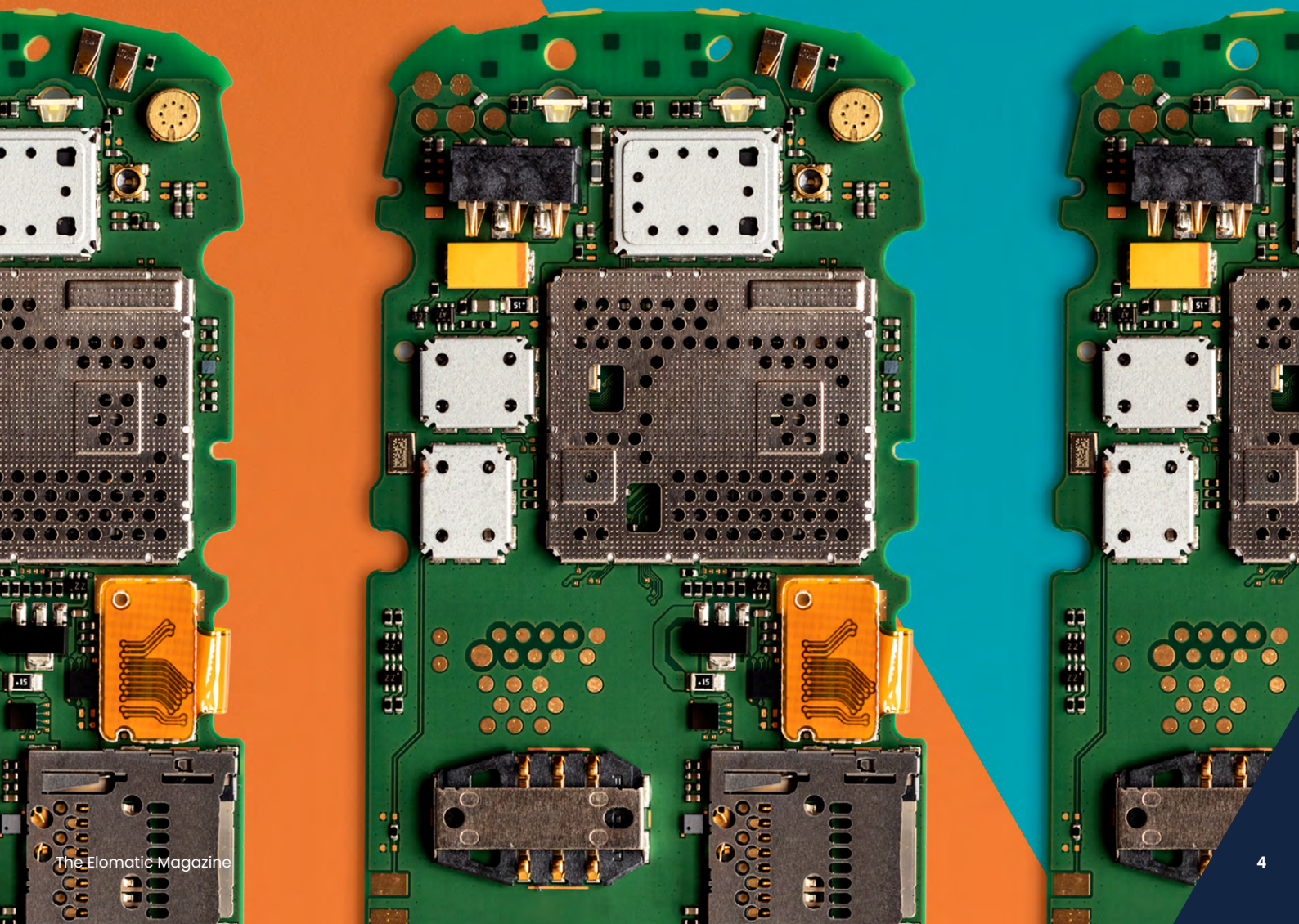
Urban mining pioneers refine rare earth metals from electronic waste

Images: iStock



A Finnish consortium has developed an innovative method for extracting rare earth metals (REEs) from electronic waste, an approach known as urban mining. This not only conserves natural resources but also reduces dependence on China. Despite current legislation not fully supporting the needs of such circular economy projects, the consortium members have diligently pushed the project forward, painting a promising picture for the future.

Urban mining refers to the extraction of metals from waste streams. This methodology not only helps to avoid environmental destruction but also significantly reduces energy consumption compared to traditional mining, with recovery rates reaching up to a hundredfold. There is a clear need for urban mining, as currently, only an estimated fifth of all electronic waste is collected and recycled.

The Finnish consortium has embarked on refining recycled materials from magnets and circuit boards, aiming for environmentally friendly and economically viable business. At the core of the consortium are the expertise of the chemistry department at the University of Jyväskylä and regional actors: energy and water company Alva, electronics producer responsibility expert Elker, and Finnish mining and factory service specialist Tapojärvi Oy.

We had the opportunity to interview Alva's Development Manager **Risto Ryymin** about their project's progress. He explains that the consortium's competitive advantage lies in a hydrometallurgical process developed by researchers over the years.

How did your project get started?

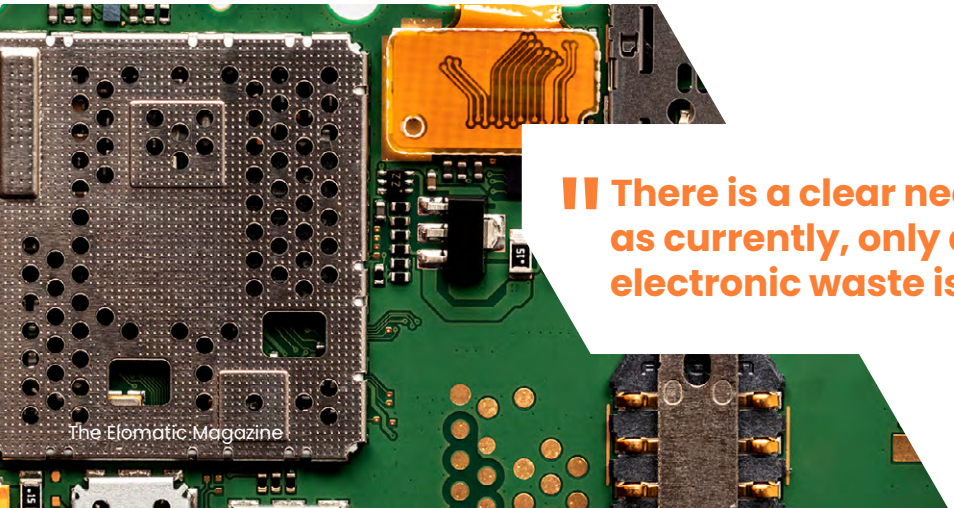
Our project began in 2010 when we conducted measurements on power plant ash with the University of Jyväskylä. We found interesting substances, such as rare earth elements, and decided to investigate whether they could also be found in peat ash. Once we confirmed their presence, we started looking into how we could recover them.

Through extraction, we realized that substances dissolve in acids in different ways, and we understood that we could recover various metals in a controlled manner. Once the method was ready, we applied for a global process patent, which is valid until the end of November 2032. At this stage, we wanted to explore whether our patent could also be suitable for handling electronic waste. We were particularly interested in selectively recovering rare earth elements – knowing that expensive metals like gold and copper could be separated due to existing demand.

Now we have a method that allows for the highly pure separation of various metals from acid solutions, suitable for recovering not only gold and copper but also REEs like germanium, gallium, indium, and neodymium.

How was your team assembled?

The University of Jyväskylä has been involved from the very beginning. Otherwise, the project has been supported by Business Finland. Elker joined through discussions with the Technology Industries of Finland, and then Tapojärvi also joined through personal contacts. We are a good trio: we are not competitors but work in



> **There is a clear need for urban mining, as currently, only an estimated fifth of all electronic waste is collected and recycled.**

> The European Union relies on external sources for critical metals, and establishing a mine takes easily over 20 years.

different industries with a common interest. We can be really open with each other, which is a very strong advantage.

