top engineer

The Elomatic Magazine 1 · 2018

Sustainable Development Issue

In addition to the environment, sustainability also includes our way of working and taking care of our personnel.
– Jari Lausmaa

Consulting • Engineering • Design • R & D • Innovation • Technical Solutions

Sustainable Development

In June 2017, I wrote a Top Engineer magazine editorial about a project we had started at Elomatic regarding the re-evaluation and rewriting of our company story. This involved revisiting our values, mission and vision. I am glad to announce that this process is almost complete and I hope to share the new Elomatic story with you later this year.

The issues of sustainability and sustainable development have come strongly to the fore in our deliberations.

The so-called Brundtland Report, which was released by the United Nations Commission on the Environment in 1987, defined sustainable development as "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This has become a widely recognised definition of the concept.

At Elomatic, sustainability is an integral part of our mission; it gives meaning to our business operations. We see our role in the world as designing working solutions that increase the wellbeing of mankind and the environment. We do this by creating sustainable and responsible solutions for the complex challenges of our times.

For this reason, I asked our experts to write articles for this edition of the Top Engineer magazine under the theme of sustainable development. This reaches into the realms of the environment, energy and material efficiency, and generally doing things better.

Some of the greatest challenges our customers face are the wellbeing of the environment and resource sufficiency. Renewable energy sources and energy-efficient solutions, smarter utilisation of raw materials, minimisation and reuse of waste, water and food supply, as well as safe and working solutions are all issues our customers grapple with.

As a part of sustainability, we, as our customers' partners, need to deliver our plans, drawings and other documents on time and with the right quality. This allows us to minimize "waste" such as production errors, waiting times and time spent on correcting mistakes.

This "sustainable development" edition of the Top Engineer is packed with interesting and informative articles on the theme. It includes, among others, articles about sustainability in the pharmaceutical industry, best practices in the circular economy, the optimization of the Mars lander, electrical networks as storage entities, efficiency optimisation of heat exchangers, the drive to more environmentally friendly products, as well as the paradigm shift in engineering towards sustainability. Jari Lausmaa, who was earlier this year appointed as the head of our Marine Business Unit, was interviewed for the magazine and asked about his views on sustainability in the marine industry.

I trust that you will find these articles both interesting and inspiring. Together, we can ensure a more sustainable future for all.

Patrik Rautaheimo
Editor-in-Chief
CEO

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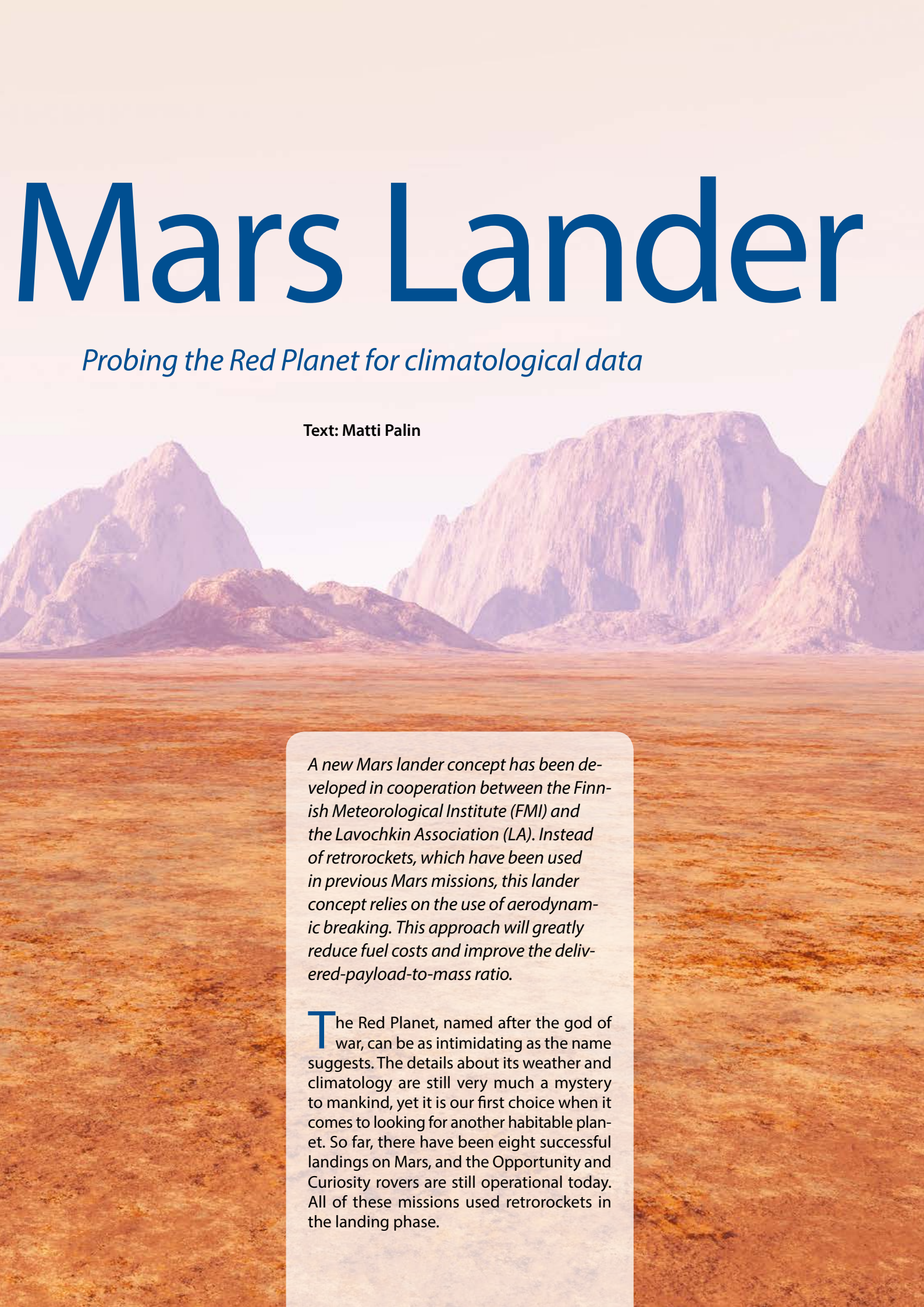
Cover: Jari Lausmaa leads Elomatic's Marine business unit operations.

The MetNet

Mars Lander

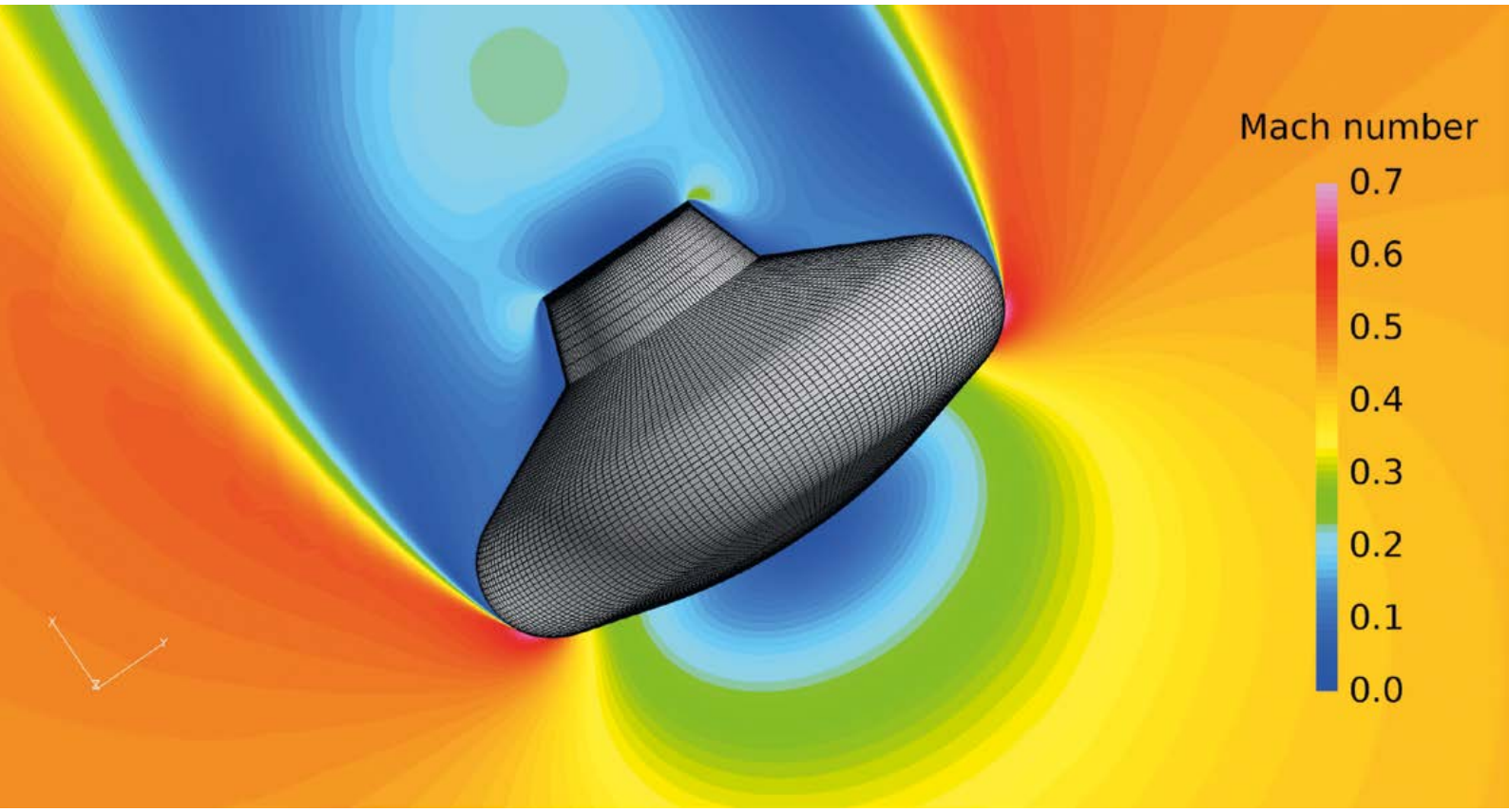
Probing the Red Planet for climatological data

Text: Matti Palin



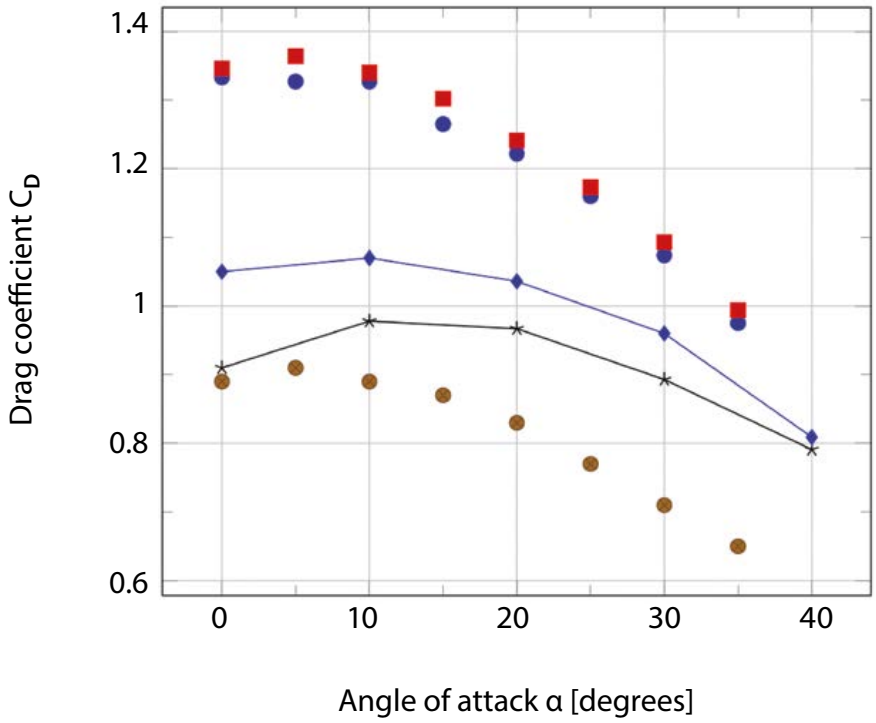
A new Mars lander concept has been developed in cooperation between the Finnish Meteorological Institute (FMI) and the Lavochkin Association (LA). Instead of retrorockets, which have been used in previous Mars missions, this lander concept relies on the use of aerodynamic breaking. This approach will greatly reduce fuel costs and improve the delivered-payload-to-mass ratio.

The Red Planet, named after the god of war, can be as intimidating as the name suggests. The details about its weather and climatology are still very much a mystery to mankind, yet it is our first choice when it comes to looking for another habitable planet. So far, there have been eight successful landings on Mars, and the Opportunity and Curiosity rovers are still operational today. All of these missions used retrorockets in the landing phase.



▲ *Figure 1. The Main Inflatable Braking Unit in flow simulation. CFD analysis is used to solve the flow field and to calculate the induced aerodynamic forces and moments.*

▼ *Figure 2. Comparison between the drag coefficients obtained with FINFLO simulations and from LA for the AIBD case. The results indicate that the drag coefficient is well above the required value to ensure the designed impact speed.*



The genius of the MetNet concept is the use of pure aerodynamics to ensure a safe landing for the vehicle. The landing system consists of a pair of inflatable braking devices that produce the necessary deceleration. This technique not only increases the payload-to-mass ratio, but is also much more ecological since no extra fuel is needed in the landing phase. See Figure 1.

Revolutionary rationale requires revolutionary research

The big question on everyone's lips is of course: Will it work? The engineering research commenced already in the early 2000s and a body prototype was built between 2001 and 2004. Wind tunnel and heat flux tests have been conducted for the key components of the structure, but the problem with these tests is that it is difficult

Most of the current research is focusing on determining the aerodynamic stability qualities of the MetNet lander

to replicate the actual descent and landing conditions on Mars. This is because the atmosphere in Mars differs greatly from that on Earth. Even though the speed of sound is of the same order of magnitude as on Earth, the Mach number at the beginning of the landing phase will still be large (exceeding Ma=20). Thus, it is out of the question to conduct one-to-one tests of the mission.

