top engineer

The Elomatic Magazine 2 · 2017

Bioeconomy and circular economy business operations have to be financially sustainable.
– Riina Brade

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

One hundred reasons to celebrate

On 6 December 2017 Finland celebrated 100 years of independence. The theme of #Finland100 has been omnipresent throughout the year. Publishing houses have been inundated with memoirs, history books and a host of other publications that all describe or tell their stories as part of the centenary celebrations and Finland's journey. Social and traditional media have also been abuzz with related features and a whole host of different #Finland100 events have marked the calendar year, culminating in the actual event.

Usually, Finns only celebrate on Independence Day itself, but the centenary celebrations kicked off already on Independence Day Eve this year. In many respects, the entire year has been a celebration with the focus not only on the hundredth year, but the whole journey that started back in 1917.

Visitors to Finland are often surprised that Finnish Independence Day celebrations are rather restrained, especially compared to those of Bastille Day in France and other independence celebrations around the globe. To a large degree, the focus here still is on giving thanks to those that fought and lost their lives during WWII, which enabled Finland to retain the independence it gained at the time of the Bolshevik Revolution.

One of the Finnish success stories worth celebrating is how we managed to transform a largely agrarian economy and poorly educated population, into one that is now at the forefront of technological innovation and which boasts one of the best and most equal education systems in the world. This was achieved, among others, by having a clear vision and common purpose. It did not happen overnight either, so hard work and perseverance have been required in equal measure. These are all qualities that are needed to be successful in business too.

So how does Elomatic's story tie in with Finland's history? We have been part of it for the last 47 years. As a knowledge intensive service provider, we are naturally immensely dependent on the educational system to produce smart designers, engineers and other professionals. Without them, we would not exist. Our customers literally buy what is between our ears. It is our ability to develop working solutions to technical challenges that keep us in business. We have also developed our own training programs and systems to ensure that these professionals continue developing their know-how and remain at the forefront of technological changes.

About 75% of our engineers received their education in Finland. In addition, we recruit top talents at our international locations. Knowledge sharing between these experts is a key component in reinforcing and developing their know-how. The Top Engineer magazine is a platform where our experts can share their expertise with their peers and our customers alike.

I would like to wish you all happy reading and a prosperous 2018.

Patrik Rautaheimo
Editor-in-Chief
CEO

Contents

top engineer

2/2017

Publisher
Elomatic
Itäinen Rantakatu 72
20810 Turku, Finland
Tel. +358 2 412 411
info@elomatic.com
www.elomatic.com

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

Editor
Martin Brink
martin.brink@elomatic.com

Art Director
Olli Tuomola
olli.tuomola@elomatic.com

If you would like to receive a copy of the Top Engineer, or would like to be added to our Top Engineer mailing list please send your request to info@elomatic.com.

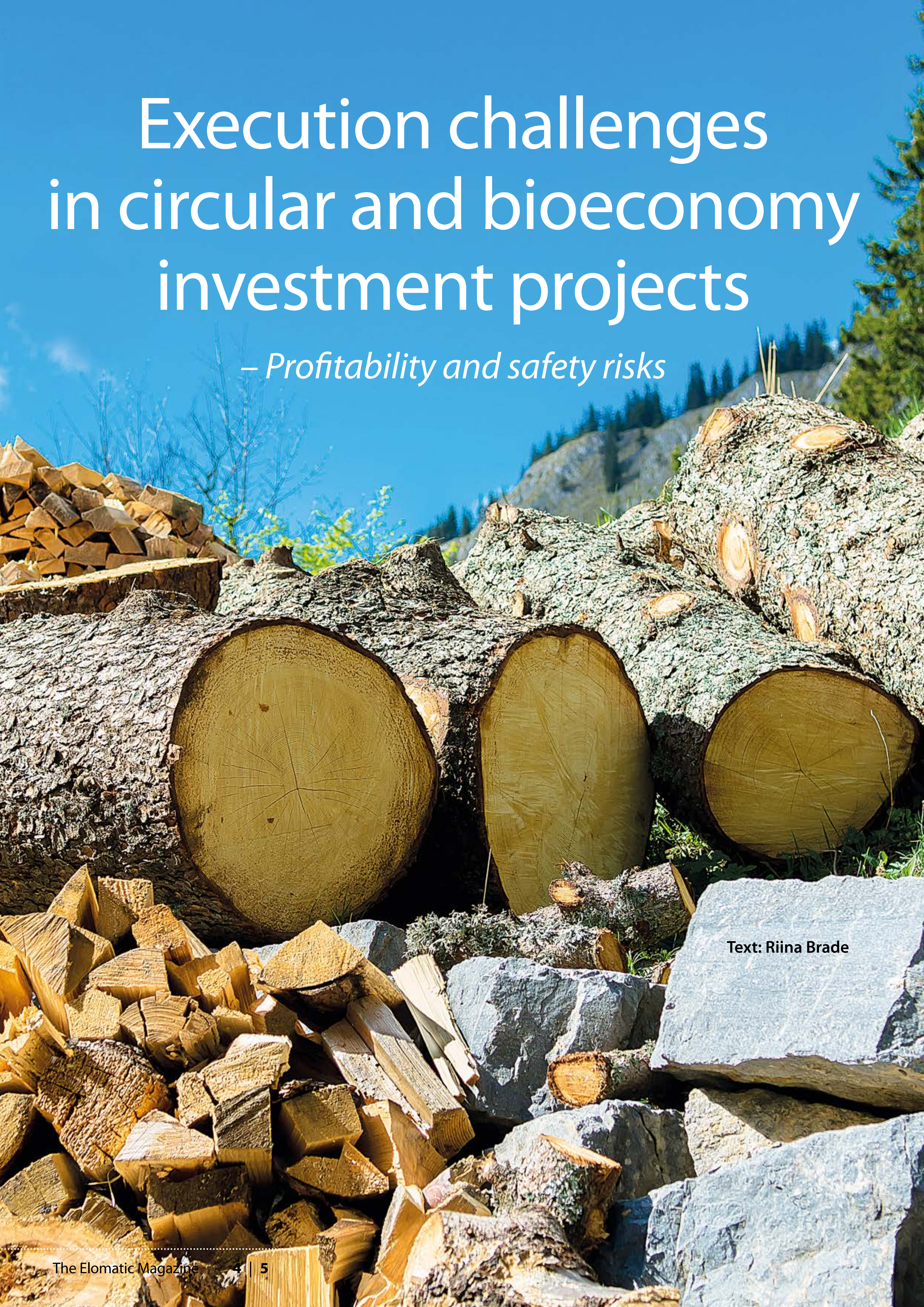
Elomatic believes that all information provided in this publication is correct at the time of printing. Elomatic is not responsible for any inadvertent errors.

Cover: Riina Brade works as a manager for process industry sales at the Elomatic Espoo office.

Cover photo © 2017 Olli Tuomola / Elomatic.

Execution challenges in circular and bioeconomy investment projects

– Profitability and safety risks



Text: Riina Brade

Climate change and population growth have been hot topics in the media recently. The overwhelming consensus is that the time has come for resource wisdom and carbon neutrality. Finally, the so-called cowboy economy, where natural resources are consumed as if they were infinite, is coming to an end.

The sustainable use of natural resources and responsible corporate operations are making inroads across the globe. Despite the improving picture and increasing environmental awareness, good examples and forerunners are still needed to secure natural resources and a clean environment for future generations. Several challenges exist in executing circular and bioeconomy investment projects profitably. This article explores these challenges.

A question that is often raised about bioeconomy and circular economy business operations, is how they can be conducted profitably? Without financial sustainability, one cannot benefit from technologies that produce lower emissions and consume resources more wisely, or support social and cultural sustainability locally, and more broadly, in the corporate supply chain. Put another way, the three pillars of sustainable development, as presented by Gro Harlem Brundtland at the UN in 1987, have to be in balance.

According to the Finnish government programme, Finland aims to be a forerunner in the bioeconomy, circular economy and cleantech by 2025. The circular economy refers to operational models and business operations where raw materials, products and materials are used as productively and sustainably as possible.

The Finnish Innovation Fund (SITRA) does not only focus on recycling in its roadmap for Finland; its vision also includes the maximisation of materials and their value in the circular flow for as long as possible, starting from primary production and material processing all the way up to product manufacturing, distribution, sale and consumption. The Finnish ministry of agriculture and forestry, on the other hand, views a bioeconomy as an economy that uses renewable natural resources to produce food, energy, products, and services. A bioeconomy is characterised by the use of technologies related to natural resources that are renewable and bio-based, cleantech, and effective recycling.

So what is slowing Finland's progress in becoming a forerunner in the afore-mentioned areas? From the perspective of an engineering company, the most significant challenges are ensuring that the new processes are technically sound and reliable, and that the projects are profitable on the whole.

Engineers are used to solving problems and developing new technologies, but solving new environmental and profitability questions, let alone social questions, require different types of analyses and know-how. Engineering companies have a good opportunity to take on and meet this challenge; we can use our techno-economic skills and ethics to affect the environment in the way we design processes and products.

Factors affecting the profitability of bioeconomy and circular economy projects

Industrial investment projects generally progress from the preliminary study and concept phases to a rough total cost estimate, which is +/- 25–40% accurate, depending on the complexity of the process and the use of new technologies. Based on this, preliminary CAPEX costs can be ascertained for financing requirements and to get permission to go ahead with the investment.

By clarifying the process demands, location and construction requirements, the costs can be evaluated more precisely, leading to estimates that are +/-15–25% accurate. This cost estimate takes more extensive design, device installations, civil and structural engineering, construction, and project management into consideration. Depending on the contractors and processes, this is further refined in detail design if necessary, at the same time when calls for offers for the most significant procurements are made. At this stage, the investment cost can be estimated with +/- 5–10% accuracy.

Elomatic often favours the EPCM project implementation model in large plant investment projects. It is very suitable for the current fast-paced industrial environment, where customers' own engineering and project management resources are limited.

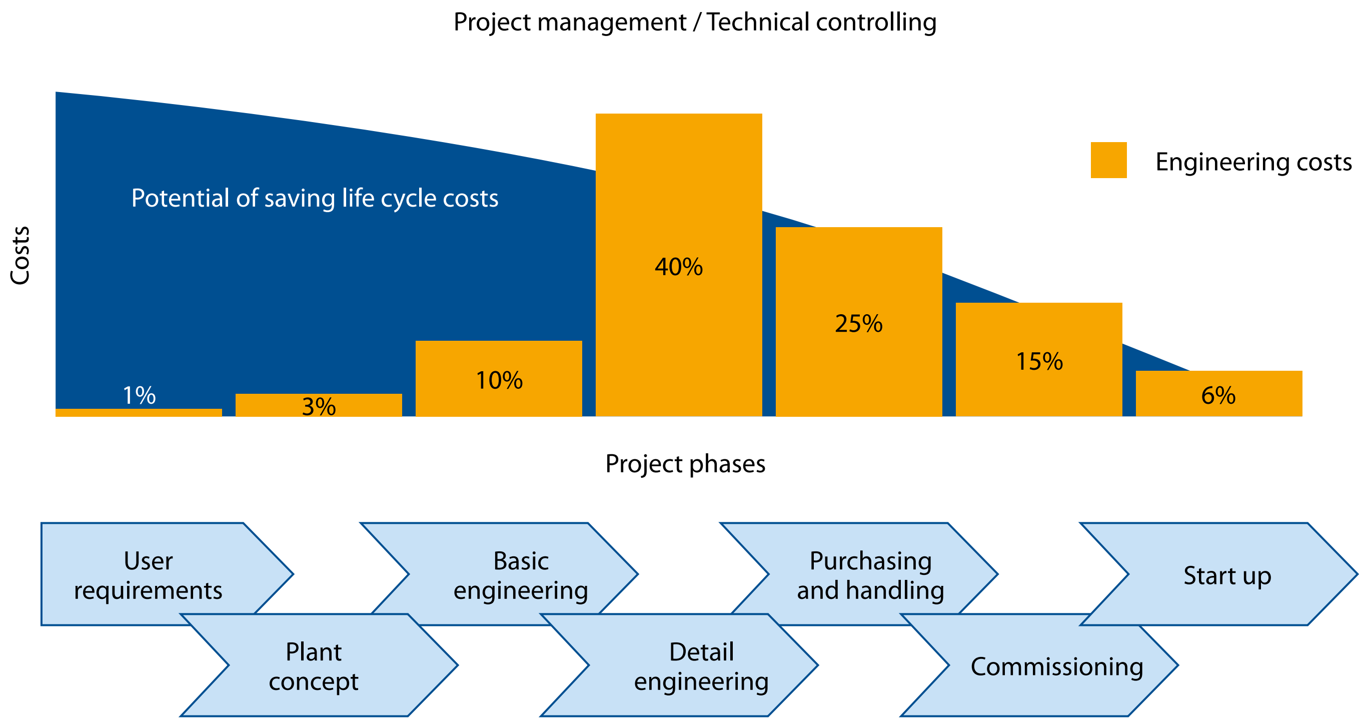
The idea behind the EPCM implementation method is to act as the customer representative in implementing projects in the agreed timeframes and budgets, with consideration for the customer's goals and cost pressures.

With several customers, the goal is nowadays no longer only sticking to schedules and cost discipline, but rather to boldly look into more sustainable concept alternatives to increase capacity and productivity already in the design phase. The investment decision is, thus, affected by the project's ability meet future corporate responsibilities. In other words, we affect environmental loads and energy efficiency and also identify industrial symbiosis alternatives.

These factors all affect the profitability of the project throughout its life cycle and can not only be seen as factors that increase costs. Financiers have also recently highlighted the ability to substantiate the sustainable development effect of investments. A "sustainable investment" grade and category has come to the fore in this regard.

▼ *Diagram 1. The success of an investment project is supported by EPCM-services and step-by-step project management.*

Project Success for Your Plant Engineering



The world of investing is obviously a highly profit-driven affair – everything usually costs too much. In practice, investors often lean towards cutting costs, for example, in engineering. This could be seen as saving in "the wrong place". In such cases, there is a desire to jump straight into implementation from the rough preliminary study phase. This is naturally possible, but then one has to accept higher cost uncertainty and increased project and procurement risks.