Is there any similar project in the world?

We have identified a pilot project in Canada and a New Zealand startup that is planning a demo plant in Europe. They use the same type of process as us, but as far as we know, no one else is yet recovering REEs. While they are currently available cheaply on the market, it is becoming increasingly evident that as the green transition and digitalization advance, our reliance on Russian sources will be supplanted by a dependency on China. The European Union relies on external sources for critical metals, and establishing a mine takes easily over 20 years.

What stage is your project at now?

We have progressed to technology readiness levels 5–6, from static to dynamic operations. Utilizing a bench scale demo plant at the University of Jyväskylä, we can now deliver metals on a larger scale with continuous feed and processing. When we run extraction solutions, we know what is happening in them, and based on this pilot equipment, we can already say that there is no fundamental conflict that would pose insurmountable challenges for us in the future.

What are your current plans regarding the industrial-scale facility?

Our current aim is to establish a pre-commercial, technology readiness 7–8 level factory where the entire process operates seamlessly, enabling the recovery of rare earth metals and solid precious metals such as copper. At this stage, we can observe how the overall process functions and work on optimizing it. This will provide us with sufficient experience to begin planning a commercial facility. Our goal is to start construction around 2027.

We are also considering licensing our technology. Our business model will be solidified in the next phase as we conduct market analyses and determine the best revenue model.

Do you already know where you will establish the facility?

The pre-commercial facility will be located in Jyväskylä, as it is close to research facilities, and we can rely on the university for analytics and process development. The commercial facility will be situated in Finland or elsewhere in Europe – somewhere near material streams where we can accumulate the types of circuit boards we can process.

What should be considered when using waste or by-products as raw materials?

The most crucial aspect is legislation, which is tailored to the needs of a linear economy and does not yet fully consider the principles of circular economy. According to the law, a raw material is either material or waste, and unfortunately, in our case, it is classified as waste. For example, if you throw away a functional mobile phone into the trash, it becomes waste, and if someone wanted to utilize its raw materials, they would be classified as waste as well. This complicates the utilization of electronic waste and imposes numerous administrative obligations on us, which undermine the profitability of our operations.

Circular economy projects also involve multiple stakeholders, which slows down decision-making, as decisions need to pass through several administrations. Our goal is to establish a startup that provides relief in this regard and facilitates ensuring that intellectual property rights are always retained.

Have you encountered any other challenges during your journey?

So far, we haven't encountered major challenges, but this journey has been a learning experience for us as well: the most challenging aspect has been challenging our own thinking as we engage in work that deviates from the norm. However, learning something new is also interesting, I must admit.

What kind of partners have you had to assist you?

We have had two crucial partners right from the beginning: Jyväskylä University, which has focused on theoretical research, and the engineering and consulting firm Elomatic, from whom we have received highly professional assistance in practical process planning and organizing tasks. Since no one in our consortium has expertise in chemistry, their support has been invaluable.

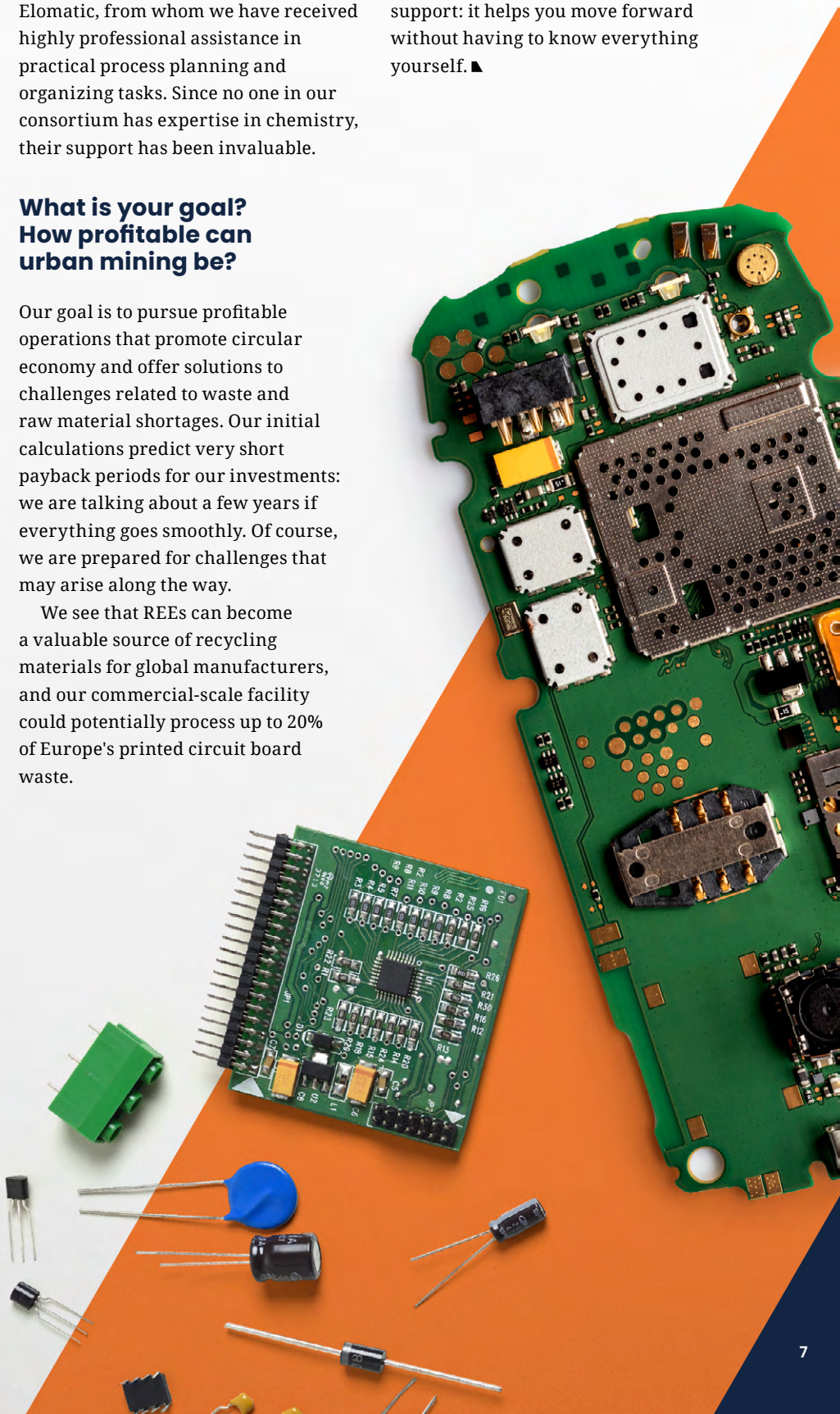
What is your goal? How profitable can urban mining be?

Our goal is to pursue profitable operations that promote circular economy and offer solutions to challenges related to waste and raw material shortages. Our initial calculations predict very short payback periods for our investments: we are talking about a few years if everything goes smoothly. Of course, we are prepared for challenges that may arise along the way.

We see that REEs can become a valuable source of recycling materials for global manufacturers, and our commercial-scale facility could potentially process up to 20% of Europe's printed circuit board waste.

What tips would you give to others advancing circular economy projects?

First and foremost, believe in your cause, even if things don't always go as planned right away. It is also important to build a network of partnerships for support: it helps you move forward without having to know everything yourself.



The increasing significance of critical raw materials

As we pivot away from fossil fuels towards cleaner energy systems, adept utilization and management of materials become increasingly important. For instance, the expansion prospects of many key technologies face constraints due to the escalating demand for critical raw materials. Concurrently, waste and by-products are emerging as noteworthy reservoirs of raw materials, underscoring their newfound significance.