From 2015, the aerodynamic research has been carried out by Finflo Ltd. The technique used in the analysis is computational fluid mechanics analysis, or CFD for short. CFD is Finflo's speciality and a self-titled code is used. In a CFD analysis, the flow field around an object is solved and the aerodynamic forces and moment can thus be calculated.

The most evident research question regarding aerodynamics is whether the aerodynamic braking is sufficient to slow down the vehicle to an admissible impact speed. The impact speed is fairly easy to derive algebraically, and the condition for the admissible impact speed ultimately boils down to the vehicle having a sufficient drag coefficient. The drag coefficient is a measure of how much aerodynamic drag force, opposing the speed of movement, an object generates. The simulation results for the landing configuration are illustrated in Figure 2.

Serious stability

The second research question is a far more difficult one. In order to land safely, the vehicle must land upright. In other words, it must not start spinning wildly around its centre of mass. This phenomenon can be examined by analysing the aerodynamic stability of the vehicle.

In this context, stability is defined as the tendency of a state to return to its original position after a perturbation. State, in this case, is the angle of attack of the vehicle. This is a natural choice, because a steady angle of attack means that the vehicle will not tumble around.

In practise, most of the current research is focusing on determining the aerodynamic stability qualities of the MetNet lander. This is by no means a simple task and has already required years of computation time.

The time accurate simulations present a veritable challenge for modern computers. Fortunately, the results have been encouraging: it was quickly seen that the vehicle is statically stable. This means that it does generate moments that oppose a change. Another side of the question, however, is dynamic stability. Does the vehicle generate a sufficiently aerodynamic pitch-damping moment?

Pushing the envelope

Although the simulations are still in progress, the results have indicated that in some cases the vehicle is also dynamically stable. However, with the design in its current form, it would not be safe to send the MetNet lander to Mars; full stability has not been ensured and it's possible that the vehicle would not land in an upright position.

In airplane design, longitudinal stability is ensured by making sure that the centre of pressure is aft from the centre of mass. This idea can also be used in the case of MetNet: the stabilising characteristics of the vehicle can be enhanced by pushing the centre of mass forward. This brings yet another level of complication to the simulations, since an optimum location for the point has to be found.

Due to the long simulation times, the aerodynamic design will still take years. In addition to shifting the centre of mass, altering the aspect ratio of the geometry has also been considered as a solution for the stability problem. Once the simulations provide enough evidence for an aerodynamically solid design, a precursor mission to Mars is planned for the mid-2020s.

About the author

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Matti Palin graduated from Aalto University in 2016 with a Master's degree in Aeronautical Engineering. He has been working on the MetNet Mars Lander project since his graduation. Working first for Finflo Ltd, he is a specialist in CFD and the main driver in the aerodynamic analysis of the MetNet lander. He has a life-long love for mathematics and engineering, as well as a broad language skill set. He currently works as a Senior Design Engineer in Elomatic's Technical Analysis team.

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Sustainability by Design

Text: Abhay Ranjan & Shailesh Doshi

An increasing number of businesses are being challenged by their stakeholders regarding sustainability. In a world where businesses are facing intense challenges driven by growing complexities in their operations and compliances, demand is growing for total quality assurance solutions; solutions that extend beyond the quality and safety of products, to those that deliver sustainable solutions in the development of products and services for the present and future.

Sustainability is the core of any business. Optimized design and engineering ensures the in-built sustainability of the entire facility, systems and operating procedures. This becomes a qualitative competitive advantage for the industry. A scientific approach for proper and optimized design and engineering, in turn, results in overall improved performance of the business which ultimately create more avenues for sustainability and economies of scale.

It's difficult to accept that biopharmaceutical or drugs manufacturing companies are facing issues related to sustainability.

Sustainability is a complex concept and is being used in various modes in different contexts. In this article, however, our focus is on the biopharmaceutical industry. Accordingly, in this context, sustainability means a balancing act and the ability to maintain a certain regulatory standard. Similar to Porter's win-win hypothesis, a trade-off is not necessary. Therefore, the approach of in-built sustainability is essential when designing biopharmaceutical facilities.

From "Quality-by-test" to "Quality-by-design"

There is a shift in regulatory thinking from "Quality-by-test" to "Quality-by-design" with an emphasis on the level of risk to product quality and patient safety.

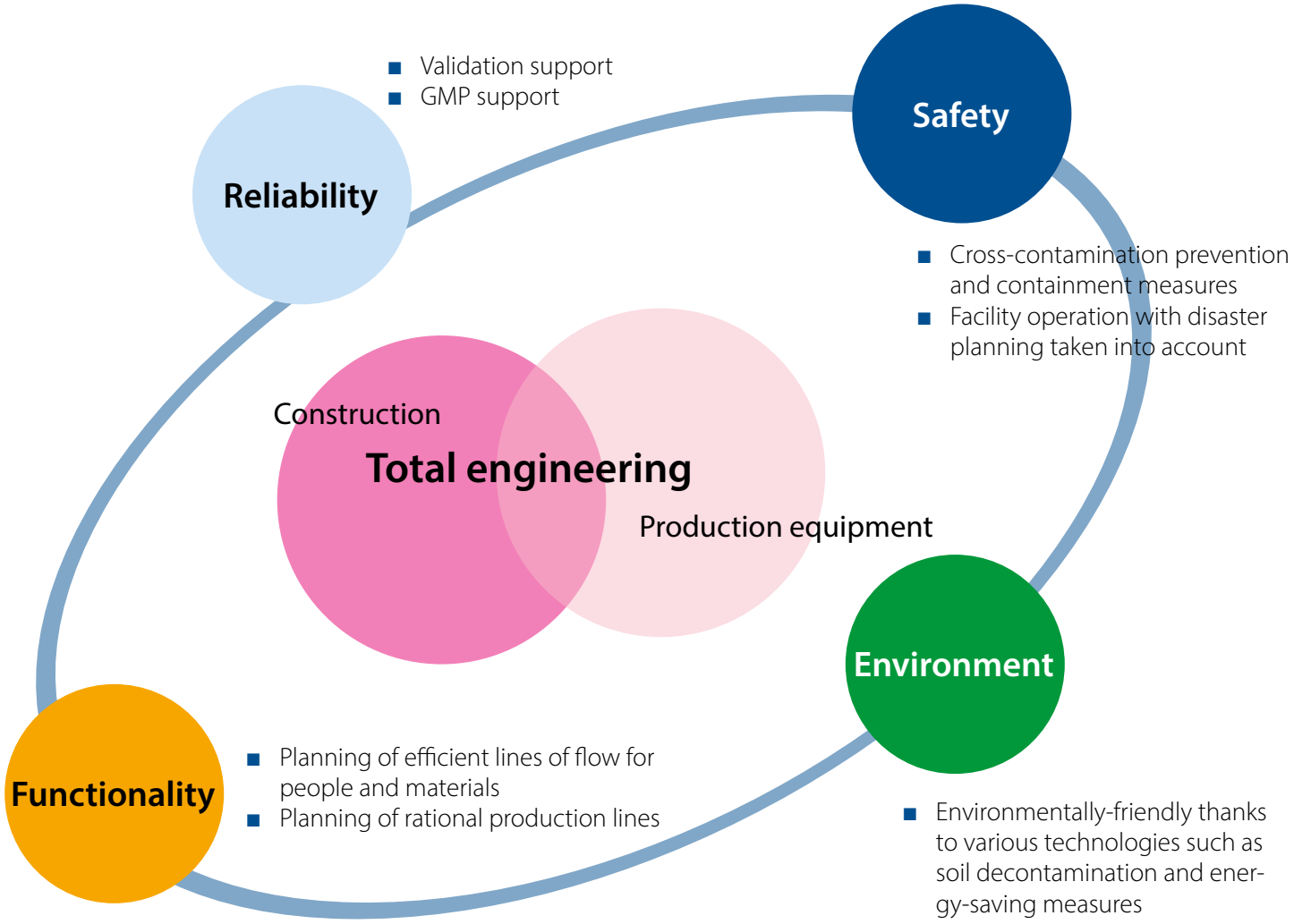
Design is a process that integrates human ingenuity with data and technology to revolutionise the development and application of manufacturing intelligence to all aspects of suitability in a business. Design should be a risk-based approach with rationales based on science and verifiable measurements.

Biopharmaceutical design should make use of resources more efficiently within the desired regulatory compliance. Industry has to tailor design to manage the entire supply chain, production sequences, disposal of waste, efficient utilisation of energy and water and overall efficiency of business. Proper design results in energy-efficient buildings, infrastructure, optimised blueprints and efficient processes.

The maximum utilisation of the facility and/or equipment machinery is critical in order to achieve better ROI. While conducting design, the designer should give due consideration to line balancing of production and ensuring the maximum occupancy of the equipment and machinery, irrespective of the in-built flexibility in the factory.

Costs increasing in biopharmaceutical industry

The biopharmaceutical industry has seen an increase in the cost levels of new facilities and in many instances the modification/correction costs in new facilities; this is partly due to uncertainty about the exact requirements or the URS. The designer should gain an appropriate understanding of the product and process requirements on which the conceptual layout is developed.



The facility layout must be an integrated design that satisfies process and equipment layout requirements, while catering for good levels of access for operability, maintenance, personnel, product, components, raw materials and waste. The design should provide a contained environment with an adequate level of hygiene and safety. The risk analysis with respect to the product, environment and humans must be established.

Optimised design should ensure the integration of EHS compliance and the efficient management of all operations. Design should ensure that all forms of compliance, albeit regulatory compliance, EHS, documentation, etc. are not necessarily a cost to the business.

Building design and building systems

Some studies have shown that about 40% of the world's energy is consumed by buildings. If building design is within the correct framework as per the requirements of the process/product/ambient conditions etc., a large part of this energy consumption can be saved. This in turn will contribute positively to bottom line of factories.

In the biopharmaceutical industry, HVAC is a source of high energy consumption, which is directly linked with the design of the facility. Use of poor quality AHU results in leakage in technical areas which is never checked and accounted for. Inefficiency in the selection of AHU, on the other hand, results in excessive electricity consumption. Optimised and intelligent design and selection can help companies to maintain the controlled ambient conditions that are crucial for product quality and, at the same time, reduce the energy consumption of HVAC.

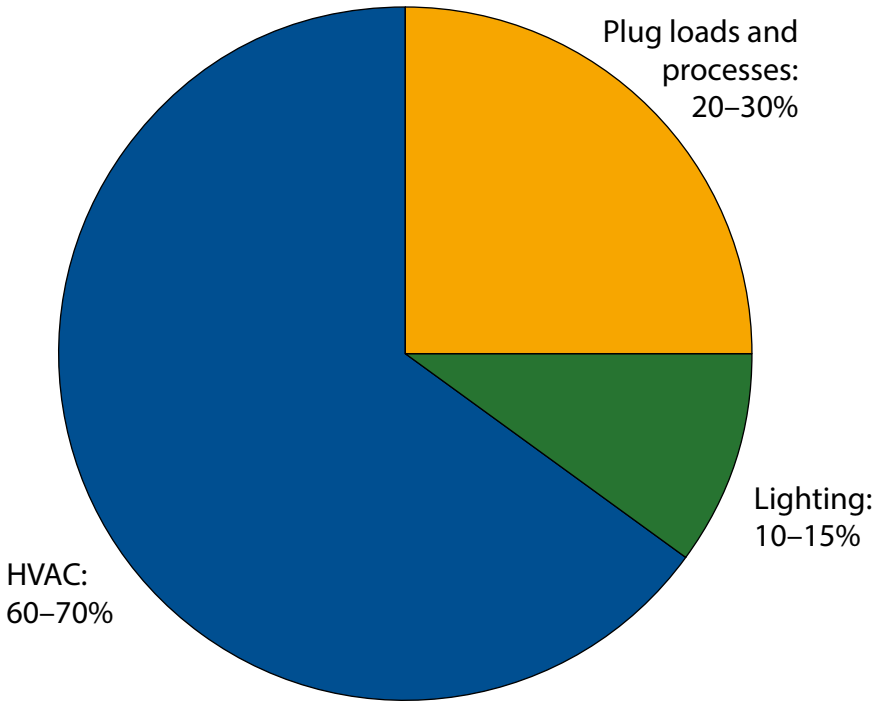
Another area of concern is the use of energy efficient devices such as motors or LED-based cleanroom lights etc. In a typical biopharmaceutical facility, for example, there are a large amount of motors. The proper selection of these motors can result in significant savings.

Maximising use of natural resources – minimising waste

Design should encourage the maximum use of natural resources such as light and air wherever possible, without impacting the product and regulatory guidelines. The biopharmaceutical industry is a heavy energy consumer and, therefore, it is crucial to have en-

◄ *Figure 1. Design and engineering that meets all aspects of the owner's expectations: Functionality, Durability, Safety and Sustainability.*

► *Figure 2. Typical distribution of power consumption in a biopharmaceutical factory.*



Sustainability in the biopharmaceutical industry is reflected in a commitment to supply high-quality and safe drugs.

ergy-efficiency inbuilt features in building design.

Several studies in the biopharmaceutical sector have quantified the generation of various types of waste. Waste is generally the result of poor design, engineering and inefficient processes. Inadequate design and inefficient processes often result in batch-to-batch product variations, in product failure/recalls/quality issues etc. Process optimisation followed by customised design are essential to reduce such waste.

In biotech facilities, a new trend is the use of single-use technology. It has several advantages over traditional, fixed SS process equipment. The inherent advantages are the flexibility of the process, the reduction in turnaround time between batches and of expensive, classified cleanroom spaces, as well as the elimination of CIP/SIP. There are, naturally, cost impacts and the economics of single use is very different to that of SS equipment.

Quality and quantity are attributes required for drug manufacturing that can be achieved either by personnel attention or by systems. While designing a facility, engineering control should be given more attention so that reliance on personnel can be avoided. Accordingly, automation is picking up in the biopharmaceutical segment, which ensures the accuracy and consistency of product quality. This results in the reduction of product recalls and overall higher productivity.