It would be better to invest in more thorough engineering so that the total cost of the investment can be estimated with 10–20% accuracy, depending on the type of project and technological solutions. Investing in engineering is the most likely way to simultaneously end up with the right, most cost-efficient and most sustainable solution.

Bioeconomy and circular economy projects also commonly have to deal with challenges related to developing technologies and changes to existing process parts. To meet these challenges, sufficient pilot-level testing and test runs are required. In such cases, the scale-up should be approached with care to maintain low costs, but also to utilise economies of scale in device and piping solutions.

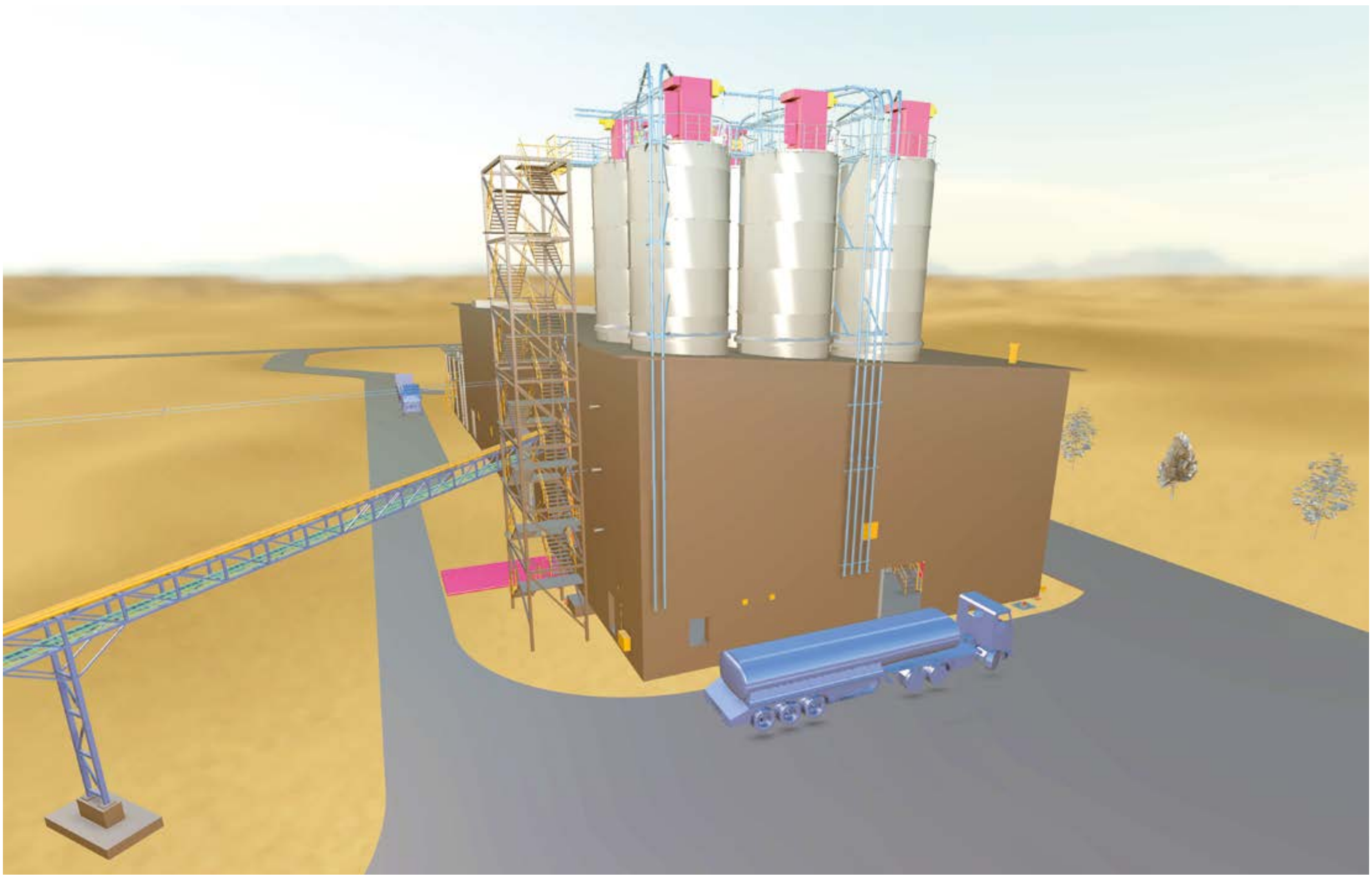
From a macroeconomic perspective, taxation has a great effect on the life cycle profitability of an investment, via its effect on raw material and energy prices. The game is no easier with regards end products – the markets and delivery chains of some novel bioproducts are only forming now. It is, as a result, difficult to make profitability calculations based on the prices of such products.

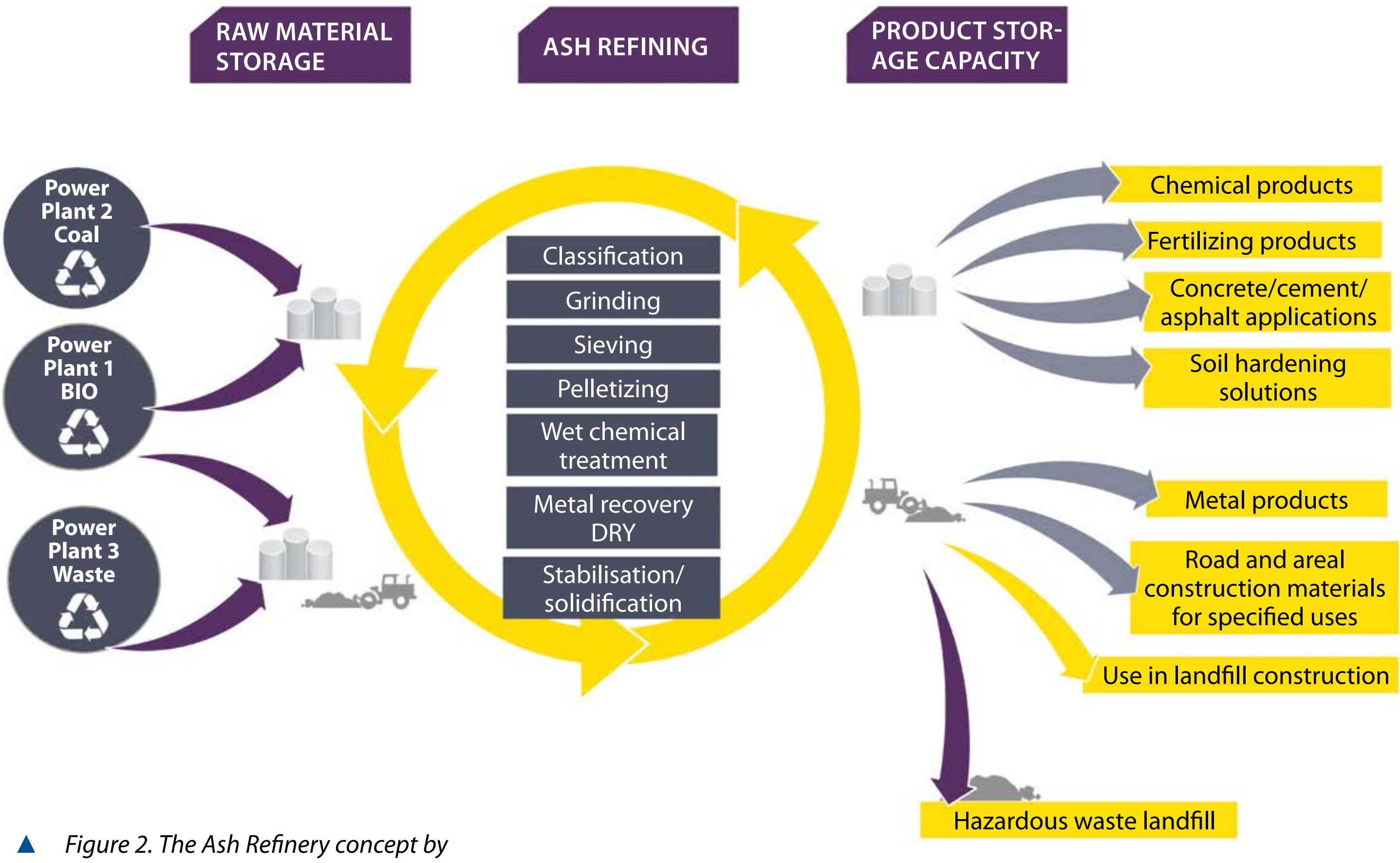
Furthermore, in order to succeed, industrial symbioses require a large degree of synergy and trust between different stakeholders. It is also challenging to acquire financing if the payback period is not deemed attractive and there is an inability to communicate the corporate responsibility benefits and savings potential over the investment lifespan to sustainable development investors.

Ash refinery investment an example of a sustainable solution

Despite the afore-mentioned challenges, new and sustainable solutions have been implemented. An example of this is Fortum Environmetal Construction Ltd's ash refinery Investment in Pori, on the southwest coast of Finland.

▼ *Figure 1. A 3D model image of the Ash Refinery plant by Fortum Environmental Construction Ltd.*





▲ *Figure 2. The Ash Refinery concept by Fortum Environmental Construction Ltd.*

Elomatic managed the project on behalf of the customer and did the technical process and plant design for the project, from the feasibility study all the way to implementation.

The plant construction project started in June 2017 and will be ready by May 2018. The wet chemical treatment plant has a capacity of 45 000 tonnes of dry Air Pollution Control (APC) waste. APC residues originate, for example, from the cleaning of flue gases at Waste to Energy plants.

The plant is the largest facility of its kind in Europe and the first in Finland. In addition to use in landfill construction, the new treatment of ash and APC waste will reduce CO_2 emissions and produce new road salt while also offering opportunities for metals recovery (e.g., Zn).

Managing new types safety risks

The Finnish government's and SITRA's plans of action to boost the bioeconomy and circular economy, do not generally highlight the recognition and handling of safety risks; this burden will be carried by companies and the safety authorities.

The Finnish Safety and Chemicals Agency (TUKES) estimates that bioeconomy and circular economy plant projects are exposed to new types of safety risks. It indicates that these risks should be systematically noted as part of companies' risk management activities. The circular economy may make use of new chemicals, new types of processes and production plants, and require storage and use of recovered and recycled materials. These elements bring with them new safety risks that companies need to take into consideration already in the design phase of plant and/or revamp investments.

A key skill for engineering companies is the ability to work with their customers and the authorities to manage these risks. They also need to keep up to date with changing process and plant safety regulations and bring safety perspectives to the fore in the different design phases. The focus is on the identification of chemical, physical, and biological risks and their timely evaluation in different design phases with regards to new raw materials and processes.

- Biological risks arise due to possible impurities and microbes contained in recovered materials. They may pose health risks to operators

Bioeconomy and circular economy projects can be profitable, if we invest in feasibility studies and engineering.

(in the form of process risks: e.g. fermentation of stored materials and gas production). End users may even be exposed to the risk of catching diseases.

- Chemicals present in recovered materials carry inherent risks. The acidity, alkalinity, and reactivity of these chemicals can, in worst case scenarios, change daily.
- Physical risks typically include different types of dirt and dust that need to be managed, even just from an explosion risk perspective. Electrochemical and fire risks, on the other hand, are normally related to battery recycling.

Consultants or engineering companies should define the risk management measures with the customer, while also taking statutory requirements (so-called minimum performance requirements) into consideration. In addition to the knowledge of safety specialists, HAZOP and FMEA analyses can be employed. Simulation tools (e.g. CFD dispersion models) can be used to evaluate the potential risks that production processes pose to the environment under both normal operation and malfunction.

Safety risk evaluations should be updated again in the detail design phase and during construction. In addition, technical modelling for different safety dimensioning could be done, classification of areas related to explosive atmospheres verified, and device/line CE marking compliance studies conducted. Care should also be taken that the results and actions to minimise the risks are taken into consideration and implemented.

Electronic and electrical waste pilot plant

An ongoing electronic and electrical waste pilot plant in Jyväskylä, Finland, is a good example of a circular economy project where safety aspects play a major role. The Federation of Technology Industries of Finland is behind the demonstration project, which has progressed to the modelling and preliminary design phase. Jyväskylän Energia Ltd, Tapojärvi Ltd and Elker Oy, which specialises in electrical and electronic waste recycling, are heading up the project, while Elomatic is responsible for plant design.

The plant will recover precious metals and, in particular, rare earth metals found e.g. in mobile phones. It has, until now, not been possible to recover these metals using traditional pyrometallurgical methods. The safety risks of the new process and demo plant will be comprehensively updated making use of the HAZOP method and working with experts from different fields as part of the implementation project.

Conclusion

The profitability of bioeconomy and circular economy projects are affected by several factors. These include the project life cycle and size, new technologies/processes applied, the project implementation method and engineering phasing, stakeholder and investor goals, industrial symbiosis options, taxation, legislation, and energy prices.

Profitable investments can be achieved by recognising these techno-economic factors and investing in feasibility studies and engineering. Projects that are marked by sustainability and corporate responsibility will then be of interest to future responsible investors. Safety risk management is not a negative aspect in such projects, but rather forms part of project management that engineering companies are ready to undertake.