Text: Teemu Turunen
Images: Elomatic, iStock

> **17 out of the 34 identified critical raw materials have been classified as strategically important: their demand is increasing while their risk of supply disruptions is assessed as higher.**

As technological advancements progress, the demand for new types of raw materials continues to grow. To anticipate future needs, the European Union has launched the Raw Materials Initiative (RMI) program, designed to tackle raw material-related challenges at the EU level. As part of this initiative, a procedure for defining critical materials has been established. Criticality assessment considers various factors, with a primary focus on both the risk of supply disruption and the economic significance of the raw material.[1]

34 critical raw materials

According to the EU criteria, 17 out of the 34 identified critical raw materials have been classified as strategically important: their demand is increasing while their risk of supply disruptions is assessed as higher. The list includes common raw materials such as copper and aluminum (see figure below).

It is important to note that classifying a raw material as non-critical does not mean that its availability and significance to the EU economy can be ignored. Increasing knowledge and potential developments in EU and global markets may affect the list of critical raw materials in the future.[1]

Impact of geopolitical tensions

When assessing future trends and needs, it is crucial to understand that geopolitical competition for critical raw materials is increasing. Logistics chains are global, and the EU finds itself increasingly competing for limited resources with China, the United States, and the global South.

The EU has taken notice of the situation, and in November 2023,

EU-defined critical raw materials (strategic raw materials in pink).[1]

preliminary agreement was reached on EU legislation concerning critical raw materials. It aims to achieve the following impacts[1]:

- Increase and diversify EU's critical raw material supplies
- Strengthen the circular economy and recycling
- Support research and innovation on resource efficiency and development of substitute materials
- Strengthen Europe's strategic independence

A broader EU goal by 2030 is to reduce its dependence on third countries for critical raw materials[1]. The objective has been concretized into four sub-goals, as presented in table.

How to prepare for risks associated with critical materials?

In a study conducted by Germany's Federal Institute for Geosciences and Natural Resources (BGR) and PriceWaterhouseCoopers (PwC), an analysis was conducted on how non-German companies secure their raw material supplies. The study also focused on the strategies currently employed by these companies and their intentions for future use, as well as the opportunities and challenges associated with these strategies. The following 11 raw material strategies were identified in the study[3]:

- Commodity price hedging
- Passing on increased raw material prices to the customer
- Storage
- Diversification of suppliers
- Long-term contracts
- Procurement groups consisting of a few companies
- **Improvement of material use**
- **Recycling**
- **Material substitution**
- Vertical integration
- IT solutions in decision-making

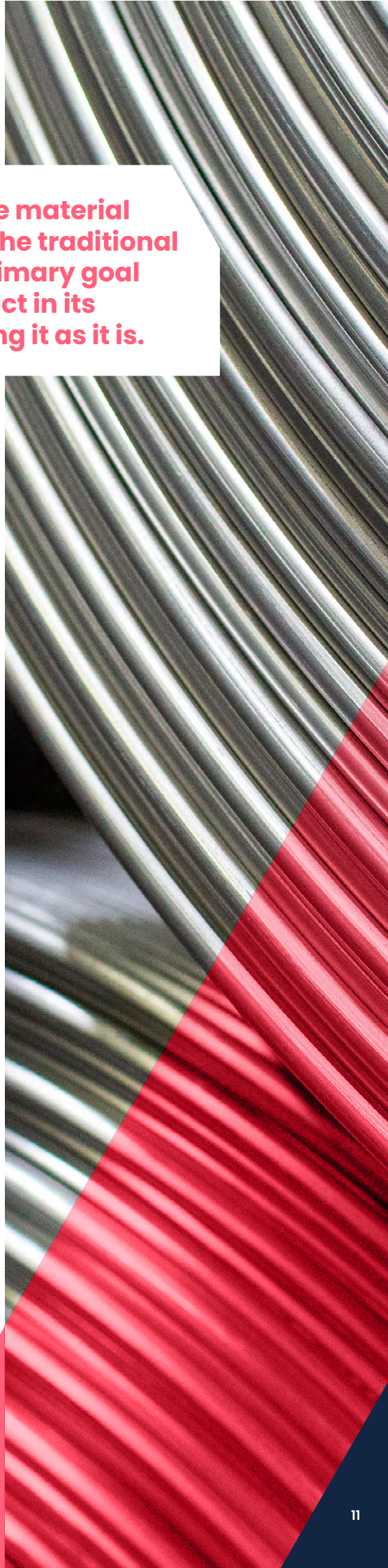
As noted above, some strategies focus on stabilizing prices or contractually preparing for uncertainties.

Extraction in the EU:
At least 10% of the EU's annual consumption comes from extraction within the EU
Processing in the EU:
At least 40% of the EU's annual consumption comes from processing within the EU
Recycling in the EU:
At least 25% of the EU's annual consumption comes from recycling within the EU
External Sources:
No more than 65% of each strategic raw material's annual consumption in the EU at any relevant processing stage may be based on imports from any single third country

EU goals to reduce its dependence on third countries for critical raw materials[1]

Watch video: Key technologies constrained by rising demand for critical raw materials (duration: 37 seconds)

Key technologies identified by the European Commission, whose growth opportunities are increasingly constrained by the growing demand for critical raw materials.[2]



> **It is essential to promote material recycling according to the traditional waste hierarchy. The primary goal is to maintain the product in its original form by recycling it as it is.**

However, it is essential to increase self-sufficiency concretely. Therefore, key strategies include improving material use, recycling, and material substitution.

The many opportunities of design and recycling

A critical moment for effective material use and substitution with less critical alternatives occurs during the design phase. At this stage, it is possible to influence both the product or solution itself and its entire value chain.

It is essential to promote material recycling according to the traditional waste hierarchy. The primary goal is to maintain the product in its original form by recycling it as it is. If this is not possible, efforts should be made to recycle the components of the product. If these are not feasible, the next option is material recycling, with energy use as the very last resort.

These methods are not mutually exclusive; on the contrary, it is essential to promote industrial recycling and industrial symbioses. In this way, sufficient scale can be achieved, and operations become efficient and profitable.

Teemu Turunen
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Teemu has extensive experience in energy and process consulting in several industries. He currently works as Business Development Director in the energy and process business area. His focus is to lead the development of sustainable solutions for future needs..

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Design Manager Marko Jaakonmäki: “Digitalization will take resource efficiency to a new level”

Elomatic's visualization team leader Marko Jaakonmäki sees digitalization as a key factor in moving towards a carbon-neutral circular economy. He predicts a new divide in the industry: companies that can quickly adopt new technologies will thrive, while those with low levels of digital maturity will lose market share.

Images: Elomatic

You have been working at Elomatic for 22 years. What has kept you here for so long?

I have always been given interesting tasks, and they have also changed every two to five years. In a way, I have had several careers within the realms of mechanical design, people management, and business development during my time here. Also, my supervisors have always been good, and I have tried to pass on the same mentoring approach by teaching young engineers and supporting their progress. I am not afraid that one day they will replace me, but I even hope that one of them will advance in their career higher than I have.

What developments do you anticipate in industrial digitalization in the near future?

At the moment, there are tremendous leaps in artificial intelligence. Generative AI is evolving faster than any technology has ever evolved and is about to start developing itself. I believe a major background factor in this is the development of quantum computers, and their computing power is already huge. According to some studies, they may be available to consumers in five to seven years. Just by combining these two technologies, you can create tremendous scenarios.

This inevitably leads to a redistribution in the industry: companies that agilely adopt new, disruptive technologies will capture even larger shares of their business sector. In contrast, companies with very low digital maturity will lose market share and eventually wither away.

What do you think about the development of the industrial metaverse?

In practice, all cloud-based business is metaverse business, and it will grow as companies rapidly move their data to cloud servers. Metaverse business was expected to grow with XR technologies on the consumer side, for example by Apple and Meta, but this has not yet happened.

According to several estimates, metaverse business will start to grow in the coming years through the industrial metaverse. Companies will begin to utilize data transfer, analysis, and simulation more effectively to maintain their competitive advantage. It is also predicted that new, previously unreachable sources of value will be found in cloud services by combining point cloud, 3D and other data sources.