The use of sensors and monitoring systems for various critical applications can be helpful for precise control and also to identify inefficiencies in facilities. An integrated process and automation system helps to ensure efficient and continuous manufacturing. Many biopharmaceutical companies are adopting advanced ERP systems that integrate all the business' processes, monitor production processes in detail and generate data for management in real time. In order to receive regulatory approval for biopharmaceuticals production, effective tracking and control of all related processes from sourcing of raw materials to dispensing, manufacturing and shipment of finished products is mandatory.

Similarly, traceability systems for finished drugs are required to guard against counterfeiting and to support patient safety, which in turn necessitates drug serialisation.

The VMP should be established during the very early stage (concept design stage) of a project and should be followed religiously throughout the project. The VMP must be a written document with a well-defined validation philosophy, methodology, as well as the responsibility and approval authority matrix within the organisation.

Accordingly, the philosophy for all qualification and validation is designed inclusive of various protocols/ SOP. Once the protocol is developed and established, it should be followed consistently. If there is a change in the

protocol, the reason for the change should be documented.

Proper documentation is the key aspect of successful and sustainable manufacturing of biopharmaceutical products. During the design stage, an adequate and secured documentation storage and retrieval system needs to be established.

Keeping up to date with changing requirements

Another challenge for the biopharmaceutical industry is to keep track of new developments, regulatory expectations and to update skill sets accordingly in the organization. Hence, the continuous training of human assets is obligatory to achieve sustainable manufacturing in the biopharmaceutical industry.

The biopharmaceutical industry is a very cost sensitive and competitive industrial segment. Proper design aids in optimising consumption of energy, water and reducing waste, while protecting people and achieving the desired drug quality and quantity. In-built sustainability in factories assists manufacturers to benchmark against their competition and to achieve sustainable long-term gains in the industry.

The design, construction, commissioning, qualification and validation of biopharmaceutical facilities raise significant challenges for manufacturers as well as for the designer. The GMP compliance is achievable through good science and sound justification of your approach.

Conclusion

The biopharmaceutical industry connects with countless lives around the world through research, development and production of lifesaving and life-enhancing drugs. Sustainability in the industry is reflected in a commitment to supply high-quality and safe drugs, while developing new therapies to address futuristic medical requirements. The biopharmaceutical industry should focus on operational excellence and sustainability, which can help it to differentiate and deliver value to society.

In its consistent efforts towards zero defect products with increased cost pressure, regulatory framework, and increased productivity goals, the biopharmaceutical industry needs to adopt a proven scientific route to design and engineer facilities that herald an era of unprecedented sustainability.

Glossary

URS	User requirement specification
EHS	Environment, Health and Safety
AHU	Air Handling Unit
CIP / SIP	Clean-in-place / Sterilisation-in-place
SOP	Standard operating procedure
VMP	Validation master Plan

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Sustainable development in Marine Industry

Interview with Jari Lausmaa

Jari Lausmaa has a wealth of experience in Marine Industry projects, dating back to when he first started out as a structural designer in 1995. Since then, he has held positions of, inter alia, Project Engineer, Technical Manager, Design Manager, Business Development Manager, Sales and Tendering Manager, and Managing Director, both in Finland and abroad. He joined Elomatic in January 2016 as Director for Marine & Offshore projects. In that role he has notably been heading the design of the MV Werften Global Class passenger vessel. In March 2018, he was appointed to lead Elomatic's Marine Business unit operations.

Sustainability should include issues beyond the environment, such as sustainable ways of working and taking care of our personnel.

The Top Engineer editorial team caught up with Jari Lausmaa to gather his views on sustainable development in the Marine Industry.

He likes to think of sustainable development in a broad sense.

"Environmental issues are important, but I feel that they are already standard, we are at least approaching that point. Protecting the environment is expected as part of normal practice and broad awareness has been created, especially among the younger generations. Sustainability should also include other issues, such as sustainable ways of working and taking care of our personnel."

Jari does not separate environmental issues from sustainable ways of working.

"Our colleagues are part of our environment together with the surrounding nature. Before, this kind of thinking was perhaps considered too soft for business life. But this soft approach generates the most valuable asset for the company; an atmosphere where know-how is developed together with true innovations.

What is the role of engineering and consulting companies with regards sustainability?

"Our main asset, practically our only asset, is our human resources. Therefore, sustainability with regards our personnel is crucial. In this field we can be a forerunner and make a difference in other companies."

According to Jari, engineers have the freedom to choose any technical solution that best fits the purpose. From his perspective, engineers are not bound to any product and are able to serve their customers without constrains.

"We develop solutions for our customers in order to achieve the best possible end result. If the customer asks us to do something that is not fit for the purpose, it is our job to guide them in the right or more sustainable direction.

Jari indicates that sustainable development issues are not only for top management to consider, but something that affects the entire organisation.

"If you think about environmental solutions, the real work is done by our engineers and designers. Orders from management do not drive employees to use their own capacity to the full. In order to always strive to find better solutions, a real interest and passion at all levels is required."

When asked about the areas of ship design and operation that will have the greatest impact on sustainability in the marine industry over the next 30 years, Jari mentions new energy sources, automation and optimisation.

"The shipping industry is already considering several options and seeking new ways to produce the required energy on board. Related to that, better and more innovative ways of automation and optimization are needed. Experiments in these fields are being conducted and we are following the results with keen interest. We also keep in touch with these topics by increasing our own understanding of new technologies and by working on new concepts, especially those where new power production methods are studied."

The BWM Convention finally entered into force on 8 September 2017. Jari suggests that it will assist in reducing the spread of harmful organisms in the ocean by setting requirements for BW treatment and operations.

"We have put in quite a lot of effort to develop our services for shipowners in the area of ballast water treatment and the development work continues so that we can do our share."

The Finnish Marine cluster views sustainability (in a broad sense) as an important topic and is, therefore, rallying member companies behind the issue.

"In order to have something real and concrete, it has been decided that each Marine Cluster company that commits to the ResponSea-project will announce its promise with measurable targets. This way we want to be open and really committed in front of everybody with regards this important topic."

In 2009, Elomatic was involved in the design of the NYK Super Eco 2030 vessel. Do you think these kinds of concepts are too idealistic or can we look forward to vessels that have zero emission by 2050?

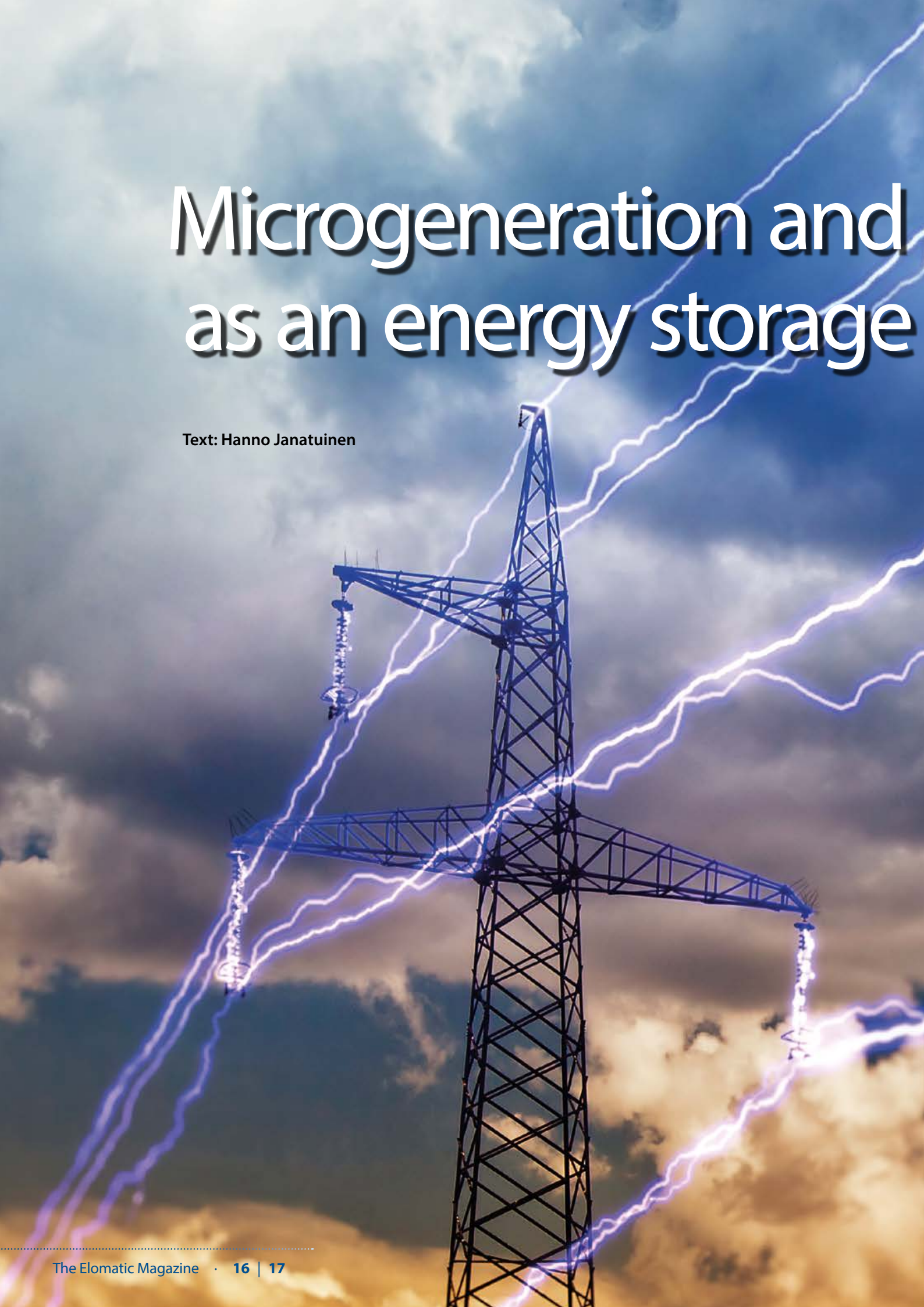
"The role of these kinds of studies is to look ahead far in the future in order to increase understanding of new technologies in ship concepts. So yes, they are too idealistic today, but we knew this already when the study was started. But these concepts help the parties to understand new possibilities and to take them into use, step by step. These kinds of studies set long-term goals and gradually we will reach the zero emissions level.

Jari mentions that there is currently a lot of ongoing discussion about ecosystems. Within the marine industry and shipping and shipbuilding ecosystem, a lot of work in being done, for example, concerning environmental issues and new tools.

"There are many new tools that can help us reach our goals. Here I am thinking, for example, of autonomous shipping and artificial intelligence. These areas are so complicated that they will need a lot of open dialog between companies and close co-operation in areas where we might normally be competing with each other. This will create totally new and sustainable ways of working.

Microgeneration and as an energy storage

Text: Hanno Janatuinen



the network entity

Recent technological and political changes have brought battery-backed "family-sized" electric power generation closer to reality. What does this mean and where are we heading?

The pressure to increase distributed renewable generation has mainly come from the general public, for whom the environment is of paramount importance. The Finnish Green Party was the first European Green party to be part of a national Cabinet in 1995. Today, many political parties share their visions.

International pressure and national decisions that support renewable energy generation and electric vehicles derive from global contracts and EU climate law. Keeping the political structure in mind, we can look at the applications, technical aspects and challenges from an economic perspective.

The biggest challenges are not necessarily technical, as a simple political decision can lead to massive macroeconomic upheaval.

Electric cars as energy storage units

Currently, the most common forms of distributed power generation are different applications of photovoltaic solar power, wind power and bioelectricity production. The systems often use combined thermal and electric generation (CHP) and the technologies are well established, yet constantly evolving. There are also many other potential forms of distributed generation, varying in size from small-scale systems to concentrated grid-scale systems.

The electric car has been a complete game changer. The trend towards different electric vehicles like cars, ships, ferries etc. explains to an extent the explosive growth of different battery technologies. The total market for electrically chargeable vehicles in the EU expanded by 39% in 2017 and hybrid car sales increased by over 50%. The battery capacity of a 2018 Nissan Leaf is around 30 kWh. A household in a Western country consumes roughly 5000 kWh of electricity in a year, which is around 14 kWh a day. Battery prices are currently around 200$/kWh and are expected to drop below 100$/kWh by 2025. In contrast, battery cost was around 1000$/kWh in 2010.

By 2025, it is expected that:

1. Small-scale electricity production will be on the increase
2. A vast amount of electricity storage capacity will be available in the electricity network
3. The battery price of a small electric car will be 30 kWh*100$/kWh = 3000$
4. One will be able to cover the daily electricity consumption of an average household with a relatively cheap car battery

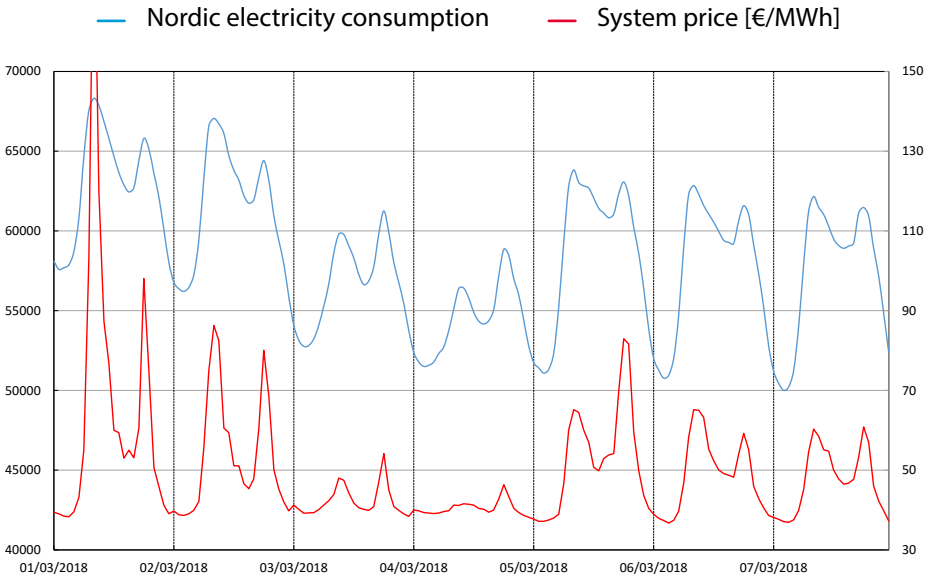
Substantial research is underway around the world to improve the economic and technical performance of storage options. In an electric power system, the benefits of storage systems are their potential to increase grid efficiency and reliability by optimising power flows and supporting the network. In March 2018, General Electric released their commercial grid scale 1,25 MW storage unit, which can hold 4 MWhs of energy (ca. 4 hours). The unit is modular, so the network operator can dimension the quantity of these units as needed.