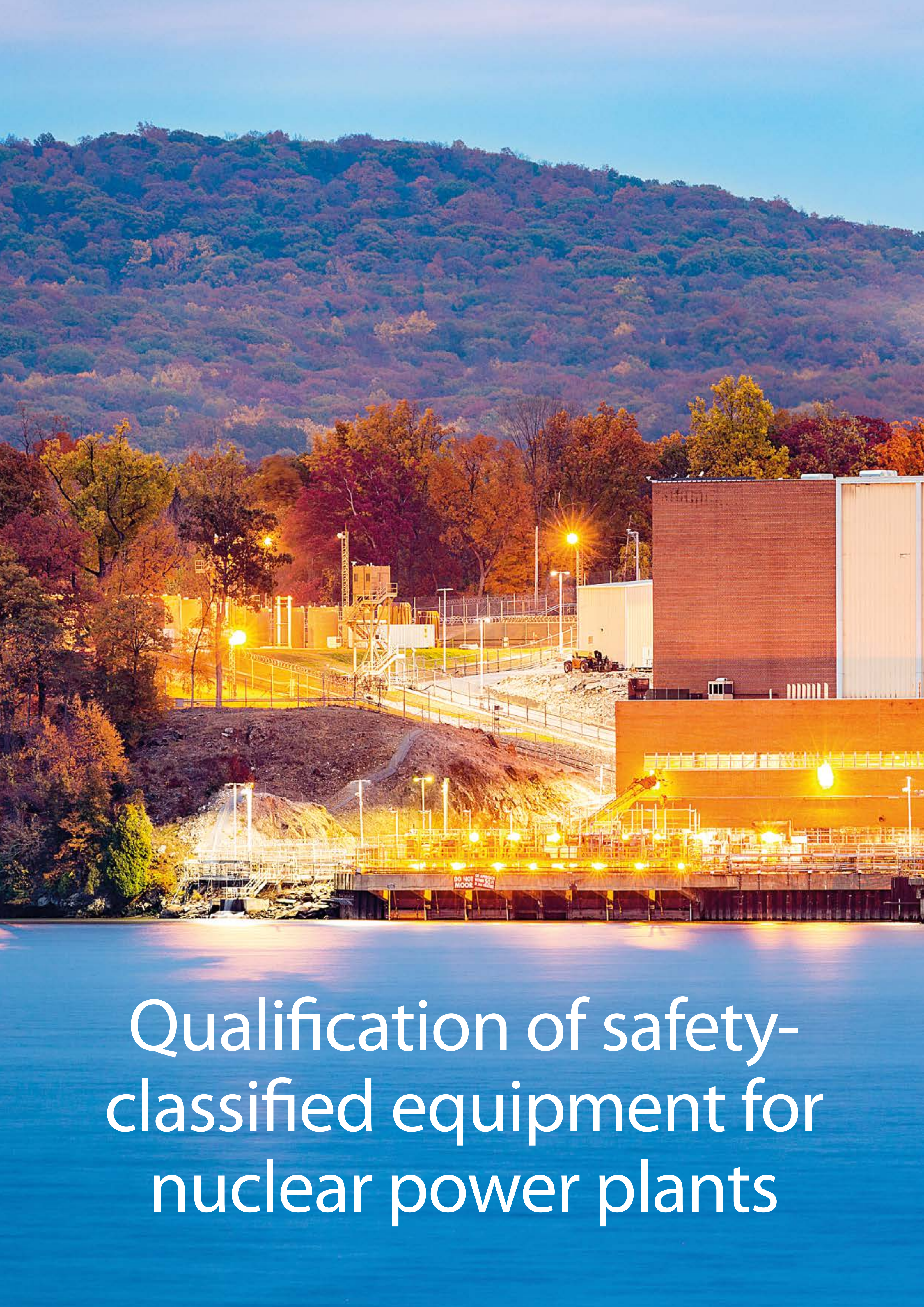
About the author

Riina Brade

M.Sc. (Chem Eng.) & MBA

Ms Brade´s 20 years' experience covers competences spanning production process development, R&D management, B2B sales and content marketing. In addition, she possesses a lead auditor qualification in QEHS management systems utilised in strategic business development. Riina joined Elomatic at the beginning of 2012 as Manager for Process Industry Sales. Over the last 5 years she has achieved a firm footing within industrial investment and revamp management supported by key customer management and project supervisory tasks.

riina.brade@elomatic.com



Qualification of safety-classified equipment for nuclear power plants

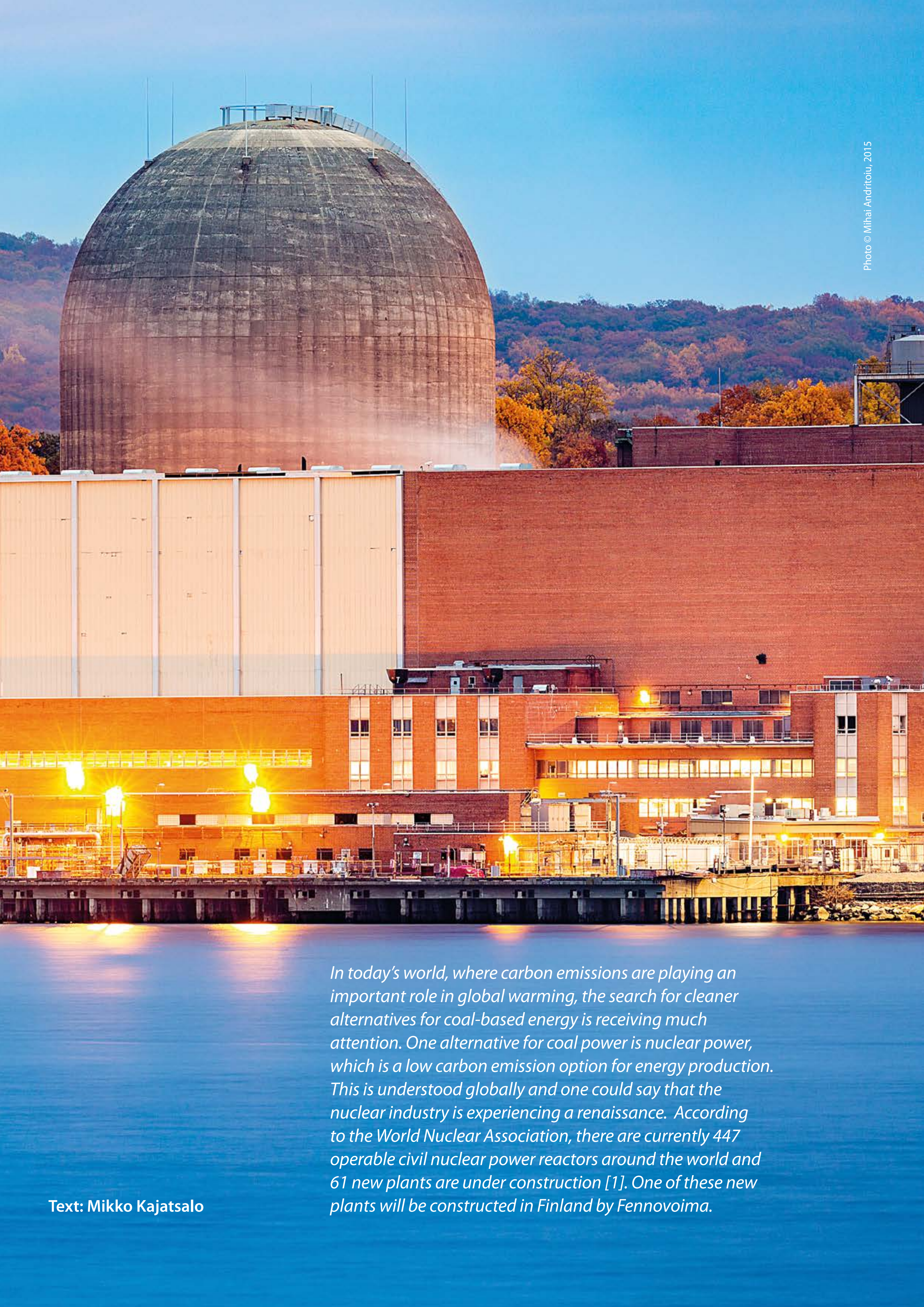


Photo © Mihai Andritoiu, 2015

In today's world, where carbon emissions are playing an important role in global warming, the search for cleaner alternatives for coal-based energy is receiving much attention. One alternative for coal power is nuclear power, which is a low carbon emission option for energy production. This is understood globally and one could say that the nuclear industry is experiencing a renaissance. According to the World Nuclear Association, there are currently 447 operable civil nuclear power reactors around the world and 61 new plants are under construction [1]. One of these new plants will be constructed in Finland by Fennovoima.

Text: Mikko Kajatsalo

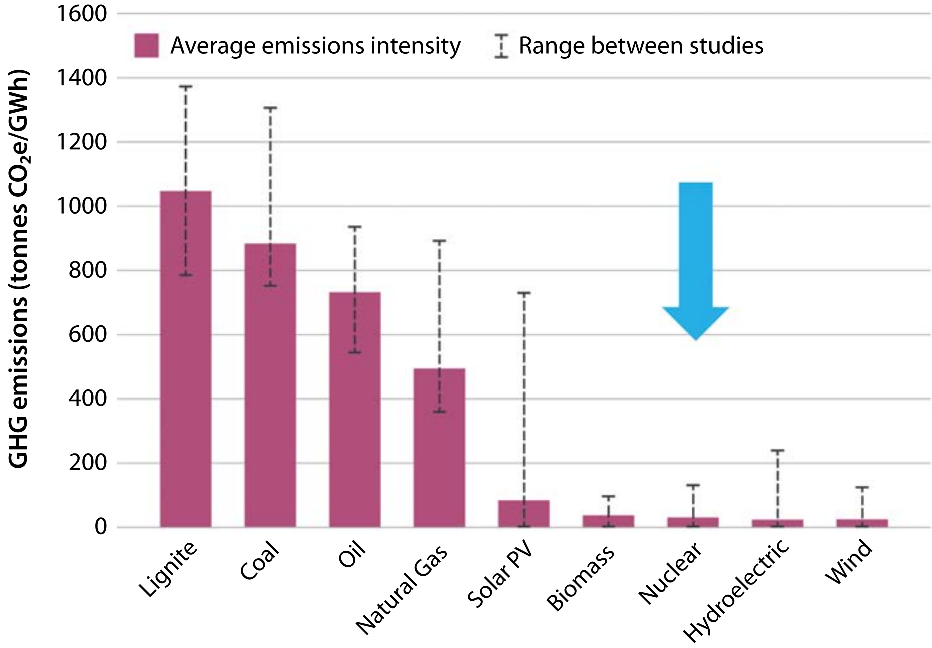


Figure 1. Decarbonising electricity generation – need for low life cycle emissions: Nuclear energy is among the best. Source: World Nuclear Association meta study, incl. IPCC 2014

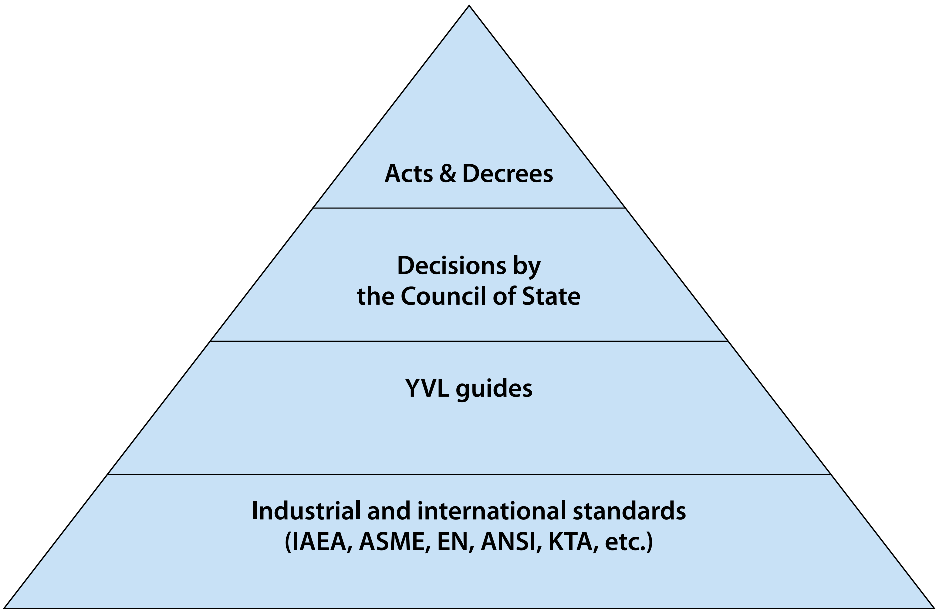


Figure 2. The hierarchy of standards and requirements that nuclear equipment must fulfil in Finland.

The most important issue when designing and building a new nuclear power plant (NPP), or upgrading an old NPP, is ensuring the safety of the plant and design compliance with national and international regulations. The safety of the plant is verified in a qualification process. The purpose of the qualification process is to demonstrate that the structures, systems and components (SSC) can perform their intended safety function(s) under applicable service conditions including design basis events, such as earthquakes, during the SSCs lifetime.

This article presents the principles that guide qualification of safety-related equipment in the nuclear industry.

Equipment qualification process

The qualification process includes several steps to demonstrate the safety of equipment. The main elements of equipment qualification are the design input, nuclear and non-nuclear requirements, qualification plan, the implementation of the qualification data, and the generation of documentation that demonstrates successful qualification.

Design input

Design input includes all the information required to identify and qualify equipment, for example, equipment performance, the environment, design basis events, service conditions, and safety function(s). Safety classification is an important part of design input and involves a process where the SSCs are classified according to their safety

Equipment qualification process

1. Design input
   a. Equipment identification
   b. Safety classification of equipment
   c. Safety function(s)
   d. Technical specification
   e. Design basis events
2. Nuclear and non-nuclear requirements
   a. e.g. IEEE, YVL, KTA, ASME, EN, US NRC
3. Qualification plan
   a. Qualification methods
   b. Acceptance criteria
4. Implementation on the qualification plan
5. Documentation demonstrating successful qualification

requirements. The goal of the safety classification is to identify and classify the SSCs that are required to protect people and the environment from the harmful effects of ionizing radiation, based on their roles in preventing accidents, or limiting the radiological consequences of accidents should they occur [2]. The classification can be done in many different ways and, for example in Finland, nuclear facility systems, structures and components are grouped into Safety Classes 1, 2, and 3 and Class EYT (non-nuclear safety).

Nuclear and non-nuclear requirements

There are several international and national regulations, standards and requirements that nuclear equipment must fulfil. The hierarchy of regulations and standards used in Finland is presented in Figure 2.