There is now a major shift in industry towards a carbon-neutral circular economy. How does it manifest in your work?

First of all, it is evident that in the EU area, regulation governs energy policy and carbon dioxide emissions are now being reduced by all means. And even though this may not be visible in the work of our 3D artist, it is visible on my desk: I have to carefully look at how legislation affects our work.

In addition, many startups in the renewable energy sector approach us now with visualization requests. We assist them in persuading investors of their novel technologies by digitally bringing their innovations to life.

A really big theme that affects many global companies is how people are transported around the world. Work is increasingly moving towards remote work, and virtual environments are good tools for that. We can use them to support our customers in, for example, reducing air travel. Gradually, companies are also adopting virtual prototypes, or digital models, to increase productivity in manufacturing, installation, and logistics operations.

Could you elaborate further on the benefits that digital models provide?

Digital models enhance business visibility as data is retrieved from machines to cloud servers for analysis using machine learning and artificial intelligence. This improves transparency and facilitates decision-making by simulating the impacts of different decisions on production and overall operations.

Virtual factory prototypes enable testing of factory operations already during product development, leading to reduced time-to-market and overall

costs. This was previously either impossible or prohibitively expensive. Additionally, digital factories enhance equipment usage and safety, eliminate errors from processes, and ease factory deployment and production optimization.

Our product, Virtual Factory, provides a comprehensive overview of processes and a visual twin to support all operations: from safety management and maintenance to tendering, change implementation, and training. The aim is to enhance business autonomy and productivity by assigning machine tasks to machines and human tasks to humans, such as overseeing and problem-solving.

Can you give an example of how digital models help improve resource efficiency?

They help identify bottlenecks in a company's operations and processes, which can be optimized to improve resource efficiency. In practice, digital models enable automatic monitoring of safety deviations. For example, an unforeseen disruption in a paper machine situation costs enormous sums when trying to determine the cause and production stops.

With the Virtual Factory model, the fault notification includes information about the location of the faulty valve, the storage location of the spare part, and the correct maintenance manual. Once sufficient data has been gathered, AI can predict potential disruptions before they occur, offering users guidance for proactive control or scheduling maintenance.

In the future, even greater value will be derived, particularly through the convergence of simulations, data, and 3D models, leading to the emergence of new types of reactive 3D simulation models. These models will be instrumental in optimizing energy consumption, reducing carbon dioxide emissions, enhancing resource management, and maximizing economic profitability.

In the future, it will even be possible to develop digital twins of factories. What additional value do they provide?

According to Nvidia's prediction, every factory will have a digital version. Such a digital factory can contain all the data related to the company's operations, and its business benefit will be enormous because all business processes can be intersected through digital twins.

Through data intersection, a situational understanding of the process is created, which identifies business pain points. With simulation environments and more transparent business, product development solutions and the effects of factory changes can be tested before the changes are implemented. This also shows where the next bottleneck is likely to occur.

What threats do you see in the development of digitalization?

As the computing power of quantum computers grows, the level of cyber-security deteriorates, as previously unbreakable encryption can be broken. Cybercriminals, together with high computing power and advanced AI, are worrying. Of course, companies' cybersecurity is also developing in the same way, but some companies are falling behind in this development.

I also see a threat in the increasing power of multinational corporations. Some companies are already more influential than small countries. For instance, companies like Tesla, Google, and Meta have established their own AI divisions. Should they attain a dominant position, it would profoundly influence the competitive landscape.

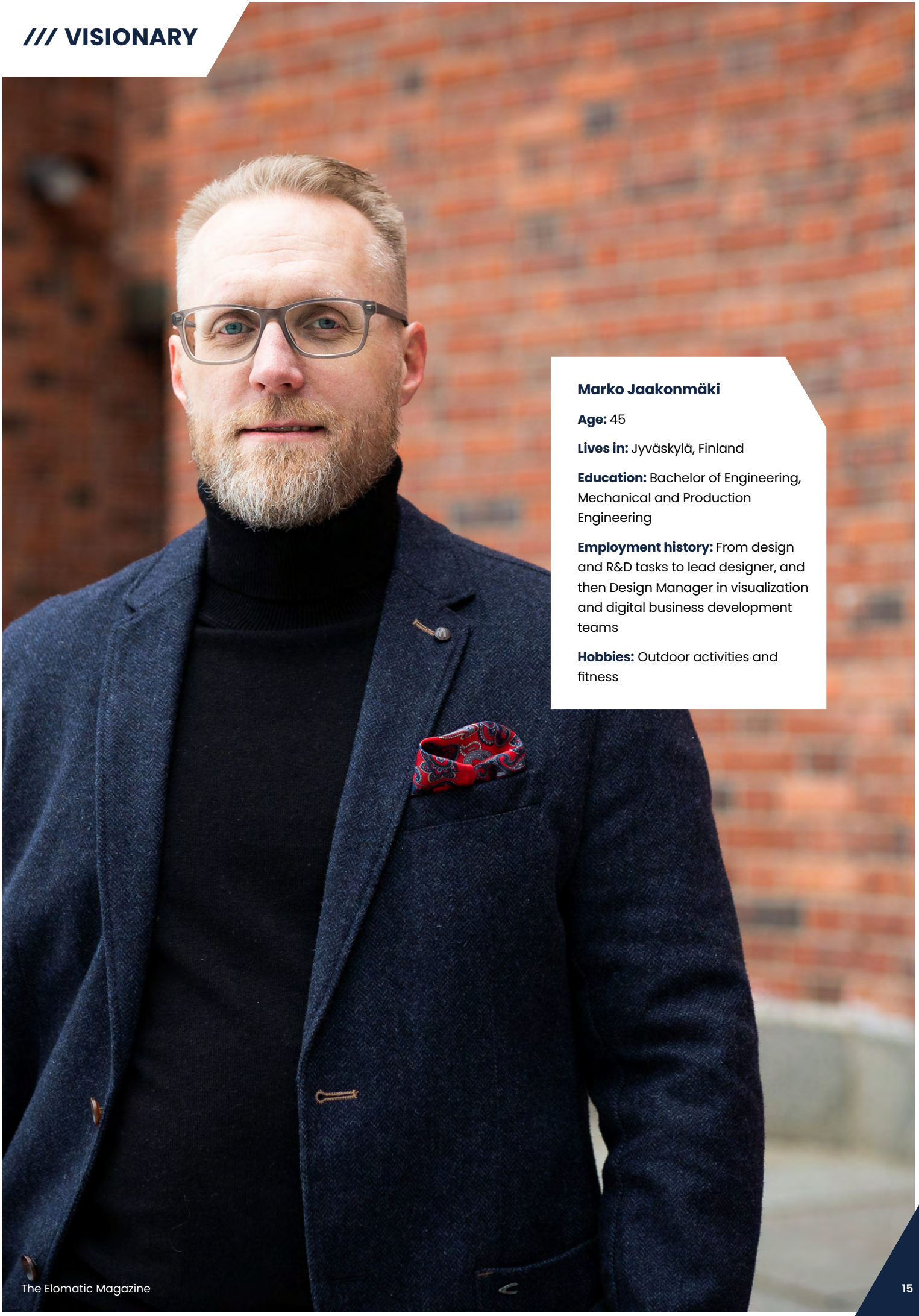
All of this raises big questions: Who will own AI in the future and who will be allowed to use it? At what level will all this happen? A large part of companies don't have the capability to use digital technologies in their operations, let alone disruptive technologies.

What innovations do you expect to see in the industry in the coming years?

I anticipate a surge in the adoption of robotics and AI within factories, leading to heightened human-machine interaction. Tesla, for instance, has already introduced a humanoid robot, albeit one without communication capabilities. As technology advances, the collaboration and communication between humans and robots are poised to reach unprecedented levels.

Factory autonomy will also increase, and employees no longer need to be stationed alongside production lines. Instead, maintenance robots and self-monitoring facilities will manage operations. Consequently, remote production work will become a viable option.