The power balance

The biggest problem in the public electricity network is maintaining the power balance. It is challenging because the timing of electricity production does not perfectly match consumption.

In most developed electricity markets, the price of electricity is often highest during daytime peak hours. Sometimes, the lack of power balance causes price spikes. For example, in the Nordic area the price of electricity can rise to 3000 €/MWh, if production cannot meet consumption. With that legally set maximum price, the average household would have to pay 42€ for its daily electricity.

The Nordic market also has a minimum electricity price: -500€/MWh, which means that the electricity producer actually incurs a cost to produce electricity for the public network. An example of the minimum price is Danish wind power. Windy conditions during low consumption hours of certain



◀ *Figure 1. On the first day of March 2018, a day hour could cost over five times more than a night hour. A better power balance would guarantee more balanced prices.*

If we reform electricity and energy markets, households could sell their home-produced electricity to households abroad.

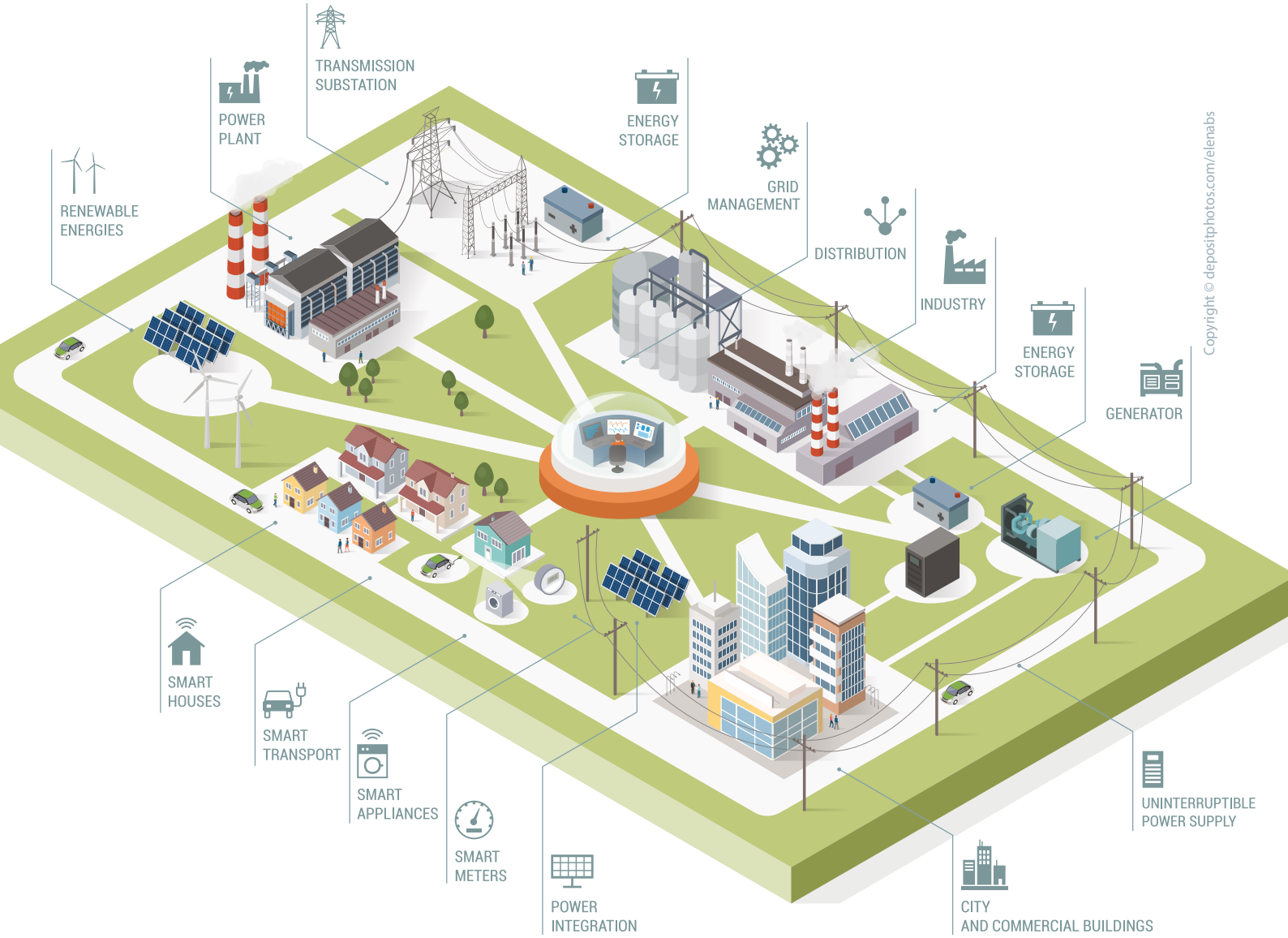
months can create the special conditions needed for the minimum price to come into effect.

The smart grid

The smart grid is a concept where the electricity network participants digitally communicate in order to react to system balance changes (See Figure 2). The main benefit is the better upholding of the power balance for the grid owner. Consumers will, however, in the end also benefit from lower electricity prices.

At the lower level, we have smart building automation. Smart building automation includes applications like the smart control of lights, sun covers, temperature control, moisture control and pressure control. The idea is that an underfloor heating system can anticipate cold weather, buy cheap electricity or heating oil in advance, and store it in the household.

▼ *Figure 2. A conceptual image of a Smart Grid.*



Communication between individual devices is commonly known as the Internet of Things (IoT). The building has learning algorithms to optimise the use of electricity and district heating. Fire and access control are common to industrial automation, but will soon be also adopted by household automation.

Challenges in the new power system

A critical turning point seems to be at hand: batteries, decentralised production and smart grids are rapidly increasing. Political pressure to make fast decisions can suddenly lead to a situation where the decisions are made with less than optimal understanding of the technical and economic impacts.

The current network technology and electricity market structures need a revamp. The impacts will have to be studied as a whole to gain an understanding of the magnitude of the challenges.

From the perspective of electrical power system engineering, there are plenty of interesting challenges: the increasing short circuit current levels, changes in load losses, voltage profile changes, power quality problems, reliability issues, the new transmission network "bottlenecks" and compromised network protection. In addition, there is a more demanding problem that can compromise the network stability and control and, in the end, the whole use of network: the loss of synchronous use.

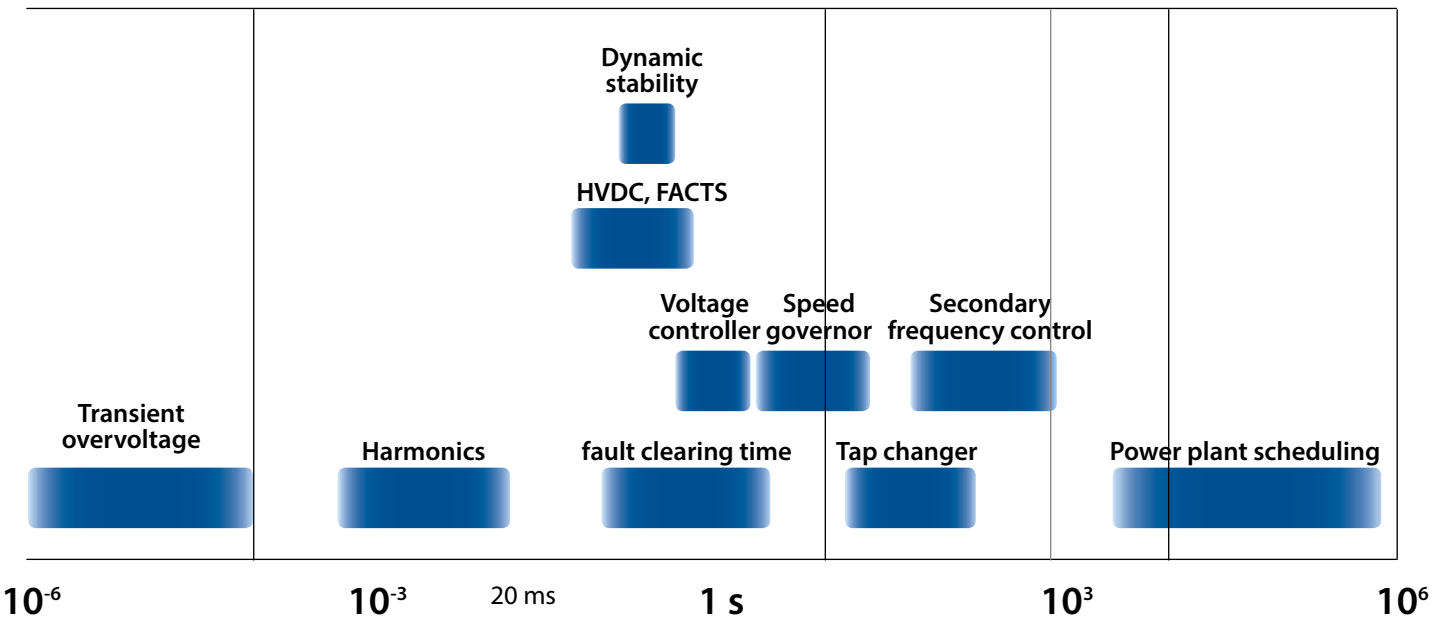
Traditional power systems rely on conventional synchronous generators. The output power of these generators is fully controllable to satisfy the power demand at each time instant. Less known is the problem of low inertia caused by non-synchronous generation. In traditional networks, the rotating mass of a synchronous generator provides or absorbs kinetic energy in the network if there is an imbalance between electricity generation and demand.

Primary and secondary control measures (based on the operating speed and capacity determined by the grid operator) can increase or decrease the generated power to balance the changes in the grid frequency, but this does not happen instantaneously. In case of a sudden power imbalance, the large rotating shaft of a synchronous generator actually acts as the first responder; the change of frequency is limited by the inertia response of the system.

Unfortunately, renewable energy sources are connected to the grid via power electronics, and unlike synchronous generators, they do not provide inertia to the grid. This means that a system with high renewable electricity generation becomes more unstable unless we provide it with some sort of support. One way to do this is the so-called synthetic inertia via power electronics.

The concept still needs comprehensive study, since without highly developed control and feedback; the synthetic inertia response will be slow and far from optimal. Sudden changes in the network frequency can cause serious challenges for conventional generator and turbine designs. Power plant relays can prevent the damage to a sin-

▼ *Figure 3. The duration of losing synchronous stability is very short. The loss of a large synchronous generator due to a network dynamic stability issue can lead to a larger blackout. (SOURCE : Power System Control and Stability, Dr Herwig Renner, Institute for Electrical Power Systems, Graz University of Technology)*



The trend towards different electric vehicles in part explains to the explosive growth of battery technologies

gle plant, but can also cause cascaded trips in other plants and lead to a larger blackout.

How does decentralized production meet the demands of the power system stability and control in a larger network? There are solutions, but they can represent significant research and investment costs. For example, in the Finnish grid the repurchase value of the electric network is close to the value of the road network. The local grids are worth around 16 billion euros and the national grid 4 billion euros. The value of the electricity network alone is close to 8000 € per household, so any major decisions require thorough research.

Electricity markets and market structures

The level of detail in market system models, drastic changes in demand profiles, and production calculations cannot be determined as easily. The financial implications of electricity imbalance settlement start with the individual consumer.

The power system is divided into multiple levels of participants, each with their corresponding imbalance. Usually, the local network operator forms a local database that includes all consumption and production data in their area and the transmission line balance between neighbouring network operators.

The operator delivers the data to an upper level correspondent and the chain continues until it eventually reaches the national grid operator. The national grid operator keeps track of the national balance and the balance between different neighbouring countries. The amount of data is often ragged all over the chain, and requires alteration before the financial transactions among the market participants are finalised.

In the process of determining the energy and power that each of the market participants has used or produced at different times, (often unique) databases are created. The size of these databases is expected to increase with small-scale production. The complexity of different electricity markets, from regional hourly electricity exchanges to future and forward exchanges, include peculiarities that have to be examined individually. Accurate analysis of the changes to market structures is challenging, until we see the wider international picture.

Could a household sell their "home-produced" electricity to a different household abroad? They could, if we invest in reforming electricity and energy markets.

▼ *Turbine in Hydroelectric Power Plant*

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Hanno Janatuinen worked on a distributed generation research program from 2005 to 2007. He completed postgraduate studies in power system control and stability in 2006. He has worked for 9 years as an analyst and portfolio manager in the Nordic Electricity markets. He joined Elomatic in 2017 as a Design Engineer in the electricity network team.

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Towards environm friendly pr

According to a recent responsibility survey conducted by communications agency Miltton in Finland, three out of four Finns are willing to pay higher prices for responsibly produced products or services.

Text: Jukka Mikkonen

more entally roducts

Responsibility has become more prominent in business operations. Responsibility commitments and social responsibility reports are signs that a company is willing to bear responsibility for humans and the environment. When customers turn their backs on an ethically and environmentally unsustainable business, investors see this as a risk; investment funds are actively guided by responsibility. Responsibility increases the appreciation of customers, investors and other stakeholders.

The life cycle of a product can be seen as a constantly changing material flow. It can be interpreted as an idea that starts by circulating on design tables, before it takes on a concrete physical state. It is equally composed of the feelings, needs and activities of customers, users and other people.