At the top there is the Finnish law including nuclear-specific laws and decisions of the council of state. At the third level there are YVL-guidelines issued by the Finnish nuclear authority (STUK) and at the bottom there are industrial and other standards. Qualified equipment must fulfil the requirements of all the hierarchy levels.

Qualification plan and its implementation

A qualification plan presents how the actual qualification of equipment is demonstrated. The plan should encompass at least the following: aging, strength and fatigue, dynamics, functionality requirements, margins, maintenance and acceptance criteria.

The actual qualification of equipment is done in the implementation phase and it can be done by testing (QT), experience (QE), analysis (QA) or by a combination of these. Typically, equipment with functionality requirements (active equipment) is tested, and equipment without (passive equipment) is analysed. Relays, electrical motors, pump units, and electrical valves are examples of active equipment. Steel structures, pipes, pressure vessels and containers, on the other hand, are examples of passive equipment.

The tests can, for instance, include type tests, seismic tests and aging tests. Typically, the purpose of the analysis is to show that the material design strength (both static and fatigue) is not exceeded in any design situation.

Documentation

The documentation of the qualification includes all the necessary data to demonstrate the fulfilment of safety function(s). The documentation includes test reports, experience data, calculation documents and all other documents related to qualification. The NPP licensee is responsible for preserving the equipment qualification to ensure that the equipment qualification documentation remains valid.

Summary

The qualification of safety-related equipment in the nuclear industry is a crucial process. All regulations of the countries in question need to be carefully adhered to. In order to ensure compliance with the regulations, it is essential to consult with an expert that has extensive experience of the nuclear business environment and equipment qualification. The role of a consultant is to assist customers in different areas of qualification, such as seismic qualification, documentation, documentation reviews, strength analysis, and comparison of requirements in different countries.

Sources

[1] http://www.world-nuclear.org/nuclear-basics/global-number-of-nuclear-reactors.aspx
[2] IAEA Safety Guide No. SSG-30, Safety Classification of Structures, Systems and Components in Nuclear Power Plants

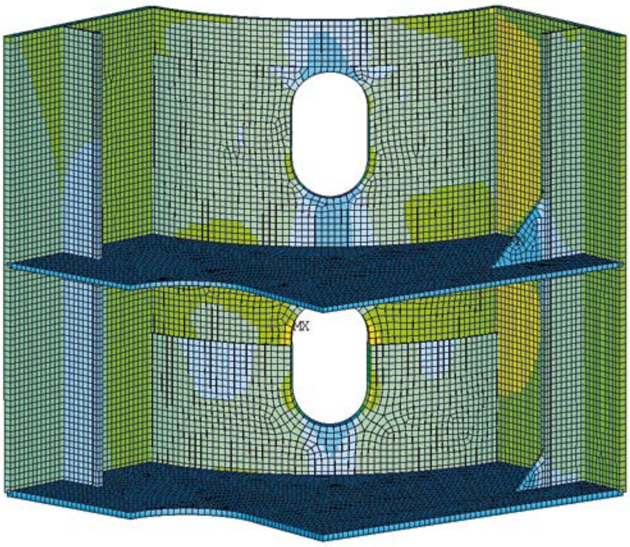
About the Author

Mikko Kajatsalo

M.Sc. (Mechanical Engineering)

Mikko Kajatsalo started working at Elomatic in 2010. Since 2012 he has been working in nuclear projects and has extensive experience of NPP structures and related equipment qualification. His tasks in nuclear projects have been related to seismic qualification in general including seismic testing, analysis and experience, as well as static and fatigue qualification via analysis and type testing. At the moment, Mikko works as a design manager in Elomatic's nuclear qualification team in Oulu.

mikko.kajatsalo@elomatic.com



Modern methods in ship structure analysis

Text: Leo Siipola

Simulations are used commonly in ship design. Finite element simulations, for example, are used in the dimensioning of ship structures and systems, while computational fluid dynamics (CFD) simulations can be used in hull design to minimise ship drag and thereby reduce fuel consumption. CFD is also applied in propulsion design and propeller dimensioning. In this article, I discuss the use of simulations and finite element analysis in ship design.

In the finite element method (FEM), a structure such as a ship hull is divided into small parts (elements), where displacements and strains can be defined with the help of mathematical equations. The equations reveal the stress levels in the elements. Very complex structures can be dimensioned extremely accurately without having to make the broad simplifications or assumptions associated with traditional analytical methods.

Modern simulation software programmes and powerful computers are used in simulations. This means that large entities can be modelled and analysed relatively quickly. In addition, changes and different structural solutions can be searched for rapidly. This allows engineers to ensure that the structure fulfils its defined requirements.

Ship dimensioning

Ship dimensioning has for long been, and still is, based on knowledge gained from experience, which is refined with analysis methods and structural solutions. Ships can be designed and dimensioned to a large degree based on classification society formulas and guidelines. This method is still used in the basic dimensioning of ships.

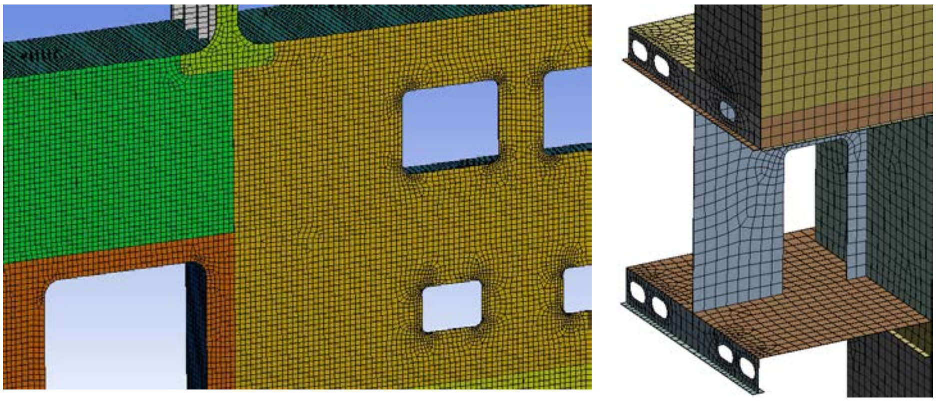
These dimensioning methods are appropriate when preliminary dimensioning is done, but they do not allow structural details to be examined, at least not easily. Classification societies also enable the use of more advanced methods. Of these methods, probably the most utilised is the finite element method.

Normally, and where the hull girder response cannot be sufficiently determined with beam theory, FE analysis is required. This is commonly the case, e.g. for ships with large deck openings like container ships, ships without or with limited transverse bulkhead structures like Ro-Ro vessels and car carries, and ships with partly effective superstructures like large passenger vessels.

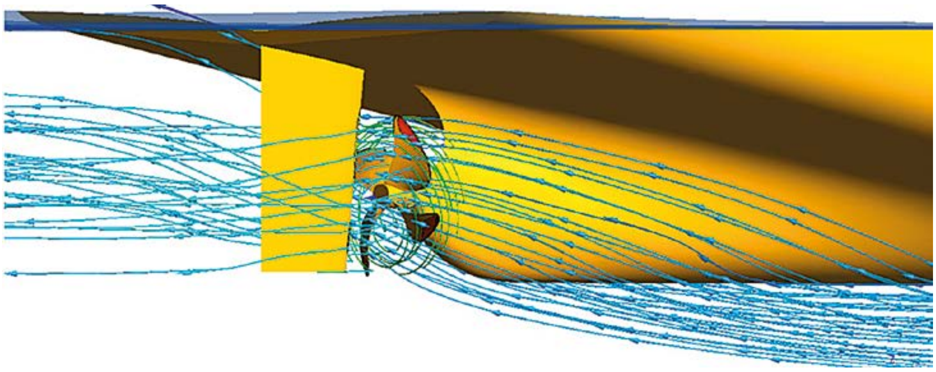
Classification societies have also provided guidelines as to how analysis models should be created and what simplifications can be employed for the results to still be reliable, and if necessary, reproduced.

From a structural point of view, a ship is a big beam that floats on water. Differently spread masses and environmental stresses bend and twist this beam. The typical cross

► *Figure 1. Typical element meshes of a local ship model. The element size is around 50x50mm and for smaller details the element size is typically t x t, where t is the plate thickness.*



► *Figure 2. CFD used in a full scale self-propulsion test for propeller/hull interaction on a container ship.*



section dimensions of a ship can be defined based on the forces and torque caused by the ship structure and loads. These dimensions include, for example, the required shell plate thickness, as well as the scantlings of girders and frames.

These typical frames are then laid out, one after the other, with a specific frame spacing. More accurate dimensioning calculations naturally need to be made for transition zones. The effects of engine foundation, for example, and those of other systems, also need to be taken into consideration.

The downside of this is that structures are easily over-dimensioned or, in the worst case, under-dimensioned, when typical structures are used throughout the ship. Nowadays, the finite element method is generally used in ship dimensioning once the ship's preliminary dimensions have been defined. Safety is, of course, behind all dimensioning actions. Without sufficient analysis one cannot be sure that a ship will withstand all stresses it is subjected to during its lifetime.

From global to local modelling

Large cruise ships are not the most typical of vessels. They are expected to deliver something different, a WOW effect, with big open spaces and promenades to attract passengers. These structures are, however, very difficult to dimension based on formulas. It is for this reason that the use of the finite element method in ship dimensioning has grown so strongly and is employed at some stage in the dimensioning of every ship.

Modern computers and software are able to analyse increasingly large targets in greater detail with the finite element method. Typically, this is done by first creating a so-called global model of a ship. As the name indicates, a global model is a model of the entire ship, which can then be divided into elements.

The element division in the global model is usually very broad; typically an element is the size of the space between main frames or between decks. The element size can, as such, be 3m x 3m. In this case, for example, smaller stiffeners of decks are not modeled geometrically at all, but should be taken into account in the stiffness of the elements in other ways. The model does not take all details into consideration, but rather aims to analyse the overall deformations and forces on the ship beam with sufficient accuracy. The model thus takes the stiffness of the structure into consideration with sufficient precision, but the stress field can be very inaccurate in places. As the computational power of computers increases, it will become possible to produce more accurate global models and stress results.

The global model is used as the base for creating more accurate models, so-called local models, which take structural details into consideration. If necessary, one can progress to even more accurate models in a step-by-step fashion, in essence, by creating local models from local models.

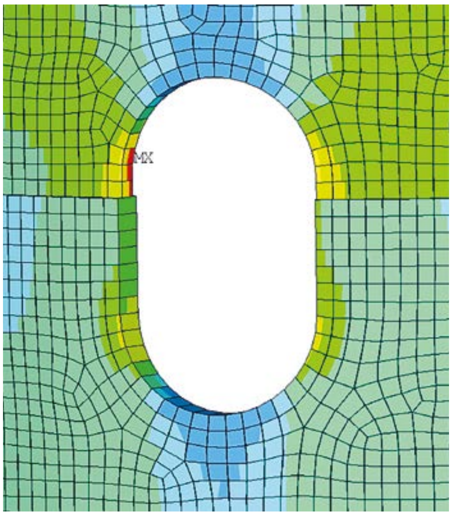
In local models, even smaller stiffeners are modelled according to the geometry, which allows a very precise analysis of the structure's stress condition. Local models are loaded on their edges by the deformations from the global model, whereby the global forces load this structural detail. In addition, local loads are also taken into consideration, such as the load on lifeboat davits. In the local model, detailed structural shapes can be more precisely defined, as well as e.g. plate strengths and local reinforcements.

A structure's fatigue durability cannot be accurately defined in a global model, but in a local model, the fatigue durability of even a weld joint can be improved, if and when needed.

Several structural details can be analysed to ensure, for example, that plate thickness is the absolute minimum. However, even with FE analyses, one has to follow classification society rules for minimum plate and stiffener thickness. Structures can also be modified relatively quickly or analysed again to allow different alternatives to be evaluated easily and reliably.

Importance of comfort factor

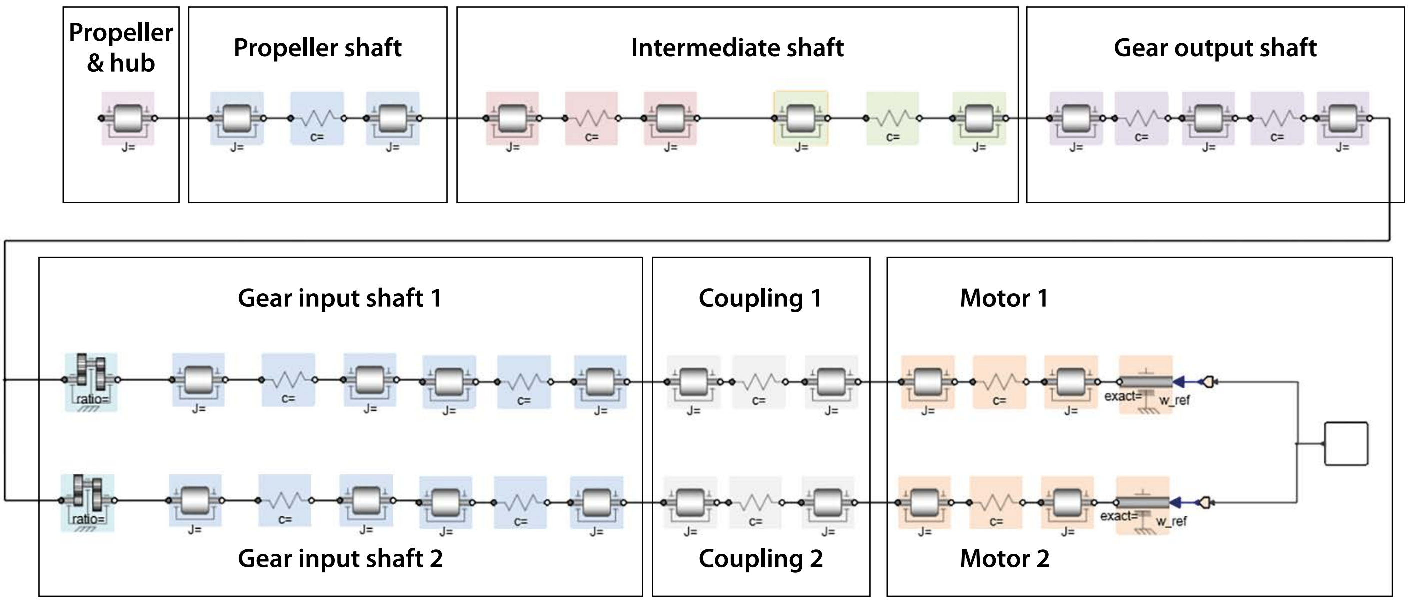
Comfort factors are particularly important in cruise ships. Comfort has to be taken into consideration in many differ-



▲ *Figure 3. Fatigue detail of a manhole edge.*

▲ *Figure 4. An example of a CFD simulation for a full scale wind tunnel test on a cruise ship to detect the comfort level in the superstructures and outer decks.*

▼ *Figure 5. An example of a traditional motor-gear-shaft type power transmission model used to calculate torsional vibration.*



Modern computers and software are able to analyse increasingly large targets in greater detail

ent areas, but with regards structures, the vibration level is a key aspect. The same element model used to analyse structural stress, can be employed to analyse vibration.