Additionally, I want to highlight the growing importance of augmented reality applications in factory environments, as the development of transparent XR glasses is now tremendous. Previously, when you put on such glasses, you ended up in a closed virtual space. Nowadays, their elements merge with the real world, offering a genuine augmented reality experience. Moreover, their usability has taken great leaps forward, and they are already very intuitive to use.



Marko Jaakonmäki

Age: 45

Lives in: Jyväskylä, Finland

Education: Bachelor of Engineering, Mechanical and Production Engineering

Employment history: From design and R&D tasks to lead designer, and then Design Manager in visualization and digital business development teams

Hobbies: Outdoor activities and fitness

From idea to production in less than two years:

Hailia devised a way to upcycle surplus fish raw materials into delicious everyday food

Images: Hailia, iStock

Hailia's Managing Director Michaela Lindström, Production Director Taina Lahtinen, and Chief Technology Officer Otto Kaukonen.

The technology developed by Finnish startup Hailia offers an ecological alternative, for example, to tuna or minced meat. It enables the transformation of small pelagic fish or sidestreams from fish filleting, typically used as feed for livestock, into versatile food products. The company's future plans include entry into international markets.

Hailia's co-founders were working in the plant-based protein sector when they came up with the idea to build a business around herring. "Although being Finland's most abundant catch, Baltic herring is underutilized as a food source, despite its excellent nutritional value and low carbon footprint," says Hailia's Managing Director, **Michaela Lindström**.

"Herring fishing benefits the Baltic Sea by reducing nutrient levels. Currently, over 80% of the fish consumed in Finland is imported," she adds.

Following the footsteps of plant-based protein sector

Hailia started building upon the research conducted at VTT Technical Research Centre of Finland.

"We were inspired by VTT's pulled herring project and liked the idea that we need to package the raw material in a form that is easy, quick, and simple to use," Lindström explains the concept.

Hailia decided to utilize all parts of herring under 15 cm in length that are usually used as feed, except for the heads and guts. One of the ingredients is oats. "The core of our product is the ability to create a texture similar to cooked fish fillet, without fishbones disrupting the mouthfeel," Lindström reveals.

Customer meetings from the outset

Once Hailia's founders had secured investors and began advancing the project, they developed the idea and met with potential customers. "We aimed primarily at public sector kitchens. We wanted to offer them products that could replace red meat and imported fish like tuna," Lindström specifies.

When the grants from the Centre for Economic Development, Transport and the Environment (ELY Centre) were secured, it was time to kick off the production planning process. Hailia chose Elomatic as their partner to assist in this undertaking, citing

the company's extensive expertise.

"Elomatic offered a wide range of services under one roof, from HVAC and electrical design to hygiene consulting. They were involved from preliminary planning to implementation and provided versatile assistance in documentation and bid preparation as well," Lindström notes.

Value of expert guidance during unexpected obstacles

Hailia's intention was to acquire premises from the coastal town of Uusikaupunki. "We began outlining what changes were needed in the vacant factory property in Uusikaupunki and what the layout of the facility should be like. Additionally, we started surveying equipment suppliers and process options," Elomatic's Project Manager **Taneli Arola** explains.

As the work progressed and the electrical work was already underway, the property suddenly caught fire, leaving the entrepreneurs with no choice but to search for new premises. To their fortune, Elomatic stepped in to assist during this unforeseen situation. Eventually, they found a suitable old food factory in Karkkila.

"In the Karkkila property, we conducted surveys into aspects such as refrigeration systems and ventilation. Additionally, we acted as technical experts towards the property owner and arranged for a third-party condition assessment of the property before confirming that the premises were suitable," recalls Arola.

Benefits of visualization

Arola tells that while Elomatic's experts engaged in discussions with equipment suppliers, considered hygiene issues, and developed the process with Hailia, they also needed to capture the big picture on paper.

"When there is even a checkmark on the paper, it is easier to discuss. We had to understand how production works when building something entirely new – not just the physical systems, but also how people operate, how waste flows, and how to maintain an adequate level of hygiene," explains Arola.

Elomatic also implemented mobile scanning in the empty premises. According to Arola, it was a cost-effective way to avoid unnecessary travel, as "there's always one critical photo missing during site visits."

> **Currently, over 80% of the fish consumed in Finland is imported.**

Production currently operating at full capacity

Lindström reveals that scheduling challenges persisted even after the COVID-19 pandemic. Additionally, the later-retracted proposal by the EU Commission to ban herring fishing caused a slight delay in the launch. However, today the factory is in full production, and the company operates independently without Elomatic's assistance.

"Many have wondered how, less than two years ago, we had an idea, and now we have a factory running and our product has been launched to the market," Lindström tells.

Lindström cites smooth communication as one of the project's success factors: "We were in contact weekly, sometimes daily, for a year and a half, and it felt like Elomatic's experts were part of our team. We were also able to leverage their networks," she describes.

> **When there is even a checkmark on the paper, it is easier to discuss. We had to understand how production works when building something entirely new.**

"Working was easy because we were on the same wavelength the whole time and maintained a good atmosphere on both sides," Arola agrees.

Big plans

Lindström doesn't shy away from the company's ambitions: "We have big plans because we know there is demand for our technology and expertise. We know there are no similar companies worldwide."

Arola states that the guiding principle throughout the project was minimizing waste: finding the middle ground that achieves crucial product safety in the food industry while considering investment costs and ensuring smooth operation in the factory's daily routines.

Lindström emphasizes that just as Elomatic has been an extremely important partner for them, all of their employees have been important players throughout the journey: "We have created a new fish product suitable for a variety of dishes, from soups to lasagna to pizza. We wouldn't have achieved this alone."

Michaela Lindström, Taina Lahtinen, Minna Kaunisto and Otto Kaukonen in Karkkila production facility.

A transformative shift in the pharmaceutical industry:

Resource efficiency with single-use equipment

Text: Mona Åkerholm
Images: Elomatic, iStock

In recent years, the global pharmaceutical industry has faced increasing pressure to minimize its environmental footprint while maintaining the highest standards of product quality and safety. One innovative approach gaining traction is the adoption of single-use equipment in pharmaceutical production processes. This shift not only enhances efficiency and flexibility but also significantly reduces resource consumption and waste generation.

Traditional pharmaceutical manufacturing relies on stainless steel equipment that requires extensive cleaning, sterilization, and validation between batches. This process consumes substantial amounts of water, energy, and chemicals while generating significant wastewater and carbon emissions. Additionally, the long lead times and high capital investments associated with stainless steel equipment can hinder agility and scalability in production.

By contrast, single-use equipment offers a compelling alternative. These disposable components, such as bags, filters, tubing, and connectors, are designed for one-time use and then safely disposed of or recycled. This eliminates the need for cleaning and sterilization, streamlining production workflows and reducing downtime between batches. Moreover, single-use systems are modular and scalable, allowing pharmaceutical companies to adjust production capacity more rapidly in response to market demand.

Let's take a closer look at how adopting single-use equipment can pave the way for a more sustainable future in pharmaceutical manufacturing.

Reducing resource consumption

One of the most significant advantages of single-use equipment is its ability to conserve resources throughout the production lifecycle. Traditional stainless steel systems require large quantities of water for cleaning and sterilization, contributing to water scarcity and wastewater pollution. By transitioning to single-use solutions, pharmaceutical manufacturers can drastically reduce water consumption, alleviating environmental pressure and minimizing operational costs.

Furthermore, the energy-intensive nature of stainless steel processing contributes to greenhouse gas emissions and climate change. Single-use equipment requires less energy for operation, as it eliminates the need for heating, cooling, and running complex cleaning cycles. This results in lower

> **"Traditional stainless steel systems require large quantities of water for cleaning and sterilization, contributing to water scarcity and wastewater pollution.**

> **Single-use systems offer inherent advantages in terms of sterility and cross-contamination control.**

carbon emissions and a reduced environmental footprint, aligning with global efforts to combat climate change and promote sustainable practices.