How can we make products more sustainable and responsible? How can more environmentally-friendly products create business success?

▲ *The ideal product method can be used to view the inherent potential and possibilities of a product in a new light. Via realistic steps, a path for an ideal product is created.*

In the rest of this article I share my views on these topics and present a case study to illustrate how more sustainable products can be achieved.

Awareness

How well do we understand the bond between business operations and products and their impact on the surrounding world? In a transparent and digitalising world knowledge and understanding have a significant impact on the ability to benefit from the potential of the company and product and to meet expectations that arise. Gaining as profound and diverse knowledge as possible provides a base and guide to the creation of better products from the perspective of humans and nature.

To what extent are we ready to take responsibility for the impacts on the well-being of people and the environment? We are equipped with personal values and ethics. The likelihood of successful solutions will be greatly enhanced if we genuinely think that accountability is important, we are ready to work for it, and even feel passionate about it.

Gaining knowledge

Knowledge of environmental impacts is required in order to produce more environmentally friendly products. Traditional methods used to study environmental impacts include different life cycle assessment methods and MIPS (Material Input Per Service unit). Intelligent digital tools have enhanced our ability to gather life-cycle information about products. Modern 3D design programs are available that, in addition to 3D design, can analyse the environmental impacts of the designed solutions. This provides a natural and fast way to guide products in a more environmentally friendly direction. The solutions may be related to material selection and quantities, waste, energy, recycling and manufacturing processes.

Analysis and simulation software programs can also be used to gather detailed information about the environmental impacts of materials and technical structures. In general, intelligent tools and digitalisation promote the generation of environmentally friendly products.

Combining know-how

In order to produce solutions that are more environmentally friendly, experts that manage, design, produce, market and sell products are required. To ensure that a product's potential is comprehensively understood and benefited from, the involvement of consumer researchers, social scientists, natural scientists, humanists, philosophers, innovators, usability experts and industrial designers is essential. A key success factor in creating the foundations

Knowledge of environmental impacts is required in order to produce more environmentally friendly products.

for successful and more responsible products can be identifying persons that are able to transcend professional boundaries.

A more environmentally friendly product's possibility of success improves when different experts cooperate effectively and dynamically. Even though a multidisciplinary approach can hamper the formation of dynamic cooperation, it is also a great opportunity.

There are many examples of working methods and working communities where people with different angles of approach together create innovative solutions. There is, for example, a growing amount of companies that produce digital services with teams that are made up of experts in the fields of service design, analysis, technology and content generation. These companies commonly apply agile development methods such as LEAN and SCRUM.

Better with less

Safeguarding the wellbeing of people and the environment begs the question how we can do things better with less. Knowledge about a product's environmental impact sheds light on how resources should be used more sparingly and wisely, while at the same time improving quality form both human and environmental perspectives.

Only knowledge about the environmental impacts of materials lead to solutions that are profitable. Environmentally friendly material selection, reduced material use and increased recycling reduce costs and environmental impacts, improve price competitiveness and increase the customers' estimation of products.

Reviewing a product from a responsibility perspective is a beneficial experience and provides inspiration for dreams and innovations. When well-being is integrated into a product, it grows in a direction that is valued and becomes something one is prepared to work hard to achieve.

The implementation of a company's vision in the form of a dream product is highly recommended. Dreaming about a carbon negative, free, alluring and ideal product is an enriching experience. Dreaming can also be boosted with the ideal product method, where one dreams and creates a path for an ideal product via realistic steps. This aids in viewing the inherent potential and possibilities of the product in a new light. It can also produce ideas for completely new products and lay the foundation for new business possibilities. Ideas and thoughts generated in dreaming can provide solutions as to how a more environmentally friendly product can be successfully implemented.

Another recommended innovation method is resource analysis, or in a broader sense, resource thinking. In resource thinking, physical and non-physical resources that are related to the product, technical details, or more broadly, the service or system entity are scanned in different ways.

The method helps to identify existing resources and to utilise them in creating product solutions and innovations. Resource thinking can be widely applied to the challenges faced in a product's different life-cycle phases. It fosters wisdom in resource use and the identification of cost efficient and environmentally friendly solutions.

Gaining insights

Products are expected to be acceptable and responsible with respect to humans and the environment. When we have knowledge of a product's environmental impact, we gain insights into the potential of reducing these environmental impacts. Reducing environmental impacts has a positive effect on humans and the environment and increases the appreciation of the product and the company.

The hope is that the emerging viewpoints assist in gaining insights into how environmental friendliness and responsibility can be integrated with product success.

Link to Elomatic's 3D Environmental Assessment Service. The service helps customers to design and implement more environmentally friendly products. (In Finnish language only) https://goo.gl/P2Vckj

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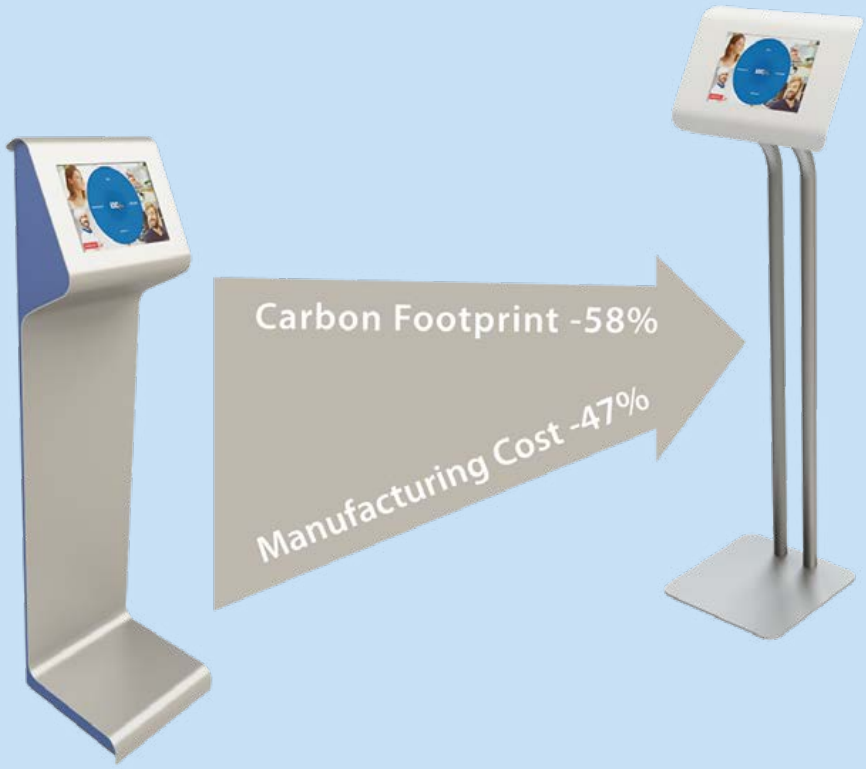


Case ESCflow:
Decreased environmental impacts and costs

The ESCflow device is a good example of how designers can use an environmental evaluation to identify areas for optimisation and develop a product into a more environmentally friendly direction.

The tablet stand that was initially designed for ESCflow did not completely meet the set requirements. A central problem was that its production costs were double the required amount.

The environmental impact of the stand was another problem area. An environmental evaluation conducted indicated that there was much room for optimisation to reduce the environmental impact and to better match the environmentally friendly vision of the service.

The third drawback was the stand structure, which did not allow the stand to be installed on walls or tables. The most important goals of the new tablet stand were lowering production costs and environmental impacts by 50% and creating a structure that could be installed on walls and tables.

The design of the new tablet stand was started with a preliminary study and idea generation, followed by prototvyping and production implementation. The work was done by a multidisciplinary team with backgrounds in mechanical engineering, industrial design, cost accounting, technical analysis, innovation and environmental engineering.

First, a roadmap for the ideal tablet stand was created, which was connected to environmental impacts and the other core product requirements. Based on the roadmap, a basic principle for the table stand was generated with which the solutions' environmental loads and costs were calculated and the environmental impacts evaluated in real time as 3D design progressed.

Prior to the idea generation phase, a 3D environmental impact study was conducted with the use of the 3D data from the initial table stand design. This data was used for comparison with the newly developed solutions.

The results of the study indicated that a significant portion of the stand's life cycle environmental impact resulted from the materials used and, in particular, from steel; 67% of its carbon footprint originated from raw steel.

In order to achieve the design goals, it was justifiable to focus on material quantities and types. A cost evaluation indicated that changing the raw steel material and simplifying the structure could significantly reduce material and manufacturing costs. It was furthermore decided to optimise the structure so that the materials would be easily recyclable.

The end result was a solution with a reduced steel quantity and a streamlined tablet stand with significantly lower manufacturing costs and environmental impacts. The solution was also suitable for installation on the floor, tables and walls. Compared to the original design, the new solution lowered the carbon footprint by 58%, emissions to water by 59%, pollution due to acidification by 57%, total energy consumption by 56%, and manufacturing costs by 47%.

Three out of four Finns are willing to pay higher prices for responsibly produced products or services.

► *The ESCflow food waste service measures a diner's edible food waste in cafeterias and eateries. The ESCflow device indicates the amount of waste and affords the diner the opportunity to rate the food. The visualisation of waste encourages the diner to reduce food waste, which in turn lowers costs and environmental impacts.*

► *A multidisciplinary team was responsible for the redesign of the ESCflow stand. A preliminary study with idea generation was conducted first, which was followed by prototyping and production implementation.*

Cleanroom Design & Construction

The A–Z of a systematic and documented approach

Text: Markku Mäkinen

GMP cleanrooms and cleanroom HVAC can be successfully designed and constructed when the customer has clarity about the requirements, chooses the right project team for design and site supervision and, importantly, engages a constructor that is familiar with GMP demands. The entire chain is kept together by a systematic and documented approach to defining, reviewing and finally verifying the relevant requirements throughout the project.

A GMP cleanroom project team is guided by current legislation, quality systems and Good Engineering Practice (GEP), which lays the foundation for Good Manufacturing Practice (GMP). In order to ensure GEP and GMP quality, project teams should follow the pharmaceutical industry standard V-model (see Figure 1) or the ASTM E2500-13 standard.

In the rest of this article, I give a brief overview of how a successful GMP cleanroom project is started, and systematically develops and proceeds to the construction phase until it is finally commissioned.

Getting GMP cleanroom project started

A GMP cleanroom project usually starts when a customer contacts the project team and a first meeting is arranged where preliminary thoughts and expectations are discussed. Normally, it is agreed that a quotation will be drawn up in the form of conceptual design, basic design, or detail design packages. The customer may also request a quotation for a comprehensive EPCM delivery.

When the customer has received the quotation, it selects a designer or EPCM contractor and offers to sign an

assignment contract with the project team. When the contract has been signed, the design phase of the project can start.

Conceptual Design

As a first step, the customer commonly orders a conceptual design (CD) package. It may include preliminary plant layout, cleanroom layout, cleanroom pressure differential layout, operating areas for the cleanroom HVAC AHUs, an implementation time schedule, risk assessment, cost estimate with ±30% accuracy, as well as a CD report.

The most important outcome of CD is information related to commercial and technical perspectives that should be observed when implementing the project. The project could end after this stage, if the customer's objectives are not met. The project can also continue with a new CD, if so desired.

A CD package entails an investment of approximately 100–200h, depending on the size of the project.

Basic Design

Once the customer is satisfied with the CD package, it may proceed by ordering a basic design (BD) package, which is more in-depth with a wider scope. It also requires a significantly larger investment. If BD aims to generate commercial and technical documents and plans to purchase and build GMP cleanrooms and connected HVAC systems, it usually means an investment of several thousand hours.

The BD goal is to produce detailed information regarding administrative, commercial and technical details related to the project implementation, so that all relevant GEP and GMP requirements are fulfilled. In general, the accuracy of the cost estimate after BD is ±10%, which in the Nordic construction environment requires contractors and equipment suppliers to give binding quotations for contracts and equipment deliveries. This, in turn, places great accuracy demands on design.

The most important documents in BD are the Validation Master Plan (VMP) and the subsequent user requirements specifications (URSs) for GMP cleanrooms and connected HVAC systems.

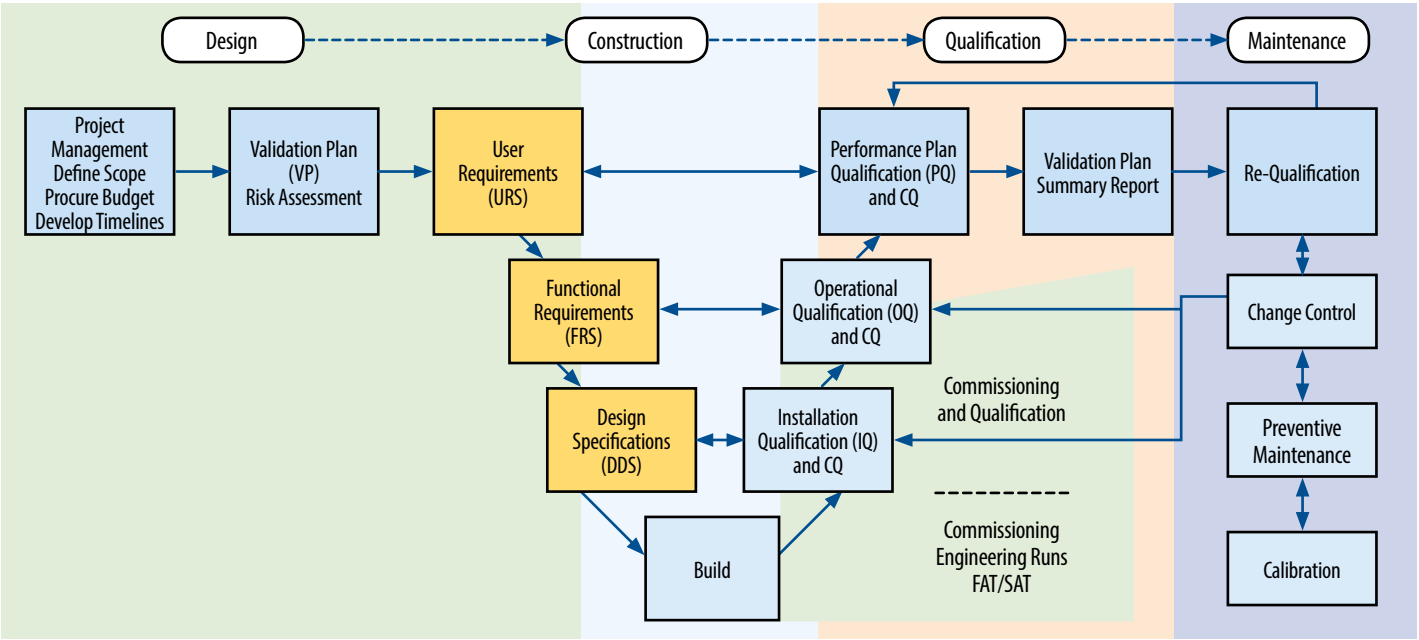
User requirements can be issued separately for all systems and equipment. The user requirements specification defines the direct impact and indirect impact factors that affect the final product quality. GEP and GMP can be used to support the selection of applying commissioning or qualification to the testing and documentation requirements. The fulfilment of numbered URS requirements is systematically verified and documented as the project proceeds.