One can also study how vibrations spread through structures and try to reduce the resultant harmful impact by making structural changes. Vibration also causes noise, so vibration dampening can increase comfort levels greatly. Nowadays, attention is also increasingly paid to the noise transferred into water and the marine environment. The harmful noise transfer to water can be reduced by decreasing vibration and, for example, by insulating motor noise.

Improving processes

Structures can also be optimised with the help of technical analysis software. Once a mathematical model of a ship structure has been created, optimisation algorithms can be used to, for instance, maximise durability and minimise the vessel's mass. This can result in significant construction savings. When this is coupled with the afore-mentioned ship hull and propulsion optimisation, one can see that large savings and reductions in pollution can be achieved over the life cycle of the vessel.

The finite element method is equally adept at analysing welding processes. The model can be used to analyse the effect that the heat generated by welding has on shape deformation and residual stress. The welding sequence can also be optimised to minimise shape deformations. This speeds up installation work at shipyards as parts do not need to be fitted, nor are harmful gaps formed between plate edges. This obviously requires very powerful computers to ensure that analysis times remain within reasonable boundaries.

Ship systems

A ship's hull is naturally important in respect of durability, but finite element analysis can be used to study many other ship systems. It is, for example, used commonly in the dimensioning of ship engines. Power transmission dimensioning is another area where the finite element method is employed, be it for traditional shaft drive propulsion, or diesel-electric propulsion, where azimuthing propellers are used. See Figure 5.

There are also many amusement park devices on cruise ships that can be beneficially dimensioned with the finite element method. The loads such devices will be exposed to, can also be analysed with dynamic simulations to get a significantly more accurate picture of the forces acting on the devices and the underlying ship structure. This also leads to more precise fatigue dimensioning.

Summary

Growing computational performance and the developments in technical analysis software allow the modelling and analysis of entire ships. The finite element method is used widely in ship dimensioning. A good example of its application is the design of the Global Class cruise ship for MW Werften, where finite element analysis has been used by Elomatic to analyse several parts of the ship structure.

Based on the analyses, for example, structures have been modified and plate thickness defined. For other vessels, we have analysed transmission line durability under ice loads, conducted different vibration analyses and studied the effect of structural deformation on ship durability.

These analyses allow the optimisation of structures, the reduction of construction costs, enhanced safety and passenger comfort, as well as the reduction of harmful air and noise pollution into marine environments.

About the author

Leo Siipola

M.Sc. (Engineering)

Leo Siipola has worked within the Finnish mechanical industry since the early 2000s. His experience covers machine design, structural analysis, vibration and fatigue of welded structures. Leo joined Elomatic in 2011. He currently holds the position of Design Manager, Technical Analysis at the Elomatic Tampere office.

leo.siipola@elomatic.com

Ship probabilistic

damage stability

– Are we heading in the wrong direction?

Text: Mikko Soininen

Ship damage stability concerns itself with the stability requirements vessels have to meet when damaged, i.e. when their normally watertight hulls have been breached and compartments in the ship hull become flooded. Commonly, these requirements become the target of close scrutiny after high profile accidents that result in large numbers of casualties, such as the Costa Concordia in 2012 and MV Sewol in 2014. Are stricter technical requirements the answer, however, or could similar calamities be better avoided by improving crew training and increasing safety consciousness?

Ship damage stability is nothing new. At the end of the 1800s, British authorities already required Atlantic Liners to withstand damage and stay afloat if any two adjacent watertight compartments were damaged. In light of this, Bruce Ismay, a White Star Line manager, boasted that their new vessel, the S/S Titanic, was a "practically unsinkable ship" as she could withstand damage to four compartments. Unfortunately, the iceberg she hit broke six compartments and the rest is history.

In the 1920s and 1930s, a Finnish commodore and the first professor in naval architecture in Finland, Jaakko Rahola, developed a set of requirements for minimum intact stability in order for a ship to survive if an accident occurred. He based his studies on statistics of damaged ships and thus developed the minimum criteria for intact stability that would prevent sinking. Some of these requirements still exist for intact stability today in some form.

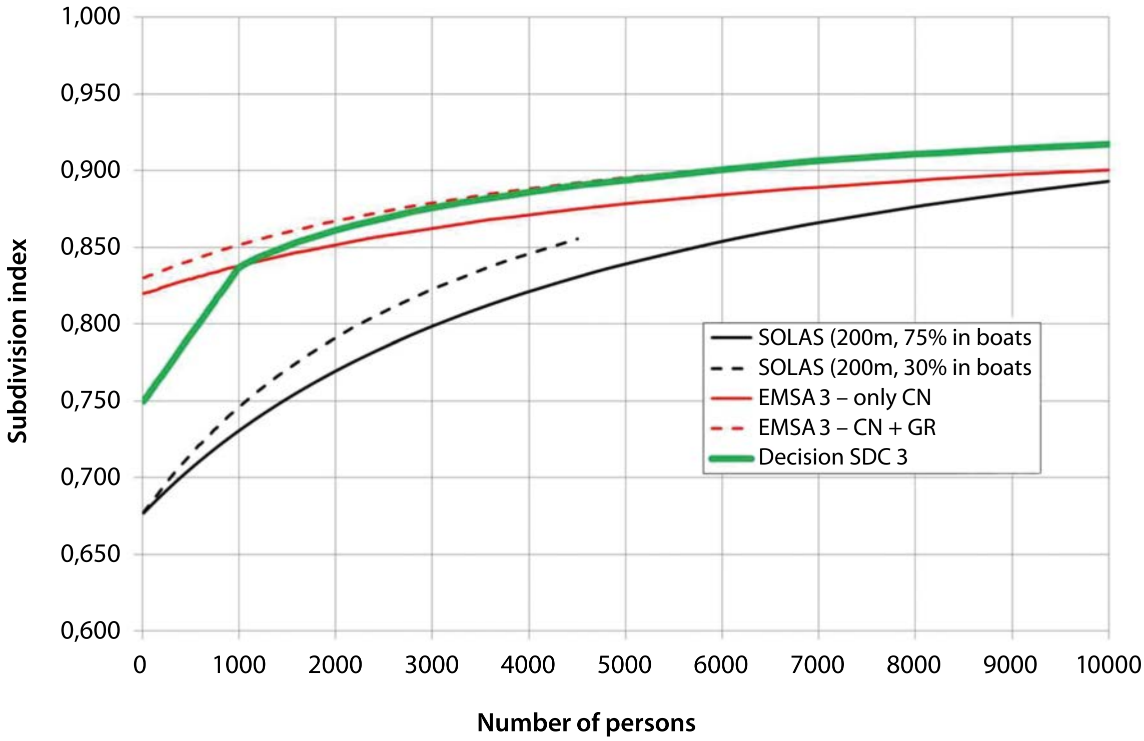
Rahola did not, however, establish specific requirements for damaged ships. These requirements were introduced for passenger ships in 1948 at the International Convention for the Safety of Life at Sea (SOLAS 1948). SOLAS 1948 provided limits for three stability components that have been updated during the years up to SOLAS-90. In these requirements, ship stability is defined in terms of damage to one, two, or three compartments, depending on ship size and the amount of passengers.

Probabilistic method relies on actual damage statistics

Cargo ships did not practically have any requirements for damaged conditions until the amended SOLAS-74, where the probabilistic method (Regulation 25) was introduced for cargo ships with lengths in excess of 100 meters. The probabilistic method is based on statistics of how probable it is that damage along a ship's length has occurred, or how deep the damage penetration is. The statistics are based on actual ship collisions. Requirements for stability after damage are given, based upon which a survivability index (A) was calculated that describes a ship's survivability with a particular damage level.

The survival index can be considered as the probability that a ship will survive a particular damage level. In most cases the value is either one (ship survives and complies fully with the stability requirements) or zero (the ship sinks). In some cases, where the survival index is something in between one and zero, a ship remains afloat but is not in full compliance with the stability criteria. Several damage cases (potentially hundreds) are calculated along a ship's length to produce the survivability index. The survivability index is then compared with the minimum required index (R). If R≤A, the ship's watertight integrity is considered to be acceptable.

A similar method was also introduced for passenger ships (the so-called A.265) and functioned as an alternative calculation method for damage stability instead of the traditional deterministic calculation method.



The methods were not eagerly adopted by flag authorities and the deterministic method was mainly used instead of the probabilistic method.

Sinking of M/S Estonia ushers in Stockholm Agreement

The next big change occurred after the capsizing and sinking of the M/S Estonia in 1994. At the time, the rules did not consider large deck surfaces such as car decks on ferries. As a result of this – and quite hastily in fact – the "Stockholm Agreement" was drawn up, which established rules regarding the amount of accumulated water on ship decks.

The agreement has not been approved worldwide, but today countries in the EU, USA and Canada have adopted the method for new car ferries. Old car ferries are also required to comply with the agreement and if they do not, are obliged to make improvements. The most common solution is so-called ducktails that are added to the aft of the ship in order to increase stability.

One calculation method for all vessels

The next step was to unify the calculation methods; the deterministic method was being used for passenger ships and the probabilistic method for cargo ships (tankers, bulkers, special purpose ships and some other ship types are not considered as cargo ships). In the mid-1990s, the HARDER's work group was established at the IMO (International Maritime Organisation) to develop a unified or harmonised calculation method for both passenger ships and cargo ships. They settled on the probabilistic approach as the preferred method.

The work group studied and estimated the probabilities of hundreds of accidents, which were mainly collisions or groundings. The study covered a wide range of ship types, but some ship types such as pure car/truck carriers (PCTC) were not included. The new mandatory rules came into force for new ships on 1 January 2009. The basic intention was that the requirement level would be approximately at the same level as SOLAS-90.

▲ *Figure 1. Present SOLAS R-index (black curves) vs. the suggested R-index curves (red and green curves). The green curve is the most probable future R-index. The R-index will, e.g. increase abt. 10% for medium-sized premium category cruise ships with 2500 to 3000 persons on board. (Uutta Laivanrakennuksessa seminar 2017 Anna-Lea Routi, Meyer Turku)*

As indicated, the existing probabilistic damage stability calculation provides a ship with a required index (R), and after calculation of all damage cases the ship attains a survivability index (A), which must be greater than or equal to R. These two indices are always <1.0. If the A-index=1.0, it would indicate that a vessel would survive any damage possible, which is not practically feasible. Passenger ships have to comply with some other damage scenarios such as bow collisions, minor side collisions and bottom damage if the double bottom is lower than generally required. Both cargo and passenger ships, however, are required to comply with the R ≤ A requirement.

In 2007 Elomatic conducted a study in cooperation with the Finnish Maritime Administration (today TRAFI) on how eight existing Finnish car and passenger ferries (RoPax) would comply with the new probabilistic rules, considering also the Stockholm Agreement. One of the ships was built according to A.265-rules and the rest were SOLAS-90 ships. All of the vessels were Stockholm Agreement compliant. Interestingly, three of the eight ships did not attain the required index of the new rules. Then rest of the ships showed no clear differences in their stability requirements.

Tinkering with stability requirements

There have already for some time been ongoing discussions about changing the requirements for damage stability. The present probabilistic damage calculation does not consider large car decks, which means that car ferry and RoPax stability must first be calculated with the probabilistic method and then with the old deterministic method as defined in the "Stockholm Agreement".

This problem has been solved by adopting stricter damage stability requirements for ferries and RoPax ships. In June 2017, at the IMO MSC98-meeting, stricter requirements were tabled, and will probably be adopted, thereby correcting the apparent flaw, at least in theory.

However, at the same meeting the R-index requirement was also discussed and a new formula for the index was introduced for approval (see Fig. 1). The push for stricter requirements has no doubt been given impetus by accidents such as the M/S Costa Concordia and other severe accidents like the M/S Sewol in South Korea, where more than 300 people perished. As indicated earlier, the R-index requirements are based on statistics of collisions and groundings and, as such, the afore-mentioned accidents do not match the basis upon which the R-index was calculated. If such accidents have nevertheless triggered stricter requirements in rules that are based on entirely different types of accidents, it could be argued that these stricter requirements are not well-founded.

The public outcry following these disasters has been amplified by politicians (who are not ship stability experts) under pressure from their constituencies. The new proposed R-index is based on collisions and groundings of RoPax ships. It is also noteworthy that no changes have been made to the calculation method of the A-index.

It is easy to understand the public outcry. It has to be remembered, however, that to date no ship calculated with the probabilistic method has been involved in any major accident that resulted in the loss of life. This means that there is an inadequate amount of references to support its suitability.

The A-index measures how well a ship stays afloat after a collision or grounding. It does not include poor operation. If poor operation scenarios were included, the whole calculation method would have to be different.

Other travel industries setting a good example

When accidents similar to the Costa Concordia occur, for example, in the aviation industry, the industry is not afraid to rectify inadequate crew training or to monitor pilots' states of mind. In the case of Germanwings Flight 9525, when a pilot committed suicide by flying into a mountainside and killing all on board, no technical solutions were introduced to prevent a recurrence. Instead, the main corrective move was introducing a rule that requires two pilots to be in the cockpit at all times.