Impact of single-use equipment on waste reduction

Another compelling benefit of single-use technology is its ability to minimize waste generation throughout the manufacturing process. Stainless steel equipment generates significant quantities of wastewater and chemical waste during cleaning and sterilization cycles, posing environmental risks and disposal challenges. In contrast, single-use components are disposed of after a single use, reducing the volume of waste generated and simplifying disposal procedures.

Moreover, the modular design of single-use systems enables more precise control over material usage, minimizing overages and reducing the likelihood of product loss or contamination. This not only enhances product quality and safety but also optimizes resource utilization, maximizing efficiency and cost-effectiveness in pharmaceutical production.

Opportunity for designing modular cleanrooms

Single-use equipment usually requires a smaller footprint in the manufacturing suite. A smaller footprint makes it possible to design and deliver modular cleanrooms. Modular cleanrooms can be manufactured at the factory and require only a small amount of installation work at the site.

For example, the Naya Cleanroom factory mainly runs on solar energy, and its production aims to minimize and reuse the waste generated. Less traveling for installation and shipment to the site will add to the decreased impact on the environment.

The largest energy consumers in a pharmaceutical manufacturing suite are the ventilation and the generation of clean utilities. The smaller footprint of the cleanrooms decreases the needed amount of air circulated, and smaller consumption of clean water and steam will decrease the energy needed for producing them. Energy-efficient production is crucial for the sustainability of the pharmaceutical industry.

Ensuring compliance

One common concern associated with single-use technology is its impact on regulatory compliance and product quality. However, modern single-use systems undergo rigorous testing and validation to ensure they meet the highest standards of safety, purity, and performance. Regulatory agencies, such as the FDA and EMA, provide guidelines and requirements for the implementation of single-use technology in pharmaceutical manufacturing, ensuring adherence to Good Manufacturing Practices (GMP) and other regulatory standards.

Furthermore, single-use systems offer inherent advantages in terms of sterility and cross-contamination control. With disposable components, the risk of microbial contamination is significantly reduced, enhancing product integrity and patient safety. Additionally, single-use technology enables more frequent equipment changeovers, minimizing the potential for product carryover and ensuring batch-to-batch consistency and reproducibility.

Empowering sustainability

The adoption of single-use equipment offers a sustainable solution to resource conservation, waste reduction, and operational efficiency. By embracing single-use technology, pharmaceutical manufacturers can minimize their environmental footprint, enhance regulatory compliance, and deliver high-quality products to patients worldwide.

As the industry continues to evolve, the widespread adoption of single-use systems will play a pivotal role in shaping a more sustainable future for pharmaceutical manufacturing.

Mona Åkerholm
M.sc.,
eMBA, IPMA B, HHJ

Mona oversees the Pharma business unit at Elomatic, leading a team of 200 professionals with vast expertise in engineering, project management, and consulting for the pharmaceutical industry. Mona has worked in the industry for 25 years, primarily focusing on the execution of small and large-scale investments.

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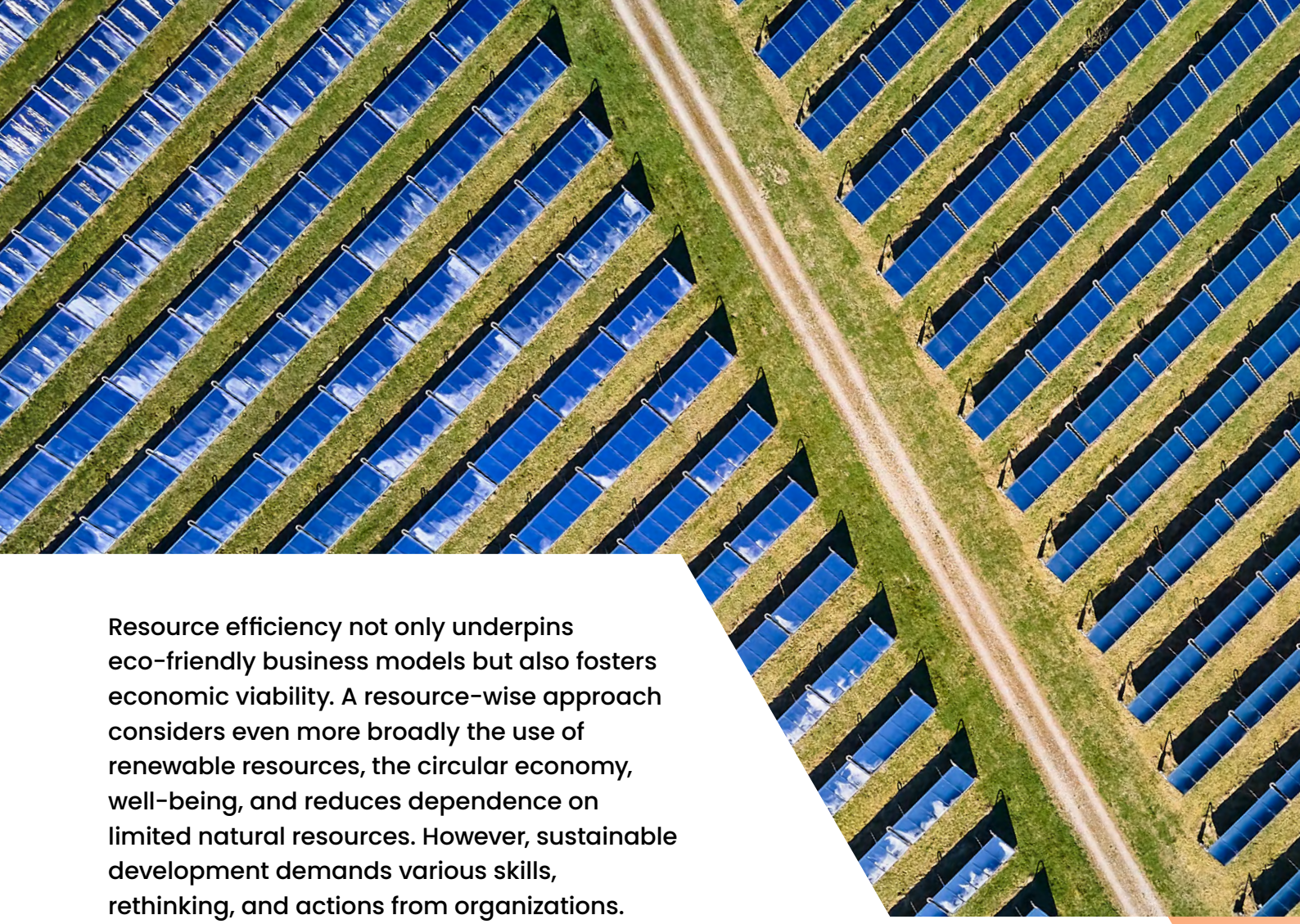
Resource wisdom

– The path to the core of responsible innovation

Text: Mika Patrakka
Images: Elomatic, iStock



Resource efficiency not only underpins eco-friendly business models but also fosters economic viability. A resource-wise approach considers even more broadly the use of renewable resources, the circular economy, well-being, and reduces dependence on limited natural resources. However, sustainable development demands various skills, rethinking, and actions from organizations.

Resource efficiency entails optimizing the use of resources such as raw materials, energy, and water in products, production, and services. The goal is to produce more with less, achieving greater value with lower resource consumption. This is not just an ecological choice but a strategic and economic decision that can lead to significant savings and even innovations.

Resource wisdom goes beyond resource efficiency, as the resource-efficient model aims to use only one resource at a time as efficiently as possible. It looks at resource consumption on a societal level to achieve the best overall outcome, as resource use affects the environment, society, and future generations (see next page).