Basic design is usually conducted with a Building Information Modelling (BIM) data model. The model includes a 3D geometry model, which can be supplemented with a 4D schedule follow-up as the construction work proceeds and a 5D cost follow-up to determine committed and predicted costs.

The strength of BIM modelling is that all information included in the model corresponds to the constructed reality. When the construction work is ready, the as-built BIM model can be used in the operation and maintenance of the building and its utility systems.

Layout and section drawings of the cleanrooms and connected HVAC systems are extracted from the BIM model

▼ *Figure 1. The Industry Standard V-model*



for contract offer calculations, work descriptions, as well as functional and circuit diagrams and equipment lists. All documents for the building management system (BMS) are created in the BD phase. Combined with the VMP and URS, these documents constitute the contract tender documents.

Detail Design

BIM modelling is utilised maximally in detail design (DD). The data inserted into the BIM model in the BD phase can be updated with equipment and component data agreed upon with the contractor, if different from that used in BD.

BIM modelling has changed the traditional interface between BD and DD; design solutions that were previously selected in the DD phase are now selected already in the BD phase. The information from the DD phase constitutes the foundation for design reviews (DR). If needed, workshop drawings are drawn in the DD phase.

In the DD phase, all functional and circuit diagrams related to the BMS system are also complemented and updated, as well as the equipment lists with the contractor's equipment and component data, if different from the BD phase. All detailed drawings needed for construction (walls, doors and ceilings) are issued in the DD phase.

Selection of contractor and equipment supplier

The project team and customer select the contractors and equipment suppliers that will be requested to provide contract or equipment delivery quotations based on the documents issued in the BD phase.

Only known contractors and equipment suppliers should be used in GMP construction. This is, however, often easier said than done. Companies may have strong references from previous and corresponding GMP level contracts or equipment deliveries, but the persons who handled these projects may no longer be employed by the companies. The project team and the customer should carefully re-audit contractor and equipment supplier candidates, when the afore-mentioned situation arises.

The selection of contractors and equipment suppliers should be based on the total points for quality and price, and not only price. Contract negotiations are conducted with the selected candidates before the final selection. These matters should be handled very thoroughly in the contract negotiations and documented in protocols that are attached to the contract agreement documents. All URS requirements and complementing work descriptions should be discussed in such a manner that the parties have a common understanding of the contents and scope of the contract or equipment delivery.

In this phase, the customer makes the final decision as to whether the GMP cleanrooms and the connected HVAC systems will be built. The conditionality of the implementation decision should be noted in the protocols of the contract negotiations. Usually, the customer's own organisation will separately make an investment decision, which can also be negative. This conditionality should also be clearly indicated in the building contract programme.

Design Review and Design Qualification

When all contract and equipment delivery contracts have been signed, the project team and the customer's repre-

Glossary

EPCM	Engineering, Procurement, Construction Management
AHUs	Air Handling Unit
VMP	Validation Master Plan
BMS	Building Management System
URS	User requirement specification
CD	Concept Design
BD	Basic Design
DD	Detail Design
GEP	Good Engineering Practice
GMP	Good Manufacturing Practice

The successful design, construction, handover, start-up and operation of a new cleanroom facility is greatly dependent on a systematic and documented approach.

sentatives convene to lead the design review (DR) meetings with the selected cleanroom contractor and supporting ventilation system contractors.

In these meetings, all URS requirements and complementing work descriptions are handled to the extent that the afore-mentioned requirements can be verified based on the design. The documents and equipment data that are discussed in these meetings, consist of plans issued by the project team, the contractor and the equipment suppliers.

Only drawings and documents that have been commonly approved in the design reviews can be used as a basis for implementation. Enough time should be allocated for the design reviews in the project time schedule. The contractors and equipment suppliers will need time to issue plans and documents and procure the needed equipment.

The design reviews are documented in protocols or memos with a clear and easily-readable structure. Based on the DR protocols or memos, a design qualification (DQ) report is issued.

The documents, protocols, memos and reports that have been handled in the DR meetings are collated in DQ binders and signed by all parties.

Construction phase and commissioning

During the construction phase, all plans that were approved in DQ are implemented. The construction work is supervised closely and systematically and the construction and supervision work is documented. Contractor and site meetings are important to ensure effective communication during construction.

The commissioning phase includes supervised GEP tests according to the URS included in the contract or equipment delivery. The results, protocols and other related measurement data from all commissioning tests are collated into one file or binder.

Installation Qualification and Operational Qualification

The installation qualification (IQ) and operational qualification (OQ) are controlled and supervised procedures for conducting all GMP tests according to the URS as included in the contract or equipment delivery.

The results, protocols and other related measurement data from the IQ and OQ tests are assembled into separate IQ and OQ files or binders.

Handover to customer

When all liabilities related to contracts and equipment deliveries have been approved, a joint handover inspection is conducted, which is documented in a handover protocol. Financial matters can also be agreed upon in these meetings, or separate meetings can be arranged to handle the final financial statements.

The successful design, construction, handover, start-up and operation of a new cleanroom facility is greatly dependent on a systematic and documented approach as described in this article. There is no room for shortcuts. All parties involved in the design and construction of the facility also need to be thoroughly familiar with GMP demands. When these elements are in place the customer can look forward to a cleanroom environment that functions as intended and required.

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Mr Mäkinen has worked within the Finnish and Swedish building construction industry, pharmaceutical industry and food industry for the last 34 years. His experience and know-how covers feasibility studies, conceptual design, basic design, detail design and site supervision. In recent years he has focused on pharmaceutical cleanroom HVAC projects. Mr Mäkinen joined Elomatic in 1982. After gaining experience further afield in 2006 he rejoined Elomatic in 2009 where he currently works as a Senior Design Manager.

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The Circular Economy

Best Available Techniques

Text: Susanna Vähäsarja

Moving towards a circular economy is a long term goal of the EU and seen as an essential contribution to the efforts to develop a sustainable, low carbon, resource-efficient and competitive economy.

The circular economy is viewed as the best option to deal with the decreasing supply of natural resources. It is also an opportunity for economic growth through the innovations required to implement the approach.

The circular economy is crucial in lowering current greenhouse gas emission levels through better waste management and reduced use of resources. In the circular economy, unlike the traditional linear economy, resources are kept in use for as long as possible and materials and products are recovered and regenerated at the end of the product's lifetime.

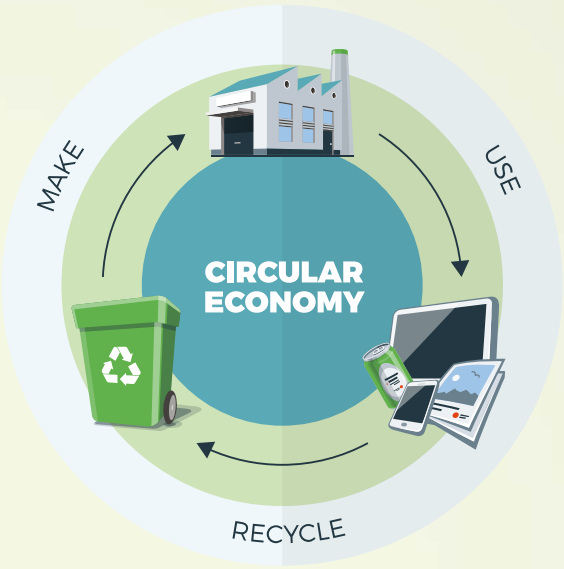
EU circular economy package

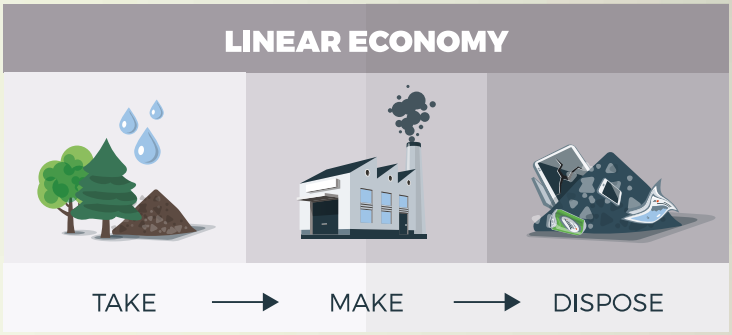
In December 2015, the European Commission presented its latest circular economy package with an action plan and legislative proposals on EU waste policy. The action plan includes several measures regarding legislation, guidance and best practices.

The best practices are provided in the so-called BREF documents (Best Available Technique Reference documents). The BREFs are prepared using experience from the European union industries and are thus a source of reference information. They describe applied techniques as well as present emission and resource consumption levels.

An important new part of the BREFs is the so-called BAT (Best Available Technique) conclusions, which is the final evaluation of the presented available and emerging techniques. The BAT conclusions include descriptions of emissions levels related to the best available techniques and the recommended emission monitoring.

The BREF documents and especially the BAT conclusions are used as a guide for decision makers (e.g. Envi-





ronmental Authorities) involved in the implementation of the Industrial Emissions Directive. This means, in practice, that when an application for an environmental permit for a new facility is made, the applicant is required to state that the relevant BAT conclusions have been met. For existing facilities, the BAT conclusions will affect the permit conditions within four years of publication.

As the BREF documents play such a big role in guiding best practices and selecting technology, they are also prominent in implementing the circular economy.

In the following section, I review some of the published BAT conclusions and evaluate how the principles of the circular economy are accordingly implemented.

- Common wastewater/waste gas treatment and management systems in the chemical sector (CWW), 06/2016
- Large combustion plants (LCP), 07/2017, covering combustion plants with a total rated thermal input of 50 MW or gasification of coal or other fuels in installations with a total rated thermal input of 20 MW or more
- Waste Treatment (WT), 2018, covering facilities treating, disposing or storing of waste

The Waste Treatment BAT conclusions will enter into force later this year when they have been published in the official EU Journal.

Main principles of circular economy

The Ellen MacArthur Foundation (a well-known British charity aimed at promoting the circular economy) has defined the circular economy based on three principles:

1. Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows – for example, replacing fossil fuels with renewable energy or using the maximum sustainable yield method to preserve fish stocks.
2. Optimise resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biolog-

ical cycles – for example, sharing or looping products and extending product lifetimes.
3. Foster system effectiveness by revealing and designing out negative externalities, such as water, air, soil, and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use

On a small scale for an individual industrial company or energy producer, principles 1 and 2 mean more efficient material and energy utilisation. Principle 3 means designing the process so that pollution is minimised, which is controlled by the binding emission levels given in the BAT conclusions. On a larger scale, the principles are achieved through co-operation between companies and industries by circulating materials, side products and waste.

Waste and wastewater management

The key measures in all the BREF documents for waste and wastewater management are:

a. Implementing an Environmental Management system (EMS) including waste and residue management and a monitoring plan
b. Following the waste hierarchy:
    1. Waste prevention
    2. Preparing/processing waste for reuse/recycling
    3. Reuse/recycling of waste
    4. Other recovery from waste, e.g. energy recovery
    5. Disposal of waste without endangering human health and the environment

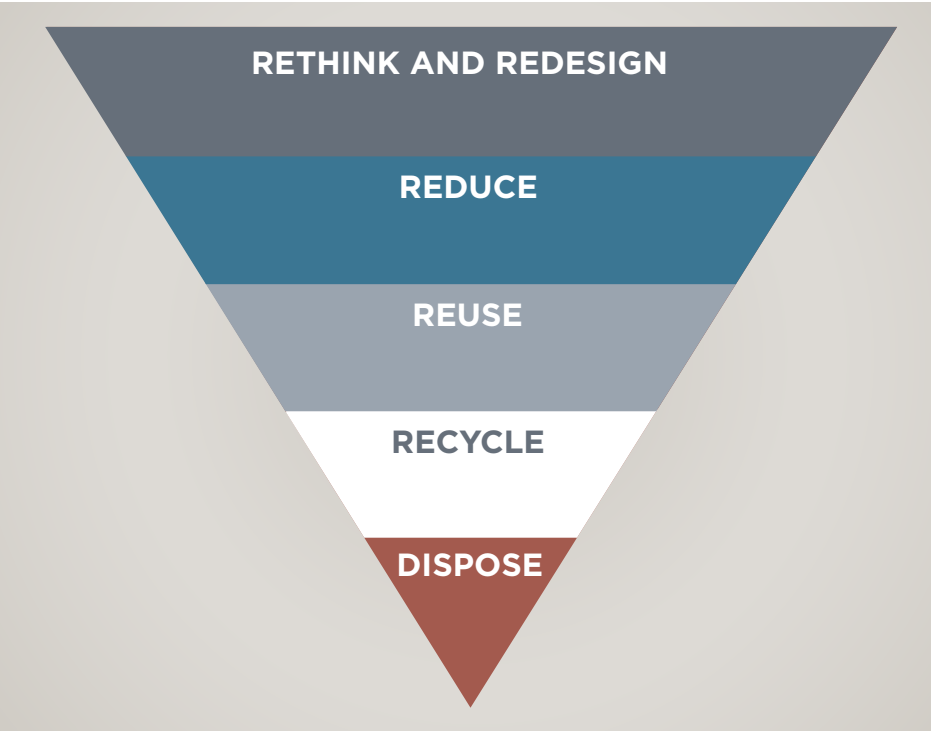
The CWW, LCP and WT BAT conclusions all contain recommendations and means for minimising water consumption and, thus, wastewater. According to the CWW BAT conclusions, the volume and/or pollutant load of wastewater streams shall be reduced to enhance the reuse of wastewater within the production process and to recover and reuse raw materials.