In road transport, where a host of gadgets assist drivers to operate vehicles safely, accidents occur mostly due to driver error. Accident investigators first focus on road conditions and driver incapacities when evaluating the cause of road accidents. This leads one to question why the shipping industry seems to be heading in the opposite direction.

Instead of focusing primarily on technical issues, much more can be achieved by putting even more efforts into enhancing the safety cultures and safety conciseness of shipping companies and crew. Many shipping companies are, however, very safety-oriented and are leading the way in this respect. Finnish/Dutch Bore is a good example: the company's training and actions aboard the M/S Norstream resulted in the rescue of the crew of the M/S Fluvius Tamar in the English Channel, when she ran into difficulty in a storm in 2017.

Reports of similar activities surface every now and then, which points to increasing efforts to improve safety conciseness in the maritime branch. The common denominator in all these reports is shipping companies that regard safety as a high priority in their operations.

Mikko Soininen

Naval Architect (B.Sc)

After his graduation in 1981 Mikko Soininen has worked on different naval architectural projects in the fields of ship theory, hull classification, general arrangements for ship concepts, basic designs and retrofits. Mikko has worked at Elomatic since 1994, mainly on cruise ship, RoPax, RoRo and special purpose ship projects. Mikko is also the main Napa software user for ship theory calculations at Elomatic.

mikko.soininen@elomatic.com

Diverse design expert

– interview with Hanne Räikkönen

Text: Olli Tuomola

As a result of automation, a paper machine designer needs expertise not only in traditional mechanical engineering, but also in automation, electrical engineering and even piping design. In her daily work, Design Manager Hanne Räikkönen often finds herself in demanding situations beyond her comfort zone.

Hanne started working at Elomatic as a designer in 2005. This year, she marked ten years in the paper machine roll design department. In September 2017 she was appointed as Design Manager of the Jyväskylä Roll Design Team. Experience is extremely important in paper design. The finer skills of design work are not something you master at school. All in all, Hanne views paper machine design as a complex task.

"In paper machine roll design, quality and reliability are key factors. When paper breaks in a paper machine it always creates unwanted additional costs," says Hanne.

The design of different paper machine parts is, in many ways, very specialised work; transferring from headbox design to roll design, for example, requires a lot of study and familiarisation.

Designers developing paper machines

In the 1900s, paper machines were designed to produce only one type of paper at a time. A change from one kind of paper to another requires extensive modifications to machines and, naturally, much design work. Modern paper machine operators can produce several different kinds of paper by changing settings. This change has required a lot of design work.

The adjustment of paper machines while in operation has also been "updated for the 2000s". In the past, paper machines were stopped to allow the operator to get in the machine to manually change the settings in cramped and dangerous working conditions. Modern paper machines are equipped with servo-controlled governors, which means that they can be adjusted from the control room "on the fly" while in operation.

This has raised efficiency and also improved occupational safety. The settings implemented are also more precise than before and remain in place better; human error has been eliminated. Automation has, thus, raised quality and efficiency.

Challenges, challenges, challenges

"Paper machine roll design has changed significantly in the new millennium. Piping, electrical and automation design have been added to the task list. The possibility to remotely control paper machine settings means, for example, that designers need the ability to solve challenges related to ducting and cabling of servo-motors," Hanne explains.

Overall, design work is more complex and demanding than before. One has to learn new things every day. The casing of electrical components, for instance, should be an electrical designers "problem" to solve. Paper machine designers are constantly out of their comfort zones. Success, on the other hand, is also rewarded.

"Even the slightest positive feedback about paper machine production is experienced as a success. Production personnel often think that designers have no idea how paper machines are manufactured." Valmet, a leading paper machine manufacturer, actively develops communication between designers and production staff in joint meetings.

Has the paper machine already been designed?

"It will take quite long before we stop designing paper machines. Paper machine design is heading in a modular direction; the basic parts have already been designed and the modules can be connected to each other with ease. The goal is, naturally, to reduce production costs. This requires standard sizes, among others.

"Even though we combine different ready parts of a modular paper machine in design, every paper machine roll is different, and requires design work." Hanne emphasises that if one wishes to develop and become better than competitors, one has to invest in design. This is true also of paper machine design; designers can always design better. Industrial automation and innovations also allow designers to solve problems better than before.

"In product development, one often is faced with situations where you have to scratch your head and solve problems," Hanne reveals.

A paperless office

Even though paperless offices have been spoken about for years, the transformation process is progressing slowly. Paper consumption has decreased in Europe over the last ten years. Graphical paper, in particular, is consumed less than before; newspapers are not read in paper format as much as before and, for many, traditional postage has been reduced to sending yearly Christmas cards.

Hanne is not concerned about the development. "Paper machines and their design will not become redundant in the digital world. Even though graphical paper use is decreasing, the use of tissue paper and carton is on the rise", Hanne sheds light on developments in the paper business.

This trend is particularly evident in China and other Asian and Latin American countries. The change is being driven by rising living standards and the growth in online shopping. Products that are sent to Europe and America are commonly shipped in carton packages.

New innovations in Finland

A new use for paper machines has been invented in Finland. The VTT Technical Research Centre of Finland has developed a foam forming technology that can be used by paper machines to produce nonwoven fabric. Nonwoven fabrics are used widely, for example, in many wiping materials and filter cloths used in earthworks .

Nonwoven fabrics can also be used in composite materials. Fabrics produced with the foam forming technology are significantly more ecological and easier to recycle than cotton fabric.

There is such a "fabric paper machine" prototype a few kilometres from Elomatic's office at VTT Technical Research Centre of Finland in Jyväskylä. Hanne did not do any design work on the machine herself, but she is eager to see such a machine in operation.

Harri Kiiskinen from VTT Technical Research Centre of Finland was also interviewed for the article. English translation: Martin Brink. Photo: Jari Pekkarinen / Elomatic.

Photo © depositphoto.com/sunflowerey

Why use fuel when there is electricity?

Combustion engines vs battery power

Text: Tomas Aminoff

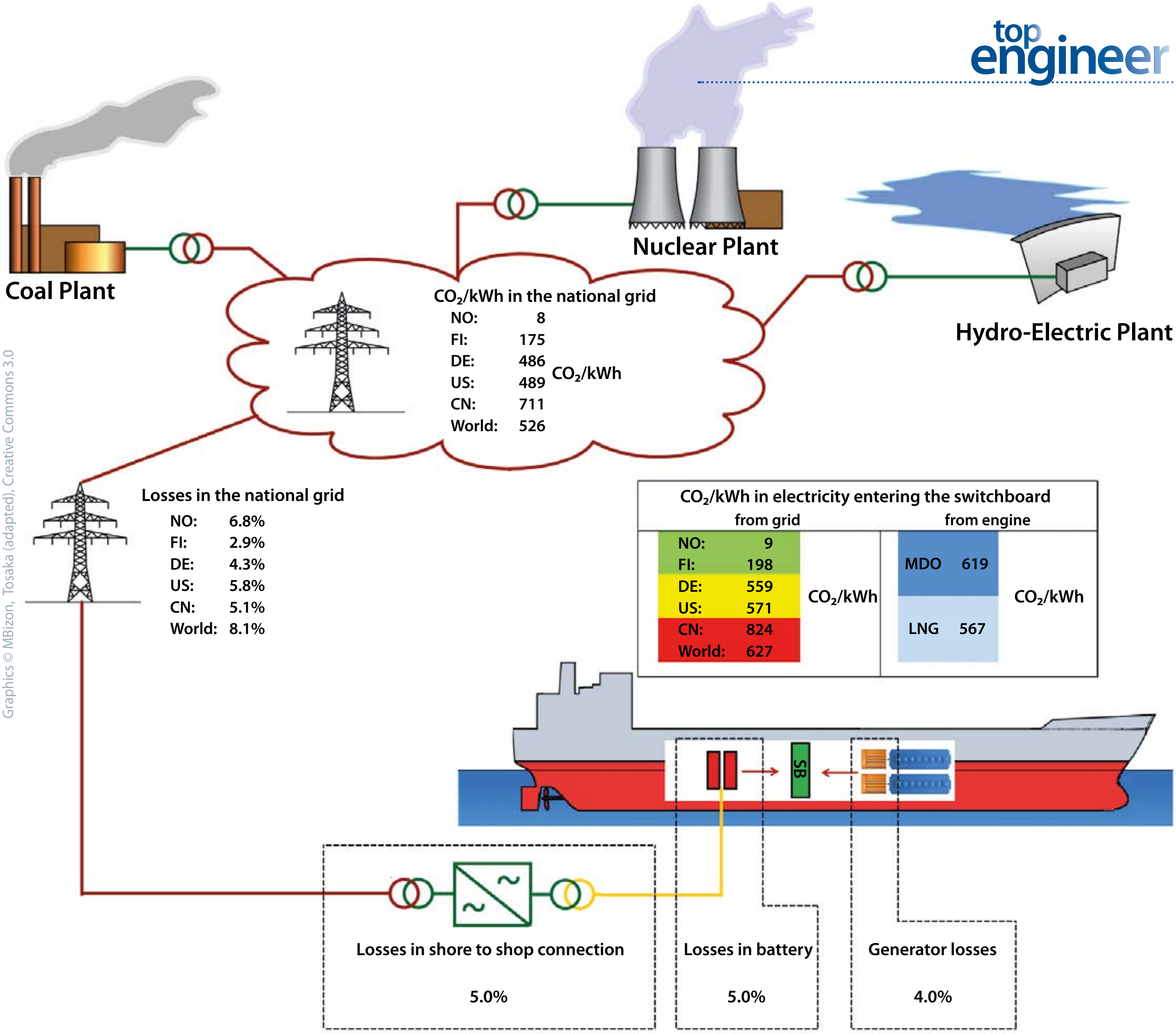
"Why use fuel when we have electricity?" is a question one hears from time to time. It is mostly asked humorously, with several variants doing the rounds: "fuel" can be replaced with "coal", "nuclear" and "gas", or basically any other form of energy generation. Today, this is as relevant as ever, especially in the euphoria surrounding battery utilisation in different forms of transportation.

It is often punted as a silver bullet in the fight against air pollution and global warming. Simultaneously, internal combustion engines have gained a bad reputation, without regard to where they are used, with what fuel, or what combustion process is involved. In this article, I discuss some of the pros and cons of battery power and combustion engines.

In Europe, in particular, several high profile politicians and cities are planning to limit the use of diesel engines. Public discussions have not delved into what exactly the extent of the limitations would be. It is, for example, not clear whether such limitations would cover both Otto and diesel combustion processes, and whether the focus would be the burning process or the fuel type used? It is, furthermore, unclear how fuels like methanol, LPG or LNG/NG will be affected.

While the discussion in the public domain is currently focused on cars, it is equally relevant to the marine industry. The same themes apply and marine industry professionals should draw parallels and participate actively in the discussion already at this point.

The different types of emissions deserve attention first. At a high level, emissions can be split into two categories: air pollution that is harmful to human health in the form of different particles, and greenhouse gases that have an effect on global warming. The former will primarily have a local effect (i.e. the harmful effects are felt in the vicinity of the emission source) while the latter has a global impact (harm-



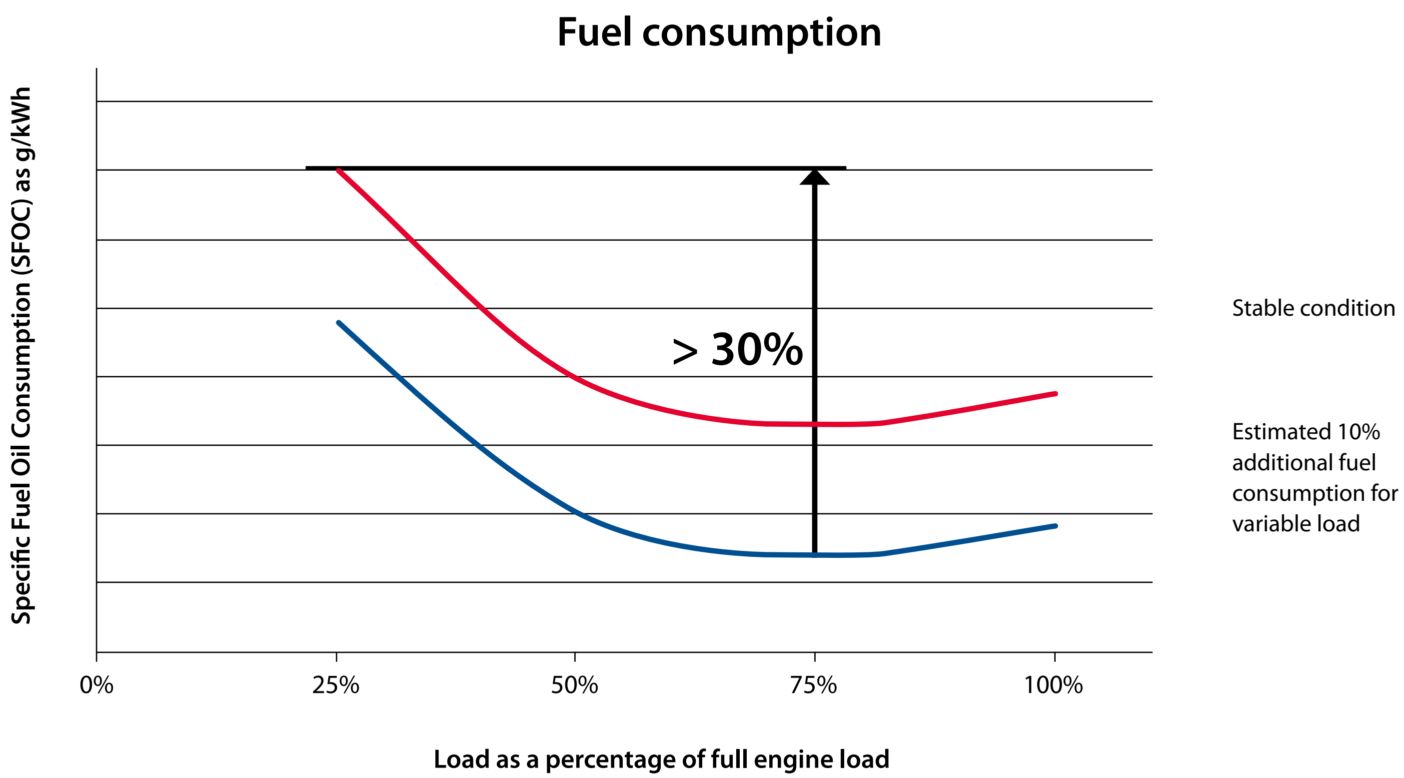
ful globally regardless of the location of the source).