Importance of resource wisdom for businesses

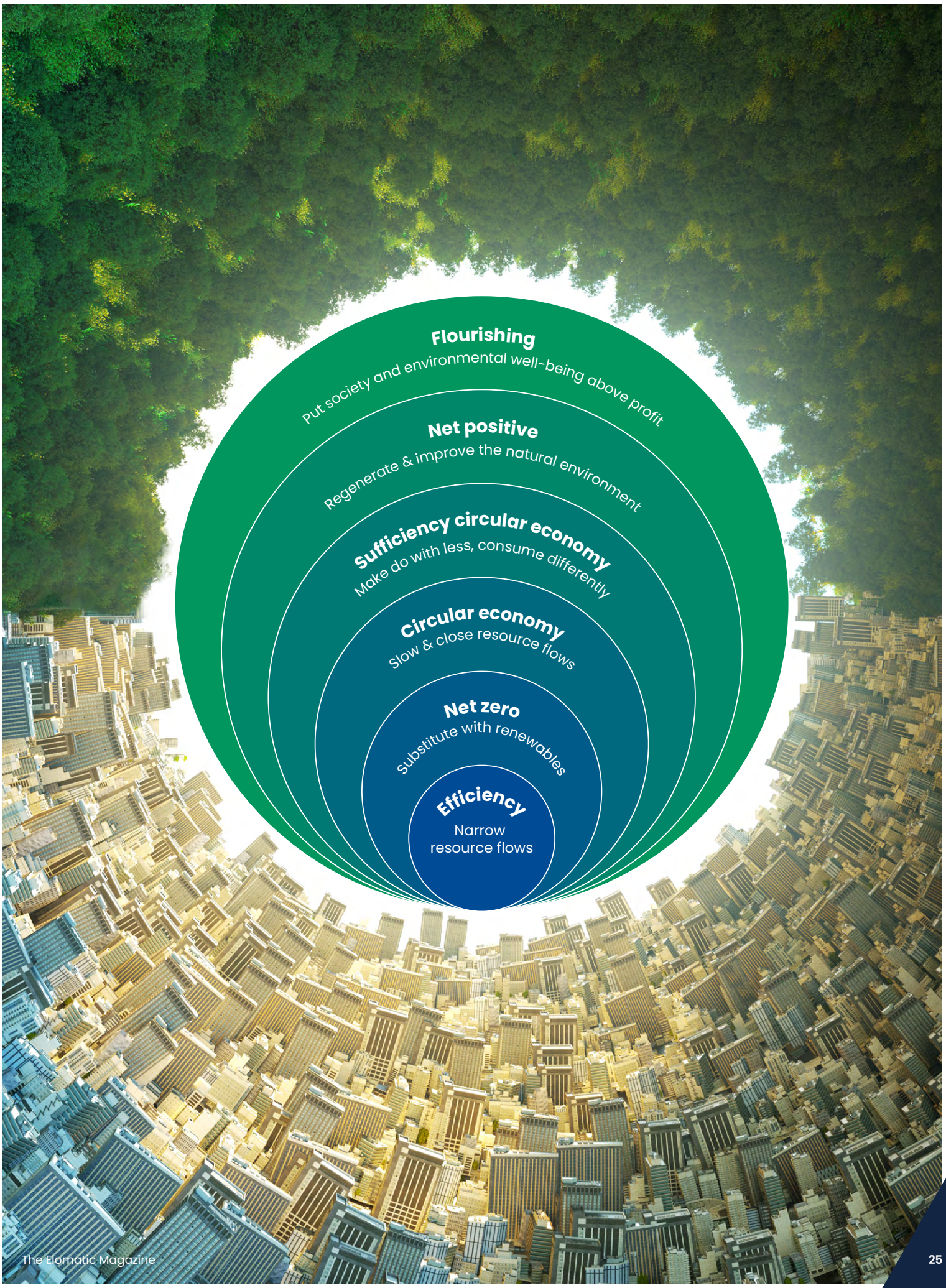
In today's fast-paced and resource-limited world, the importance of resource wisdom becomes increasingly crucial even in machine and equipment manufacturing businesses. The benefits of resource wisdom include:

- **Cost savings and efficiency:** By using resources more efficiently, companies can reduce costs, especially for raw materials and energy. This can lead to significant savings and enhance a company's competitiveness.
- **Promoting innovation and competitive advantage:** Focusing on resource efficiency encourages innovation in production processes and products. This helps companies differentiate themselves in the market and offer customers new and sustainable alternatives.
- **Reducing environmental impacts:** More efficient and wiser resource use reduces environmental burdens, which is crucial for mitigating climate change and ensuring sustainable use of natural resources.
- **Enhancing responsibility and improving corporate reputation:** Increasing awareness among customers and investors about environmental issues has put pressure on companies to act responsibly. Resource efficiency is an effective way to demonstrate commitment to sustainable development principles, not to mention resource wisdom.

From optimization to radical innovations

Resource efficiency often involves optimization, which means making things slightly better. However, significant challenges cannot be solved by doing a little; instead, a vision, desire, and ability to change the way of working and create something new are required. The best results are achieved when cause-and-effect dynamics are analyzed and the best course of action for the entire order-to-delivery chain is carefully weighed.

Toward a new sustainable society (The Sufficiency-Based Circular Economy — An Analysis of 150 Companies, 2022)



To ensure vitality, radical innovations, such as technology that produces protein from the air, are needed, as new economic models based on the circular economy and renewable economy require them. They can be risky, but they have the potential to create significant value and competitive advantage. It is also essential to remember that radical innovations require patience, and action must be taken immediately because the spread of innovation requires will, time, and resources!

Implementing resource efficiency in practice

To achieve effective resource management, companies need to assess their entire value chain. It is not enough to evaluate just one aspect; instead, all actors and practices in the value chain must be examined.

1. Start with value chain analysis.
By understanding where resource consumption is highest in the value chain, it is possible to identify areas where efficiency can be improved. Tools such as value stream mapping or GAP analysis can help with this. Productivity does not improve merely by adding resources; instead, a change in working methods enables productivity leaps by increasing value added in the input-output ratio. One of the Lean principles is waste elimination, and I think its importance is emphasized in resource efficiency.

2. Understand cause-and-effect relationships.
It is worth investing in understanding cause-and-effect relationships because saving resource in one place can easily mean wastage in another. This can be approached and reflected, for example, by considering:

- What changes need to be made in different parts of the supply chain?
- What requirements does it create?
- What new approach does it require?

> **To ensure vitality, radical innovations, such as technology that produces protein from the air, are needed.**

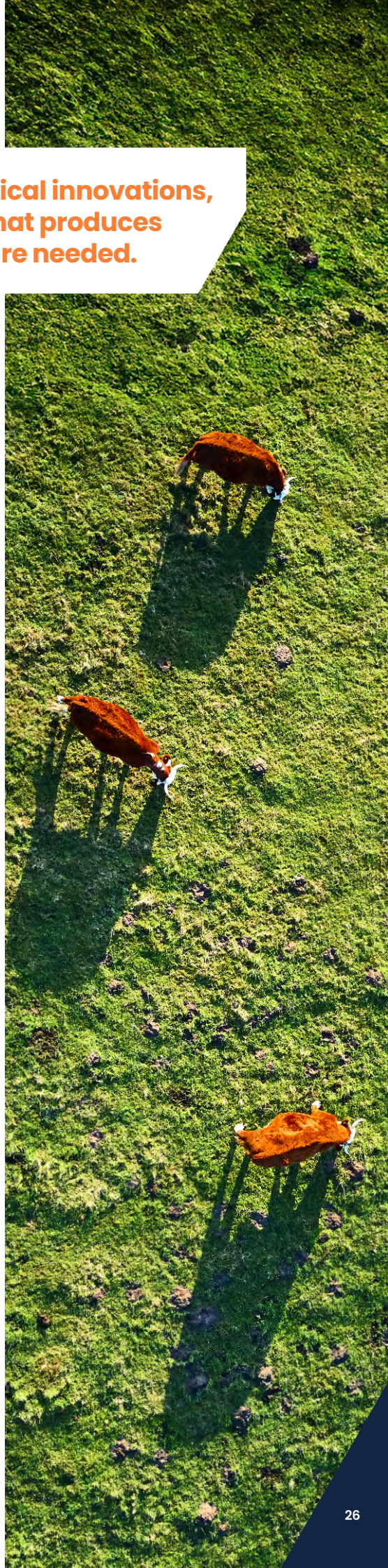
3. Leverage technology.
Modern technology, such as artificial intelligence, increases efficiency and reduces resource use. Efficient resource development is, in fact, the most demanding work because the goal is to manage with as few resources and operations as possible. There are also technologies, such as additive manufacturing, that enable completely new shapes and structures to be achieved, resulting in almost no material waste.