For minimising fresh water consumption and wastewater generation, several measures are described in the CWW BAT conclusions including process alteration, substituting water cooling with air cooling, recycling wastewater directly or after pre-treatment in processes which are not influenced by the contaminants, and washing at high pressure at a low flow rate. They do, however, indicate that some water saving measures might under specific circumstances lead to negative environmental impacts and thus need to be carefully considered.

Material efficiency

For material efficiency and recovery, both the CWW and WT BAT conclusions include utilising waste as raw material. The CWW BREF describes purifying slightly contaminated raw material and auxiliaries e.g. with ion exchange or filtration/adsorption and using the purified waste as raw material instead of virgin material.

The WT BAT conclusions indicate that materials should be substituted with waste, in order to use materials efficiently. Waste is used instead of other materials for waste treatment (e.g. waste alkalis or waste acids are used for pH adjustment, fly ashes are used as binders). The LCP BREF document includes good practices for utilising



◀ *One of the key measures in all the BREF documents for waste and wastewater management is following the waste hierarchy.*

Implementing a circular approach requires knowledge of the processes, substances and associated material flows.

residues from combustion processes (ashes, slag) in e.g. road construction, surfacing and landscaping work and manufacturing of cement and concrete. It also describes means of optimising the quality of gypsum recovered from flue gas treatment processes in order to make a by-product that can be sold.

Nutrient recycling

In addition to material and water recycling, nutrient recycling is part of component recycling in the circular economy. Nutrient recycling means utilising residues from organic waste treatment (e.g. digestate from anaerobic treatment) as fertiliser and thus returning the nutrients from the organic material back to the soil. The CWW BREF document acknowledges that wastewater sludge from the chemical industry is generally not suitable for agricultural purposes as fertiliser due to the heavy metal content, organochlorines and other persistent sludge components.

The WT BREF document describes the use of digestate from anaerobic treatment of source-separated bio-waste or from industrial and agricultural bio-waste. It indicates that digestate processed from MSW or sewage sludge with an industrial feed may contain metals preventing its use as a fertiliser. In this case, energy recovery by incineration is recommended.

Sludge treatment and utilisation has been a topic of discussion and debate lately. The BREF documents do not offer a ready answer for the discussion or requirements for fertiliser/sludge quality. National legislations and sludge end users provide these requirements.

Energy efficiency

The LCP and WT BREF documents include BAT conclusions for energy efficiency. The LCP BREF document gives BAT-associated energy efficiency levels (BAT-AEELs) for solid biomass and/or peat boilers for net electrical efficiency and net total fuel utilisation. No energy efficiency limits are provided in the WT BREF document. There are, however, recommendations for preparing energy efficiency plan and energy balance records.

Conclusions

The circular economy principles are in many ways implemented into BAT conclusions. For many industries water recycling and reducing the need for fresh water has already become common practice. In Finland, we have the luxury of vast water resources and water saving has not always been a top priority. Circulating materials and components and minimising waste are practices that need more attention.

Implementing a circular approach requires knowledge of the processes, substances and associated material flows. For designers, it means re-thinking old familiar processes in terms of water and material recycling and recovery. Increasing internal recycling in processes leads e.g. to higher concentrations of various substances, which may require changes in the required equipment and piping materials.

New raw materials created from waste may have properties that are not fully known in the prevailing process conditions. Doing things in a new way requires a careful risk assessment in order to maintain process safety and operational reliability.

Overall, re-thinking the processes is both an interesting and challenging task for engineers.

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Performance monitoring of heat exchangers

Not as simple as it seems

Text: Jussi Parviainen

When a heat exchanger generates little heat loss, it may seem that the device works in every way as intended; the heat received by the cold fluid corresponds very well to the heat delivered by the hot fluid. The efficiency approaches unity and the customer can be informed that the heat exchanger works in the desired manner. A closer look, however, shows that the performance evaluation of heat exchangers is not quite such a simplistic matter.

Often, heat exchanger functioning is monitored only for the rate of heat transfer. Furthermore, the heat transfer rate can be controlled by altering flow rates. An experienced process operator can see when a heat exchanger no longer transfers its typical thermal output under certain flow conditions. In such cases the operator has three options available to handle the situation:

1. Increase the flow rate to increase the thermal output.
2. Reduce the flow rate to achieve the required outlet temperatures of the fluids.
3. Do nothing.

In the first alternative, the heat transfer rate of the heat exchanger can be raised to its former level, but the outlet temperatures of the fluids do not attain their former levels. In the second alternative, the outlet temperatures of the fluids can be returned to approximately the starting position, at the expense of the fluid flow rates, which may slow down production. In the third alternative, both the outlet temperatures of the fluids and the heat transfer rate are driven further away from their original operating points. It is clear, nevertheless, that in such a situation the heat exchanger's performance has deteriorated and the previous operating level is no longer possible.

The most significant reasons for the reduced performance of heat exchangers are the running methods and fouling. Substances dissolved or mixed with fluids may accumulate on heat transfer surfaces and slow down the flow of heat from one fluid to another. However, fouling does not increase heat loss and, therefore, does not affect efficiency at all. The performance reduction is only indirectly reflected in the heat transfer rate and must always be compared with the conditions prevailing in the process.

Parameter tracking in relation to flow conditions

The explanation for the reduction of the heat exchanger's performance must, therefore, be found in other parameters than the heat transfer rate or efficiency. Many parameters vary greatly depending on fluid flow rates. In order for the parameters to be comparable they must, therefore, be proportioned to the prevailing flow conditions. Appropriate efficiency monitoring methods are limited by the available process measurements. However, diverse analyses can also be conducted with very few measurements. The efficiency of a heat exchanger can be examined, inter alia, with the help of the following measurements:

- Temperature
- Pressure
- Flow
- Concentration

The simplest indicator of the performance of a heat exchanger is the temperature change of the fluid under consideration. From our high school lessons on thermodynamics, we can recall that the rate of heat transfer is the product of the rate of heat capacity and the temperature change. Thus, the temperature change can be interpreted as the ratio of the heat transfer rate

Implementation of heat exchanger efficiency monitoring at CP Kelco Oy

In the autumn of 2017, performance monitoring was carried out for strippers and preheaters at CP Kelco Oy in Äänekoski, Finland. Performance monitoring was implemented using Savcor's Wedge software, which enabled real-time performance monitoring. This made it possible to note the performance reduction in the preheaters between washes and its relation to the increased energy consumption of stripping.

The operation of the preheaters was monitored with regards the transferred thermal power. The aim of pre-heating the stripper input stream was to reduce the stripping energy needs. However, no methods were available for evaluating the status of the preheaters or monitoring the stripper's energy consumption. As there were no methods available for real-time evaluation of the preheaters' condition, they were washed during production shutdowns and were run continuously until the next downtime.

Implementation of efficiency monitoring

It was found that the fouling of preheaters occurred readily in their specific heat flux, so their performance monitoring was focused on this area. The decrease in the performance of the preheaters was found to correlate with the increase in the specific energy consumption of the strippers. This helped to identify the costs of the reduced preheater performance.

An annual savings potential of about 1800 MWh in a single preheater was identified, which can be achieved by correctly timing the washing of the preheater. In addition, on the basis of the review, Elomatic was able to recommend better running conditions for the preheaters.

▼ *Ilkka Tenander (left) from CP Kelco and Jussi Parvianen (right) from Elomatic. Performance monitoring for strippers and preheaters at CP Kelco Oy in Äänekoski, Finland identified an annual savings potential of about 1800 MWh in a single preheater.*

Photo © Niko Ihalainen

Heat exchanger performance can be evaluated flexibly with a small amount of measurements.

to the heat capacity rate, i.e. when the temperature change increases, more heat is transferred from one fluid to another in relation to the heat capacity rate. The mere change of temperature can therefore be interpreted as an indicator of the performance of the heat exchanger.

When the temperatures of both fluids on both sides of the heat exchanger are known, the following can, for example be determined for it:

- effectiveness,
- the degree of approach for outlet temperatures of the fluids and
- specific heat flux.

The effectiveness is the ratio of the transferred heat output to the theoretical maximum heat output of the heat exchanger. The approaching degree of the fluid temperatures, on the other hand, shows how much the outlet temperatures of the fluids approach each other in the heat exchanger and can be used to evaluate how the heat exchanger is used. The specific heat flux indicates the overall thermal conductance of the heat exchanger relative to the heat capacity rate of the fluid.

An elevated fluid pressure differential across the heat exchanger, i.e. a pressure drop, is a sign of fouling of the heat exchanger, which generally degrades the performance of a heat exchanger. The fluid flow rate in a heat exchanger is directly connected through pumping to the pressure drop therein. For filtering the effects of the changes in flow rate, the pressure loss can be used for calculating, for example, the specific pressure drop per mass flow, whereby the cleanliness of the heat exchanger can be estimated irrespective of the flow conditions.

The fluid flowing through the heat exchanger may include components with distinct specific heat capacities. In this case, fluctuations in the concentrations of the components lead to fluctuations in the resulting total specific heat capacity of the fluid. Increased specific heat capacity, however, results in a decrease in fluid temperature changes, which can be mistakenly interpreted as a decrease in the performance of the heat exchanger. In this case, concentration measurement can be utilised to filter the effects of changes in concentration, whereby the performance calculations are comparable even with different input stream compositions.

Relative performance monitoring in other parts of the process

Performance calculations such as described above can also be applied to other processes. For example, the specific energy consumption of a stripping process can be seen as the ratio of the vapour consumption of the stripper and the feed stream of the stripped fluid. In this case, changes in energy consumption rate can be detected regardless of the amount of feed stream.

For larger process entities, it is also possible to determine their own separate performances as a ratio of production to resource use, but this is often a complex problem. The process can consume and produce both raw materials and energy in various forms, so the overall performance is not unambiguous. Performances of the individual parts of a process can be combined to make up the efficiency of larger entities by scaling the performances across the same value range. It is then also easier to focus performance monitoring on the most interesting targets.

Conclusion

Typically, the performance of heat exchangers is monitored only for the heat transfer rate and the operational efficiency is generally not considered. However, the performance of a heat exchanger can be evaluated flexibly with a small number of measurements. As the number of measurements increases, the number of possible analytical methods also increases. This information can be considered as a justification for increasing the number of measurements in some places. Performance monitoring can also be extended to other processes, whereby the performance of separate processes can be combined to make up the performance monitoring of larger entities.

About the author

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Jussi Parviainen graduated from the University of Oulu in 2018, majoring in process engineering with a focus on process automation. He has gained experience in process efficiency monitoring and data analysis since he joined Elomatic in 2017. Jussi currently works as a Senior Design Engineer at Elomatic's Jyväskylä office.

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Sustainability-driven engineering

A paradigm shift

Text: Rami Raute

Challenges regarding the sustainability of technologies and consumption are reported on a daily basis in the press. These challenges act as drivers for change and include, among other, climate change, plastic pollution in the oceans and collapsing bird populations. They have forced us to completely rethink the roadmap to sustainable life on earth. We are witnessing a paradigm shift to sustainability in engineering and all other aspects of life.

I have worked nearly 25 years with inventions as well as product and technology development. At the beginning of my career, in the late 1970s, this saw me working on combustion engines where the only goal seemed to be to achieve as much horsepower as possible: I have lived the life of a young car enthusiast with tremendous horsepower combustion engines and moved on to that of an aging engineer confronting sustainability challenges. My understanding of technologies and their connection to the environment has changed completely.

In this article, I present some pioneers of sustainable thinking, the ideal of 0-effect and forces shaping the changes required in our ways of doing things. This will require a fundamental shift in how we operate and think.

Change is gaining momentum

One can already see changes in some companies where engineers are seriously working on new and more sustainable technologies; taking the first tiny steps to the future.

The changes are important. It is widely held by climatologists and the scientific community at large that even significant changes in production and consumption patterns may not be enough to ward off catastrophic climate change. The planetary boundaries model developed by the Stockholm Resilience Centre indicates that many other boundaries than climate changes are approaching or have been exceeded. The goal can only be sustainable human operation.

Pioneers of sustainability

Too few people have considered sustainability from human and engineering perspectives; a few examples, nevertheless exist.

In the late 1960s, Richard Buckminster Fuller, who had already in the 1920s critiqued and reflected on

the unsustainable way of human life, penned the "Operating Manual for Spaceship Earth". It contains interesting and relevant thoughts for today with regards sustainability and its meaning.