The emission impact of batteries

With regards environmental impact, the unquestionable strength of batteries is the total elimination of local air pollution, e.g. in the form of PM, NOx and SOx. This is particularly important for activities in the vicinity of humans, such as cars in a city centre, or a ship in a harbour or close to shore. However, the relevance of such emissions or the lack thereof, diminishes while operating in less densely populated areas such as highways, the countryside, or the extreme case of the middle of the ocean. It should be remembered, however, that batteries are by no means a primary fuel. They merely store energy, which must be produced with some kind of fuel. At this original source of energy generation, both air pollutants and greenhouse gases will be produced. The fact that the energy generation occurs in less populated areas than city centres or harbours, as indicated earlier, makes air pollution emissions less significant.

For emissions with a global warming potential, such as CO_2, the issue is more complex. It does not matter where CO_2 emissions are produced; they are equally harmful regardless of the location of the source. The global warming potential is entirely dependent on the energy mix in the grid, which again is different from country to country. Figure 1 indicates the amount of CO_2 per kW/h when electricity reaches the main switchboard of a ship as a function of the original energy source. The CO_2 impact is clearly better for electricity from the national grid in Finland and Norway, while for Germany and US the

▲ *Figure 1. The CO_2/kWh equivalent depending on source of fuel. CH_4 is taken into account for marine engine burning LNG. (Sources: Wikipedia (MBizon; Tosaka), IEA CO_2 emissions from fuel combustion 2016 (data from 2013), SINTEF GHG and NOx emissions from gas fuelled engines, equipment suppliers material.)*



▲ *Figure 2. Efficiency is highly dependent on engine load and operating conditions.*

outcome is almost equal and dependent on the fuel type used on board the vessel. For China and the World average, the CO_2 impact of electricity from the national grid is higher than electricity produced on board a vessel with a modern, mid-size, medium-speed engine on a high and stable load.

Battery manufacturing not environmentally friendly

An additional disadvantage of batteries is that their manufacturing is not particularly environmentally friendly; as the required minerals are not found isolated in nature and mostly only in small concentrations. Furthermore, the raw materials required for battery manufacturing are not evenly spread on the planet, a situation that can cause additional geopolitical tensions.

Batteries are also expensive, and unlike engines that are priced in kW, batteries are priced in kW/h. As a consequence, instead of costs being incurred in terms of power produced, the costs are determined by the capacity of batteries.

The behaviour of combustion engines

The amount of emissions from internal combustion engines are dependent on the burning process, fuel type, and engine load, including whether it is a stable or variable load.

1. *The burning process, Otto vs. diesel*
   Diesel typically offers higher efficiency and, thus, lower CO_2 emissions, while higher local hots spot in combustion tend to produce higher NOx emissions.
2. *Fuel type*
   The chemical composition of different fuel types results in different emission profiles. For example, sulphur emissions are directly dependent on the amount of sulphur in the fuel. As such, 3,5% S HFO will always produce 35 times more sulphur emissions than 0,1% MGO. Also, CO_2 emissions are dependent on the carbon content and the ratio of carbon (C) and Hydrogen (H) in the fuel. Fuel also contains impurities that reduce the heat value and thus increase the CO_2 to energy ratio.
3. *Engine load*
   The engine load depends on the application, but in the marine world it is traditionally optimised at about 85% load (100% for gas engines with an Otto process). The further you move from this point, the lower the efficiency will be, which means that the fuel consumption i.e. CO_2 will increase per produced kW/h. Furthermore, other types of emissions like NOx, PM, and CH_4 have a tendency to increase more rapidly than the reduction in efficiency when the engine is operated (far) from its optimisation point. It needs to be noted that more recently, some engine manufactures have offered more flexibility in selecting an optimisation point that is likely to be closer to the actual operating

If battery applications are chosen carefully, the environmental and economic benefits are undeniable.

profile, thereby reducing both fuel consumption and emissions.

4. *Stable load vs. variable load*
   It's well known that combustion engines perform best when operated without any disturbances, on a stable load. However, a wide range of load variations from acceleration and load drops disturbs operation and results not only in lower efficiency, but also remarkably higher air emissions. Black exhaust fumes from cars when accelerating from a stop, or the equally black fumes from vessels when starting or accelerating are familiar sights. The increase in fuel consumption from variable loads is not well documented in the public domain. However, at least a 10% increase in fuel consumption has been measured in dynamic position (DP) operation compared to stable operation.

Reducing emissions

What can be done to reduce emissions? LNG is the most common alternative fuel today, and possibly the only one available in large enough volumes to fully satisfy marine demand. Is it, therefore, the obvious choice? It depends. Putting abatement technologies aside for this article, the use of LNG is the most widespread method used to cut emissions. It works very well when all four the afore-mentioned emissions-determining factors can be favourably applied.

This favourable condition can be expected in multiengine gas-electric installations with rather stable loads over long periods, such as cruise ships or blue sea merchant ships operating for prolonged times with the same engine load. Under such conditions, methane slip, which is the biggest drawback of low pressure gas engines, also remains at a manageable level. This is demonstrated in Figure 1. On the other hand, if vessel operation means that the engine frequently operates at low or very low loads with a highly variable load demand (e.g. an OSV in DP), The LNG-Otto process combination is hardly environmentally friendly. The efficiency drop in combination with low and variable loads results in excessive methane slip pollution.

Combining combustion and battery power

There is a strong case for combining battery and combustion solutions, thereby taking advantage of the strengths of both technologies. Batteries produce zero local emissions and are ideal in areas where this is essential. They are most cost efficient if they can be charged and uncharged frequently, and if the size of the battery pack can be kept reasonably small. Internal combustion engines operate best at relatively high loads in stable conditions. Thus, when a ship operates for a prolonged time on a stable load, e.g. during transit in the open sea (or for a car on the highway) the best result is achieved by using the combustion engine and charging the batteries.

When operations result in load variations and/or require one or several engines to operate on very low loads, batteries can be used to balance the load changes and enable the operation of fewer generators. Thus, the remaining generators can operate on higher and more stable loads, resulting in up to 30% enhanced efficiency and lower CO_2 with significantly lower NOx, PM and CH_4 emissions (depending on emission type over 50%). Battery packs dimensioned carefully for this purpose will also be smaller, require fewer rare metals and have the smallest environmental footprint on a life cycle. They will also be cheaper and thus enable electrification for a larger population.

In view of the afore-mentioned points, it is clear that applications for batteries should be selected carefully. Once this is done correctly, and only then, the benefits are undeniable from economy and environmental standpoints alike.

About the author

Tomas Aminoff

M.Sc (Naval Arch.)

Tomas Aminoff graduated from the Helsinki University of Technology in 2002 with a major in Marine Engineering. He has worked for 15 years for a major marine equipment supplier with special focus on alternative fuels, machinery solutions and portfolio management. Tomas has extensive knowledge of LNG as a marine fuel and has played an important role in introducing several gas powered engines to the market. Today, Tomas works as a Senior Consultant in Elomatic's Marine Consultancy and Life Cycle Solutions department.

tomas.aminoff@elomatic.com

Concept and preliminary design of energy efficiency measures

– Turning optimisation suggestions into reality

Text: Teemu Turunen & Jussi Jääskeläinen

Energy efficiency audits often generate good efficiency optimisation recommendations, but these are rarely developed into a form that allows practical implementation. The actual investment is clouded in many uncertainties that require clarification, even if the optimisation potential is known. In many cases the next step in optimisation projects is developing a concept, or in the best case scenario, a preliminary design.

In Finland there is a long tradition of energy efficiency operations and most companies have conducted at least some kind of energy analysis of their operations. This is a good starting point, but in order to achieve real savings the efficiency measures need to be put in place.

In optimal cases the measures are related to operational technicalities. In such cases savings can be accrued immediately, for example, by changing a process run method or altering building management system settings. In several cases, optimisation requires investment, which can become a bottleneck in energy efficiency work.

Results from the 2015 annual report of energy efficiency contracts in Finland indicate that a large part of optimisation measures are classified as "under consideration". In energy intensive industries, for example, 72% of the optimisation measures are classified as such. From a savings perspective this amounts to 63% of savings, which is the equivalent of € 271 million a year (see Table 1). It is noteworthy that the heating and fuel savings measures "under consideration", are significantly larger than electricity savings measures. Similar trends can be seen in other business area reports.

Energy efficiency measures easily find their way to the bottom of in-tray paper stacks

Why is it that even good optimisation measures gather dust at the bottom of in-trays? One reason is obviously related to the profitability of the optimisation ideas. In many industrial companies, energy efficiency investments compete directly with other investments where the payback demands can even be as tight as one or two years. The price of energy naturally also affects profitability; at current electricity prices it may be difficult to achieve profitable optimisation measures.

Another factor that probably slows the implementation of optimisation measures is the fact that investments cannot be directly implemented based on optimisation recommendations. In many cases, more detailed analysis, planning and the evaluation of effects on other operations are required before a final investment decision can be made. This phase is often a bottleneck, but this does not have to be the case.

Concept and preliminary design to unclog bottlenecks

Typically, preliminary design is started after an audit. This approach is good if the optimisation investment is a clear entity and the different implementation models were thoroughly investigated during the audit. In preliminary design, matters related to the dimensioning of measures are clarified, which leads to more precise investment requirements and cost levels. The changes required to existing systems and new connections are also defined more accurately in flow diagrams, device layouts and lists. This enables the company to get a more comprehensive view of the extent of the measures and their effects on other systems or processes. Possible changes to automation and other control systems are also specified. Usually, the ideas behind the suggested measures are refined and their profitability calculated with more precision. The operational costs of devices, maintenance, and operability throughout the entire life cycle should be analysed in sufficient detail to ensure that the energy savings delivered by investment provide ROI for as long as possible. During preliminary design, offers can be sought from device suppliers for comparison purposes. After preliminary design, the measures are ready for decision-making and possible detail design.

If there are many implementation models for the optimisation measures, however, concept design may be the right choice to make headway.

In energy efficiency concept design, different implementation alternatives are analysed, including their profitability in view of the offers received, as well as their effect on other operations. When the measures introduced affect larger systems or processes, their operation needs to be checked to ensure that they deliver energy efficiency benefits as required.

Typically, a concept design delivers the following:

- More precise analysis and measurements
- Possible adjustment to energy balance taking the effect of different alternatives on the whole operation into consideration
- Cost and profitability comparisons of different alternatives
- System operation description
- Dimensioning of energy technology for main devices
- Cost estimate based on budgeted offers
- Flow diagrams
- Preliminary layout and device positioning
- Review of safety and environmental considerations
- Final report and preliminary project plan, time schedule
- Clarification of energy subsidy matters and presentation of procedure

The concept design content is naturally defined on a case-by-case basis according to the particular features and scope of the target. A concept design works best, for example, in cases where different alternatives for heating, heat recovery processes or industrial air-conditioning development are being considered. A concept design can also focus on a process device (e.g. a furnace or drier) environment, where different suppliers' solutions are compared and their functionality checked as part of overall operations.

▲ *Figure 1. Field measurements support audit observations*

How are energy efficiency concepts and preliminary designs implemented in practice?

Concept design implementation can be divided into three main parts:

1. *Field work*
2. *Dimensioning and design*
3. *Cooperation between different stakeholders*

Design work always requires sufficiently detailed initial data and field observations. In some cases audit measurements need to be supplemented and/or expanded on. In order to evaluate device positioning, the feasibility of piping, and labour costs it is important to check distances and device positioning to a sufficient extent. Even though it may seem that this increases the workload, it will result in further savings in the workload of the next phase and possible implementation.

Different experts are consulted in the design and dimensioning phase. The extent to which such experts are required depends on the comprehensiveness and quality of existing documentation and observations.

Successful cooperation between different stakeholders is a very important part of concept design and preliminary design. Good communication is needed when the project goals are defined to ensure that the customer's

▼ *Table 1. Energy intensive industry measures per classification in 2015 (Motiva)*

	Amount		Electricity		Heat + Fuel		Savings	
	No.	%	GWh/a	%	GWh/a	%	M €	%
Implemented	140	19	193	24	1,124	28	86	20
Decision made	64	9	281	35	450	11	73	17
Under consideration	531	72	334	41	2,467	61	271	63
Total	735	100	808	100	4,041	100	430	100

goals are communicated well to the engineering organisation. It is also important that information about audit observations is transferred effectively to support design. It is a particularly key issue for designers to communicate effectively with device and solution suppliers so that offers received are based on the correct initial data and can be used for comparison. Fluent communication with authorities and regulatory institutions also goes a long way to smoothing the subsidy application process.

The foremost goal of concept and preliminary designs is to produce reliable information for decision making about the technical implementation of an investment, the costs associated, and its profitability.

Efficient use of energy subsidies

In energy efficiency optimisation investments, it should be remembered that subsidies are available provided certain conditions are met. When applying for subsidies the following factors and conditions should be taken into consideration:

- The subsidy is dependent on a direct payback period of three to seven years
- The subsidy can be a deciding factor in project implementation
- Subsidies are not granted for revamps or repairs, unless the energy efficiency improvement part can be separated from the rest of the investment
- The energy efficiency optimisation solution needs to be described in sufficient detail
- It is important to note the labour costs of design and implementation in overall costs
- Control automation often plays an important role in energy efficiency investments
- The subsidy application must be made before the investment decision is taken

Master's thesis on preliminary design

– Baptism of fire in working life for new designer

Varkauden Aluelämpö Oy is a company jointly-owned by the city of Varkaus and Savon Voima Oy in Finland. It generates and distributes district heating to the Varkaus region. Environmental friendliness and energy efficiency have long been at the core of the company's operations. This is reflected in the company's decision in 2015 to modernise its old oil burning boilers into pellet dust burning boilers.