4. Build collaboration and partnerships.
Collaboration with suppliers and other stakeholders can help find more sustainable solutions and promote common resource efficiency goals. By leveraging the by-products of the circular economy, significant savings can be achieved both in production and mineral extraction, to mention an example.

5. Continuously monitor and evaluate the results.
Promoting resource efficiency is a continuous process that requires regular monitoring and evaluation of operations. Continuous improvement and an open and curious attitude enable finding new ways.

Tools, rethinking, and courage towards wise solutions

Pursuing an ideal solution does not mean that a perfect solution is always achievable. Instead, it serves as a good guideline and motivator, encouraging creative thinking. At the core of innovation activities is solving problems in a way that meets all needs without compromise or negative side effects. Identifying conflicts is important to keep in mind all the time, and only



> **Pursuing an ideal solution does not mean that a perfect solution is always achievable. Instead, it serves as a good guideline and motivator, encouraging creative thinking.**

examining cause-and-effect relationships enables the creation of resource-wise and sustainable solutions.

- Lifecycle thinking must be considered throughout product development, from raw material procurement to manufacturing, use, and finally recycling or disposal. This approach helps identify all stages where resources can be used more efficiently.
- Ecological design and design methods help focus on minimizing the environmental impacts of products. This may include material efficiency, energy efficiency in production and during use, and considering the longevity and repairability of products. Similarly, it is good to use design methods that support resource efficiency, such as Design Thinking or the TRIZ method.
- Modular and sustainable design produces modular products, making it easy to repair or replace parts without replacing the entire product. Sustainable design also includes choices that extend the product's lifespan and reduce its environmental impacts.
- The use of renewable materials should be explored, utilizing more sustainable materials that can reduce environmental impacts or improve resource efficiency. This may include recycled or renewable materials.
- Managing cause-and-effect relationships is emphasized, and the goal is to understand how different factors affect each other and outcomes to make better decisions and manage risks more effectively. When aiming to develop products in line with sustainable development, it is important to strive for a comprehensive view. Several conflicts are easily encountered in the examination, which, when solved, result in sustainable solutions.

Resource-wise development brings true benefits

It is easy to create complex products or heavy processes that consume resources because their design doesn't require much creativity. However, the mindset of "everything is always available and we settle for the first ideas" distances us from creativity. Therefore, investment in innovation thinking is essential. We must be able to search for ideal solutions to real problems and goals with minimal resources.

Multiple actions and approaches are needed to integrate resource efficiency into product development to ensure that products are designed and manufactured with minimal environmental impact and resource use. The benefits attainable are significant: real environmental and societal well-being and a regenerative and flourishing future.

Mika Patrakka
(B.Sc.)

Mika works as a Business Development Manager in the Machinery and Equipment business unit. He has more than 10 years of experience in various roles in design, development and management. Mika promotes sustainable growth and the development of products and services and helps companies create circular economy-based business and strategies. His development philosophy is guided by the growth mindset and customer experience, and he utilizes service design and agile methods in his work.

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Differences between TRIZ and Design Thinking methods – both are needed at the same time

Both the TRIZ and Design Thinking methodologies emphasize precise problem definition before seeking solutions. This helps ensure that solutions are targeted and effective – only what produces real value and is meaningful is done.

One essential and fundamental assumption of the TRIZ method is that most problems are rooted in fundamental contradictions: for example, a structure must be strong but lightweight. In other words, strengthening the product structure may increase its weight, which is undesirable. Therefore, the willingness to solve problems should emphasize the need to address these contradictions.

While Design Thinking starts from the same premises as the TRIZ method, the difference lies in that TRIZ emphasizes technology more, whereas Design Thinking starts from the needs of the user or customer. Design Thinking thus emphasizes user-centeredness and business, aiming to understand and consider user needs and experiences to achieve sustainable business.

/// INSIGHT ///

What innovative practices can companies in your field adopt to enhance resource efficiency?

Petteri Immonen | **Manager** | Energy & Process Consulting

Enhancing resource efficiency involves achieving optimal results while minimizing resource usage, including time, energy, water, raw materials, and costs. This can be achieved through innovative methods such as water efficiency assessments, big data analysis, machine learning in production processes or energy system simulations, Lean thinking, design automation, and digital twins for energy systems.

In my view, the implementation of these advanced methods hinges on fundamental factors, notably having skilled and motivated personnel dedicated to a common goal. Therefore, fostering an environment conducive to employee engagement and idea generation is crucial when aiming to boost resource efficiency within a company's continuous improvement framework. Collaborating with our customers, we at Elomatic have deployed various strategies, including workshop methodologies, facilitated brainstorming sessions, and organization-wide initiatives like the ISO 50001 energy management system.

Subsequently, audits or project development studies provide invaluable insights into asset and material utilization, guiding efforts to enhance efficiency for both usage and monitoring purposes. With this groundwork established, we progress to the implementation planning phase, encompassing production operational changes, process modifications, and investments, whether minor or major. Moreover, in the design of new industrial facilities, resource efficiency perspectives are seamlessly integrated into the continuous improvement model of design.

Juha Tanttari | **Lead Consulting Engineer** | Marine & Offshore Energy

For ship owners or their representatives, there are a plethora of alternatives available to enhance resource efficiency. During the design phase of a new vessel, careful optimization of the ship's hydrodynamics and machinery holds tremendous potential. While modernizing existing vessels presents certain limitations, it remains crucial to consider resource efficiency in retrofit designs as well.

The most promising opportunities for resource conservation lie under the water surface, particularly for large ships. A well-designed hull plays a pivotal role, as a significant portion of energy consumption stems from hull form and underwater appendages, as they contribute to water resistance against the hull.

Efforts to enhance ship hydrodynamics can be finely tuned through computational fluid dynamics (CFD), ensuring high level efficiency and safety in vessel operation. For example with existing vessels, reducing operational speed would benefit bulbous bow and main propeller optimization to the new speed.

Improvements to hydrodynamics could be gained with energy saving devices like duck tail, interceptor or bow thruster tunnel grids or streamlining existing appendages like fin stabilizer recess. One notable example of energy saving devices is our Elogrid solution, which improves bow thruster tunnel hydrodynamics. It is installed in tunnel openings to enhance maneuverability and minimize ship resistance.

Marko Mäkinen | Chief Design Engineer | Machinery & Equipment

Given my background in product development, I believe companies can influence the utilization of resources needed for production and consumption by offering products designed for long-term retention. When the cost to maintain the product is right and the quality, value and the performance of the product is well preserved, the owner may think of keeping and renovating the used product as more attractive option than premature disposal. Here are some strategies to support this approach.

Utilizing digital twin technology coupled with real-time monitoring data enhances the capacity to predict the maintenance and repair requirements, thus preventing failures resulting from unforeseen operating conditions or loads. Moreover, digital twin technology aids in optimizing product performance and streamlining maintenance activities, thereby improving efficiency and reducing maintenance costs.

The resource efficiency related to the production of services and products can also be improved with digital twin technology and simulation methods based on multibody dynamics, for example.

These tools empower companies to test products with fewer physical prototypes and shorter timeframes, expediting market entry. In addition to developing long-lasting products, companies can explore business models that incentivize prolonged product retention. Assessing the life cycles can provide valuable insights into the resource utilization and environmental impacts of various product development and business decisions.

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