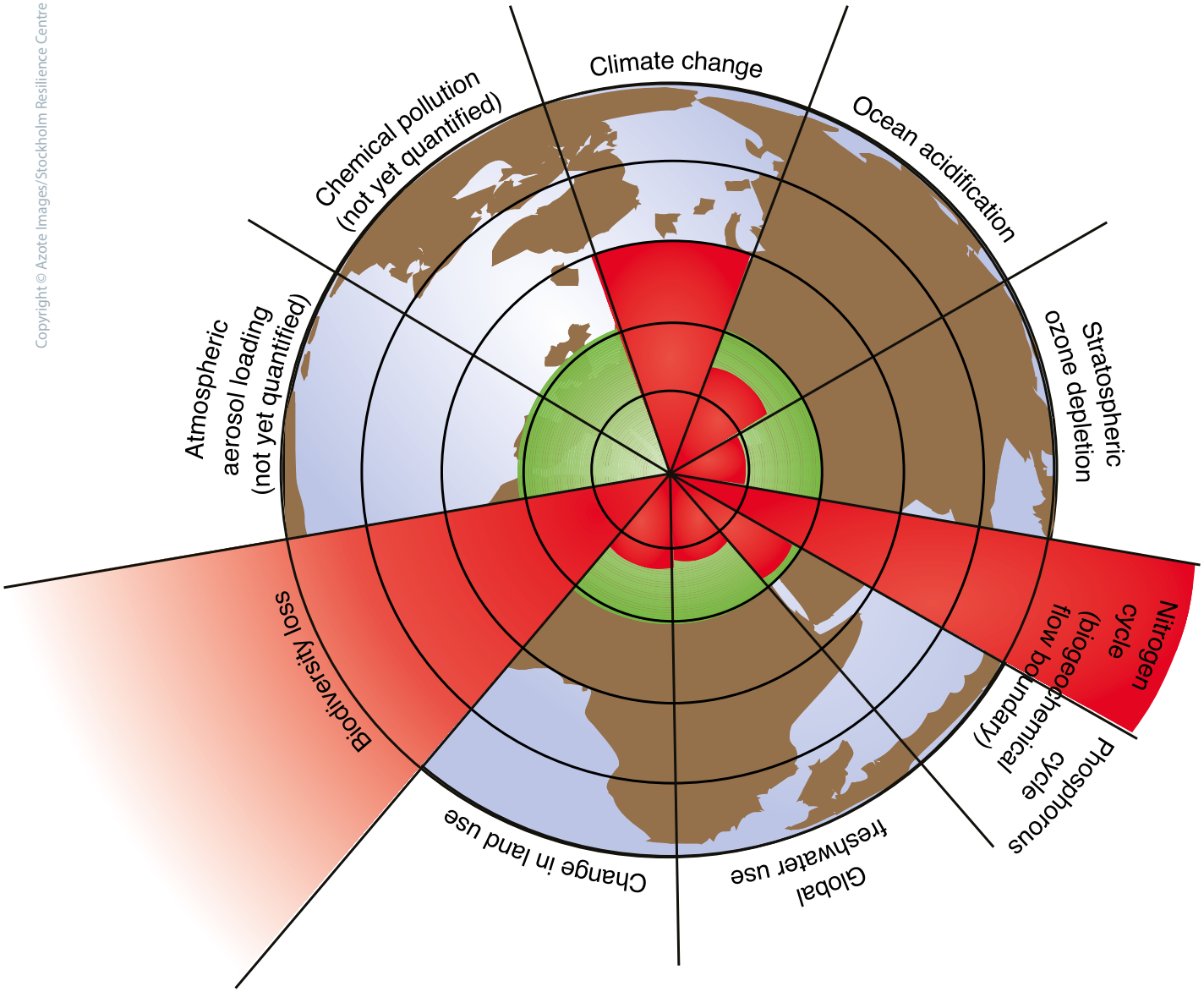
Buckminster Fuller's definition of sustainable technologies is particularly interesting. In his definition, he compares the use of fossil fuels with a car battery that has to be charged after use. He indicates that the carbon used should be bound before more can be used. In his view, this limits the use of fossil energy only to the manufacturing of production devices and tools. With today's knowledge, we can see that Buckminster Fuller was very close the correct evaluation of the sustainable possibilities of carbon consumption.

He also popularised the term ***synergy*** and the expression ***doing more with less***, which refers to the necessity of synergetic use of resources, e.g. in rooms and spaces that are underused such as beds that are slept in only 33% of the time.

In the 1970s, Paul McCready, who lead the development of aircraft powered by small energy sources, ventured that a human could fly with the help of only muscle power and solar energy. He also led the development of the first generation of prototypes for mass production electrical cars.

A lesser known fact is that AeroVironment Inc., which was founded by McCready, has been a top drone technology developer and forerunner; applications that use little energy and provide concrete proof of the saying doing more with less.

▼ *Planetary boundaries/Stockholm Resilience Centre.*



Ray Anderson is often referred to as the world's greenest CEO. When managing the world's largest modular carpet company, Interface Inc., he showed that even wall-to-wall carpeting production can be sustainable. Anderson's goal for the company is to erase its negative footprint on the environment completely by 2020.

If we're successful, we'll spend the rest of our days harvesting yester-year's carpets and other petrochemically derived products, and recycling them into new materials; and converting sunlight into energy; with zero scrap going to the landfill and zero emissions into the ecosystem. And we'll be doing well … very well … by doing good. That's the vision.

– Ray Anderson, 1997

I am familiar with the idea of considering matters for a solution perspective in development work. In this article, I also approach the problem of sustainability from a problem solving perspective, by creating scenarios for development and an engineering goal framework.

Not sustainable, not affordable

From practical experience the following three factors tend to play the biggest roles in in engineering and development decisions: Cost & profitability, technical feasibility, and market approvability. The weight and order of the factors vary. Other factors naturally also play a role, but the above-mentioned are the most important.

In the paradigm shift in engineering, it will be essential to increase the role of sustainability. It should, in fact, become the most important factor in decision making and be integrated with specifications and legislation; if something is not sustainable, it is not affordable. Sustainability will, as such, be more important than even price or high profit margins.

We often hear examples of technologies that we cannot develop or that are impossible to develop with current know-how. At the same time, several studies indicate, for example, how much energy is wasted.

The example in the text box regarding the efficiency of energy use is from the book "Sustainable Engineering". It illustrates that the overall efficiency of a pump, whose energy has been generated from oil, is quite low. 87% of the energy is lost along the way. We naturally have to review and develop the entire chain to achieve better efficiency and all parties in the supply chain need to participate therein or to exit the chain.

The flow chart in Diagram 1 is from the Lawrence Livermore National Laboratory. It displays US energy consumption and losses in 2017. It indicates that only 31% of primary energy is preserved for use. By studying LLNL's flow charts dating back to the 1970's, it becomes clear that the efficiency of energy use has not increased since the 1970s, in fact, the situation has worsened.

We can also ponder whether this and supply chains of similar efficiency have been designed as such, or whether they were created by chance and have, over time, become part of our industrial culture?

Towards a sustainable future

In product development and problem solving, different methods have been created to support thinking and understanding. Together, these methods form streamlined process tools. The tools listed below were used in the following sustainable scenario example:

1. Timeline method (Vocabulary book)
2. Ideal solution (Description from TRIZ method)
3. Scenarios

To create scenarios, we set an ***ideal goal*** as per Fuller: Recyclable and renewable materials, renewable energy, harmless to all living organisms on earth. Scenarios for the timeline can be created e.g. as follows:

► *Diagram 1. Estimated U.S. Energy Consumption in 2017: 97.7 Quads. (Source: LLNL, April 2018. https://flowcharts.llnl.gov/home)*

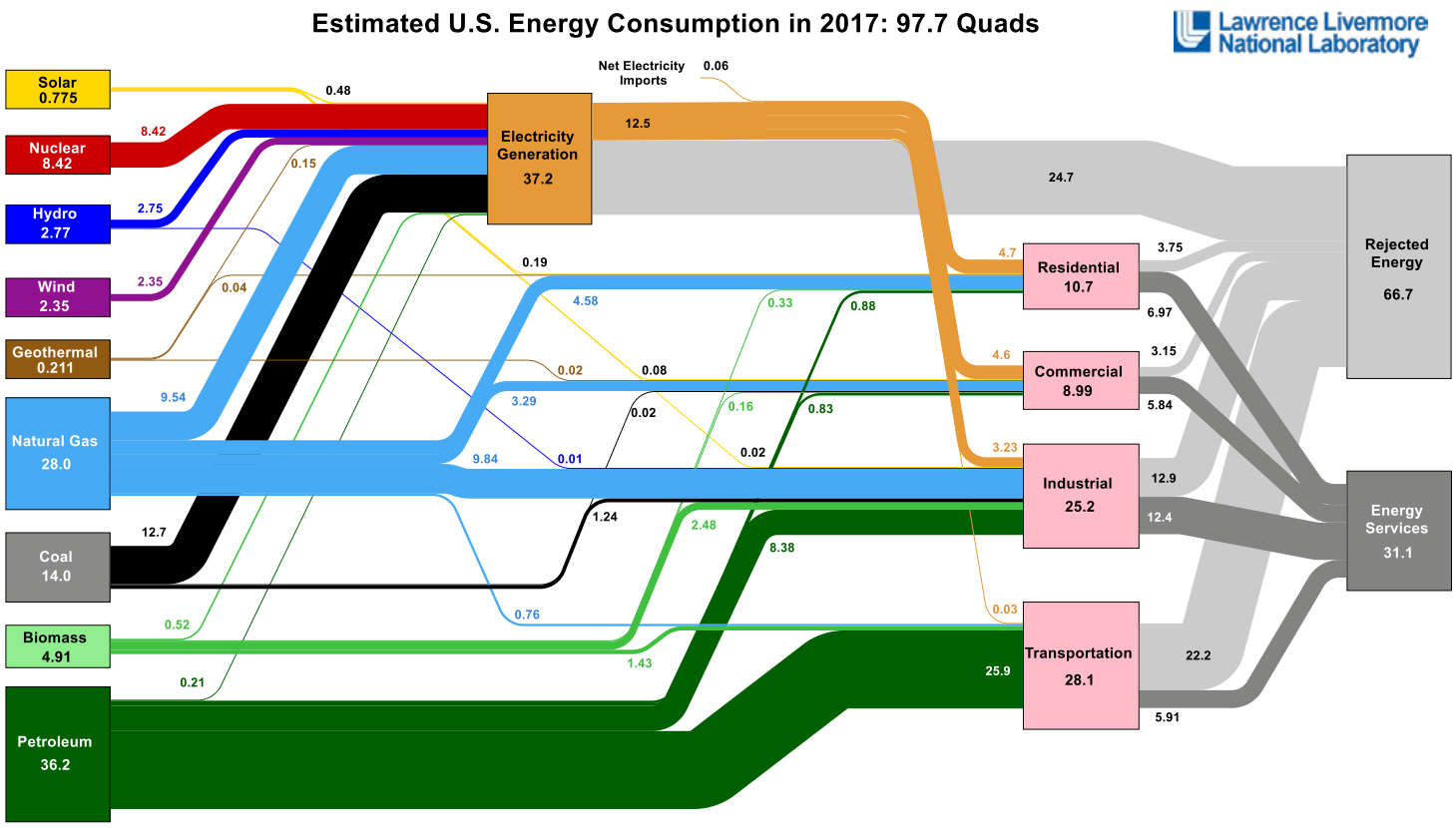
1. 2020 developing sustainable thinking, tiny steps achieved led bulbs, EU truck regulations etc.
2. 2050 Changed paradigm of engineering and technologies, 0 carbon nominal applications
3. 2100 0-effect technologies increased volume of lifeforms and volume on planet earth

The idea behind example scenarios is that the sustainability goals guide technology development in a more sustainable direction at first, and finally in a definitively sustainable direction. By 2100, the majority of technologies used by humans should be completely harmless to the environment and allow the development and reproduction of living organisms on earth. When we compare the goals to environmental research, currently available technologies and their environmental impact, known development projects and our own experience of the speed of technological development, it is easy to see why environmentalists are concerned.

Summary

Changes in the world and environment are forcing us to alter the way we make technical decisions and plans. In many areas, we have already exceeded the boundaries of sustainability. All engineering is done for the future. Currently, we have better engineering and analysis tools at our disposal than ever before in our history.

We cannot engineer the future only based on best practices of the industrial age. We have to create new ways of working, a new engineering paradigm where sustainability is a significant factor in decision making and, in the end, the most important.



Efficiency of energy use

Determine the efficiency of energy utilization for a pump. Assume the following efficiencies in the energy conversion:

- Crude oil to fuel oil is 90% (0.90) (i.e. the energy to produce and refine crude oil consumes 10% of the energy of the crude oil input to the process).
- Fuel oil to electricity is 40% (0.40) (i.e. the conversion of thermal energy into electrical energy occurs with an efficiency of 40%, roughly the average for the U.S. electrical grid).
- Electricity transmission and distribution is 90% (0.90) (i.e. losses of electricity in transmission from the power plant to the point of use are 10%).
- Conversion of electrical energy into mechanical energy of the fluid being pumped is 40% (i.e. the efficiency of the pump in converting electrical energy into the mechanical energy of the fluid is 40%).
- SOLUTION: The overall efficiency for the primary energy source is the product of all of the individual conversion efficiencies.

Overall efficiency = (0.90)(0.40)(0.90)(0.40) = 0.13 or 13%

Source: Sustainable Engineering, Allen & Shonnard, p. 7

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Rami Raute has worked in several Finnish consulting and industrial design companies. He has over 20 years' experience in developing different products and concepts and leading product development projects. Rami started working at Elomatic in 2011 and currently holds the position of Product Development Manager at the Elomatic office in Espoo.

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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.

www.elomatic.com

VTT and Elomatic deepen cooperation

VTT Technical Research Centre of Finland Ltd and Elomatic have signed an agreement for the supply of expert and engineering services.

According to the agreement, Elomatic will supply VTT with project management services and comprehensive consulting and engineering services for VTT's fibre product, foam forming fluidised bed and grate firing process technologies and their testing devices.

Elomatic and VTT have cooperated in the past, but the agreement strengthens the partnership. The agreement also eases doing business in day-to-day commissions. Elomatic's services to VTT range from small individual engineering commissions to comprehensive project management on an EPCM basis, including engineering, procurement and construction management.

"This is a very significant agreement for Elomatic. VTT represents the top-end of research in Finland and we want to be associated with such expertise. It also allows us to network with new technology providers. We are proud that VTT trusts our ability to supply them with critical project, consulting, and engineering services for their research projects," says Senior Vice President, Mechanical, Timo Martikainen.

▲ *The VTT foam forming platform enables efficient R&D from laboratory to rapid upscaling for industrial use.*

The service contract went through the prescribed public tendering process, which was won by Elomatic.