As a result of the modernisation, the share of renewable fuel used by the company rose to over 90%. The renewable fuel is also completely traceable and produced from certified wood. Energy efficiency was also a key aspect of the modernisation project.

After the modernisation project it was noticed that high flue gas temperatures reduced the durability of flue gas filters. It was decided, therefore, to start the preliminary design for a heat recovery solution. The preliminary design was completed in the form a master's thesis by Aleksi Varis, an energy engineering student at the Jyväskylä University of Applied Sciences. Experts from Elomatic supervised and supported the study, which progressed according to plan and received a 5/5 pass mark. Via the study, Varkauden Aluelämpo received a preliminary plan for a heat recovery system from where it can proceed to project implementation.

"Aleksi's work was technically very precise and detailed, which means that it can be used as the basis for a possible implementation project. The chosen implementation model for the preliminary design was very suitable since we are a small organisation and did not have the resources to manage the project ourselves. Elomatic's previous experience in similar projects provided a guarantee for the quality of the work and also meant that the study had access to the latest information available. I can recommend this implementation method to other small companies," says Varkauden Aluelämpö CEO Mikko Onkalo.

According to Olli Schemeikka, Elomatic Vice President (Energy), master's theses are also important to Elomatic as they develop skilled employees and at the same time bring fresh perspectives and developmental ideas to the company's operations.

► *Aleksi Varis completed the preliminary design of a heat recovery solution for Varkauden Aluelämpö Oy as the subject of his master's thesis.*

The subsidy is a maximum of 20% for traditional projects and a maximum of 40% for new technology projects. It is easy to forget certain aspects of subsidies, even though companies may have extensive experience in this regard.

Firstly, subsidies can also be granted for the procurement of production processes and devices, if they have an energy efficiency effect. This opens the door to new possibilities, as subsidy applications have traditionally focused, for example, on heat recovery optimisation and process modifications in auxiliary systems.

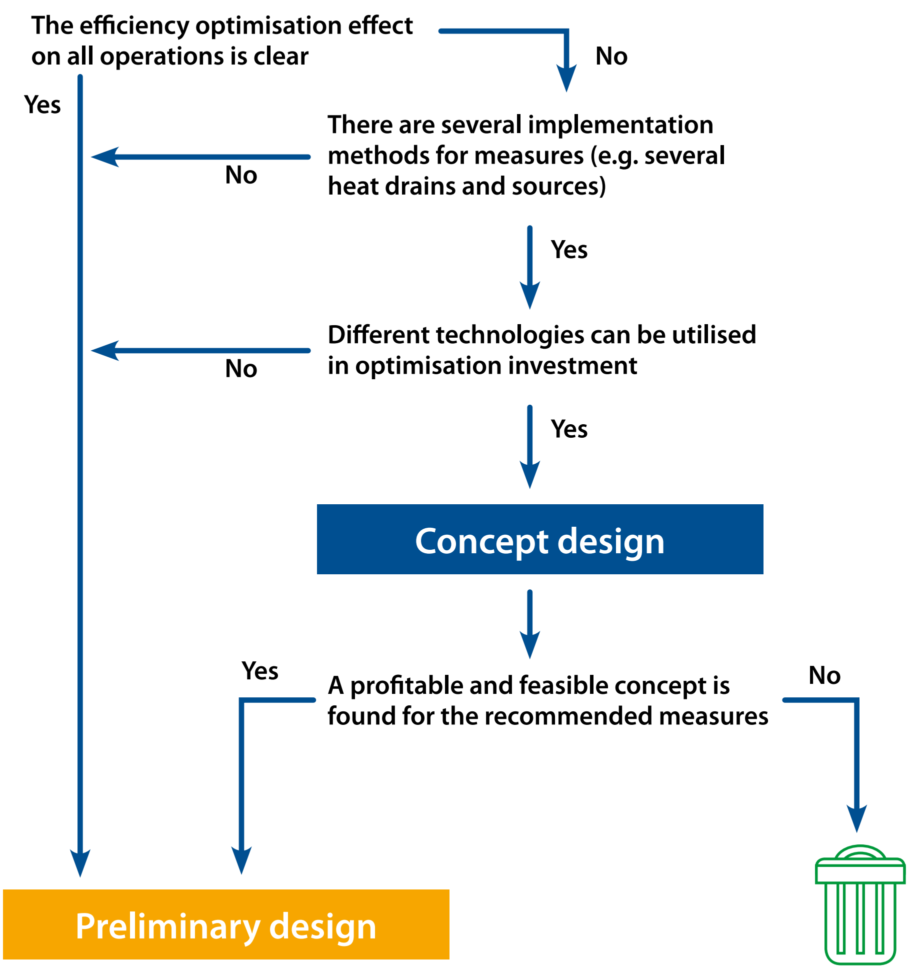
Secondly, subsidies are allocated for the entire investment, starting from design work all the way through to start-up and personnel training. Investment verification measurements can also be included in the investment and, as such, are covered by the subsidy. Energy subsidies should be applied for in good time, to ensure that all project elements are included.

Applying for subsidies is an essential part of the design process, albeit a concept design or a preliminary design.

Summary

By developing concept or preliminary designs based on energy efficiency measures identified in audits, we can aid companies to better evaluate the operational benefits and costs. Armed with this information they are able to make informed decisions regarding investment implementation. This enables companies to improve their energy efficiency with profitable measures, which have life cycles that are as long as possible.

▼ *Figure 2. Flow chart for concept design/preliminary plan selection*



About the authors

Teemu Turunen

Phil. Lic. (Env. Science)

Teemu Turunen has worked within industrial measurement and control since 2005. He has extensive experience of different field studies and audits for a wide range of industrial areas based on data analysis. He currently works as a project manager at Elomatic's Jyväskylä office and is responsible for developing Elomatic's data analysis services.

teemu.turunen@elomatic.com

Jussi Jääskeläinen

M.Sc. (Physics)

Jussi Jääskeläinen has worked in process industry development and energy efficiency service positions since 2004. He has experience in process development, production line energy efficiency and industrial energy audits. He is also thoroughly familiar with energy efficiency monitoring systems and process diagnostics. He currently works as a project manager at Elomatic's Jyväskylä office and is responsible for developing Elomatic's data analysis services.

jussi.jaaskelainen@elomatic.com

Electronic Waste

– growing problem requires urgent attention

Text: Martin Brink

Electronic waste (e-waste) is made up of more than just old mobile phones or laptops. It includes a whole host of devices used in our homes and office environments; these include printers, copiers, scanners, communication devices, computers, monitors, radios, and game consoles to name a few. It is estimated that about 50 million tonnes of electronic waste will be produced in 2018. The insatiable demand for electronic gadgets and their short life cycles make this a rapidly growing global headache.

E-waste contains many valuable materials, of which circuit boards and hard discs are some of the most commercially interesting elements. A tonne of circuit board waste, for instance, contains 500 grams of gold, 3500 grams of silver, 150 grams of palladium, a few hundred grams of platinum, as well as small amounts of rare-earth metals. [3] Metal extraction from electronic waste, a potentially lucrative operation, has so far not been implemented successfully on a commercial scale.

The United States Environmental Protection Agency indicates that only 12.5% of e-waste is recycled. The rest, a staggering 87.5%, finds its way to landfills or gathers dust at the bottom of drawers and cardboard boxes around the world. Most readers of this article probably have a drawer or bag exactly like this, filled with broken mobile phones and other unwanted electronic apparel.

This begs the question why we recycle so little of our electronics, and why so many of us have resorted to hoarding.

Electronics recycling challenges

One of the most obvious reasons for the lack of electronics recycling is the level of difficulty and cost involved. Electronic devices are, quite simply, not manufactured with recycling in mind. In most cases, they need to be painstakingly and manually disassembled and sorted before any recycling or extraction processes can be started. The recycling and extraction processes are also capital intensive and require the use of hazardous materials.

Electronics contain poisonous heavy metals such as lead, cadmium, chromium, and mercury as well as other harmful contaminants. This means that electronics recycling poses serious environmental and health risks.

It is the world's worst kept secret that many industrialised nations still export their electronic waste to Asia and West Africa, instead of recycling the materials themselves. In many cases, the environmental and health risks are not managed well in these "electronics dump sites", to the detriment of local populations and the natural environment. A large export business has, nevertheless, begun flourishing in shipping electronics waste to these countries.

Another aspect that has hampered recycling has been the inability to reclaim the most valuable materials contained in electronics. Rare-earth metals are a case in point. New technologies are, however, beginning to pave the way for further exploitation.

Electronics hoarding

As indicated, the overwhelming majority of discarded electronics do not find their way to recycling centres. Consumers are often expected to go out of their way to safely and legally dispose of malfunctioning or unwanted electronics. In Finland, where recycling is common, most housing companies offer recycling bins for cardboard, carton, paper, glass and metal. E-waste, however, needs to be taken to special recycling centres for processing.

As a result, many people still resort to hoarding their growing piles of unwanted electronics or dispose of them at dump sites and elsewhere. E-waste recycling in Finland is actually at a comparatively good level, even though much needs to be done to ease the entire recycling process.

Short life cycles and high demand driving waste problem

Many electronic gadgets have very short life cycles, lasting only a few years at most; they are not manufactured to last longer, and eventually need to be replaced when they malfunction.

This has become a common and lucrative business model. Gone are the days when one could purchase a mobile phone that will last for years and which comes with a battery that can be replaced when needed. In this respect, manufacturers are culpable in electronic waste proliferation by producing electronics that become obsolete quickly, or contain parts that cannot be easily replaced.

The cost structure of certain products is also increasing the amount of discarded electronics. Printer refill cartridges commonly cost as much or more than a new printer! There is, therefore, a disincentive to refill and an incentive to upgrade, which leads to more waste.

Consumers are equally at fault; the high and indiscriminate consumer demand for new electronics is the

An e-waste centre in Agbogbloshie, Ghana. Electronic waste is burnt and disassembled at the site without taking environmental contamination and health risks into consideration.

Hoarding of electronic waste in Bengaluru, India

The insatiable demand for electronic devices is driving the rapidly growing global e-waste problem.

reason manufacturers can get away with the afore-mentioned practices. If consumers demanded that their latest iPhone had to last five to seven years and that it should be repairable when needed, Apple, and others like it, would have to rethink their strategies. These same consumers would also need to curb the desire to have the latest gadget on the market, just because it is available.

Recycling deposit

An innovative strategy to ensure greater cooperation from manufacturers and consumers alike would be the introduction of a recycling deposit. Under such as system, consumers would pay a deposit on any electronics devices purchased. Manufactures, on the other hand, would be obliged to refund the deposit when the product has been returned.

Legislation can be used to oblige manufacturers to recycle these returned products. Such a system would work best if the original product packaging can be used with prepaid postage, or the recycled materials could be disposed of in another easy way. One cannot simply rely on the good intentions of consumers. Recycling must be easy too.

Ground-breaking electronics recycling pilot plant

As mentioned, one of the challenges in electronics recycling is extracting all the useful materials contained. The extraction of rare-earth metals, for instance, poses numerous technological challenges; they are present in very small amounts and extremely difficult to separate from other components. As a result, it has not been possible to recover these metals using traditional pyrometallurgical methods.

Fortunately, research is being conducted around the globe to develop effective and commercially viable extraction methods. The most interesting rare-earth metals that can be extracted are neodymium, gadolinium and europium.

A ground-breaking pilot plant project in Jyväskylä, Finland, aims to do exactly this; it will extract precious and rare-earth metals from electronics waste. The project is headed by the Technology Industries of Finland and the project participants include Jyväskylä Energy Ltd, Tapojärvi Ltd and Elker Ltd. Elomatic is responsible for the design of the pilot plant.

Jyväskylä Energy Ltd has for years been cooperating with the Department of Chemistry at the University of Jyväskylä. to develop processes for metal recovery from electronics waste and power plant ash. The pilot plant aims to test the successful laboratory processes on a larger scale. The long-term goal is to use the pilot plant to develop a viable export concept.

At the time of printing, the project had progressed to the modelling and preliminary design phase.

Conclusion

The amount of electronics waste worldwide is growing at an alarming rate. A multi-pronged approach is necessary to contain the problem and achieve sustainability. This will start with consumers that consume responsibly and take care of recycling their unwanted electronics. Consumers should also demand that manufactures produce products that last and can be recycled easily.

Manufactures, on the other hand, need to invest in manufacturing processes that support recycling and take ownership of the whole recycling process. Authorities can to do their part by legislating wisely: innovative methods, such as goods deposits have be considered.

Electronics recycling should be prioritised by society as a whole; recycling a mobile phone should be no more troublesome that of a glass bottle. Industrial players and technology developers will boost the process by developing more effective, efficient and safer recycling and recovery methods. As can be seen from the Jyväskylä pilot plant example, progress on this front is being made.

A lasting solution to e-waste proliferation will only be found, if sustainable solutions can be found on all these fronts.

Sources

[1] http://www.electronicstakeback.com/resources/problem-overview/
[2] https://www.thebalance.com/e-waste-and-the-importance-of-electronics-recycling-2877783
[3] http://www.tekniikkatalous.fi/tekniikka/ict/elektroniikkaromun-kierratyslaitos-nytkahti-eteenpain-harvinaisia-maametalleja-pyritaan-ottamaan-talteen-6672830
[4] https://en.wikipedia.org/wiki/Electronic_waste

ELOMATIC

CONSULTING & ENGINEERING

Scientia vires est

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

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

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

www.elomatic.com

WE DONATED OXYGEN TO THE BALTIC SEA!

We have given the Baltic Sea oxygen-rich water by donating the funds earmarked for Season's greetings to BSAG's work for a healthier Baltic Sea.

www.joululahjaitamerelle.fi

BSAG®
Baltic Sea Action Group