Case study

Carried out together with Accus, a Swedish OEM

RI.
SE

Circular signs at Accus

Accus is a sign manufacturer located in Malmö in Sweden that design develops and assembles both single signs and larger sign systems for private and public customers, in combination with assembly and maintenance services. A small portion of production is handled internally in Sweden while the major part is produced by subcontractors in Europe.

The business landscape

Accus's main customers are commercial property owners and architects. Change of tenants in the property owners' budlings, as expansions or closure, building renovations, or new building projects create needs for new graphic identity, renewal, or dismantling of existing signs. Advertising agencies have an important role in creating changes of graphical identities that often require new signs. The costs for signs can be from some thousand Sek., up to million Sek. for very large facade signs. The frequency of change can be from months to many decades depending on the type of business. There are two main sign types that Accus offer, sign systems where generic graphical content can be applied, and individual signs where the sign is closely connected to a specific brand and typographic. While the generic signs continuously can be upgraded when a change occurs, the specific signs will usually be scrapped after exchange. Accus is responsible to take back their signs according to ERP regulations but at the expense of the customer. Costs are the main criteria for purchasing, and usually, one-time signs are the default option.

Circular vision strategies at Accus

Accus CEO that is a part of the owner family has a bold vision for achieving as circular products as possible or “create visual communication with positive societal impact” and reducing Accus's sustainability impact on society and ACCUs has in previous research projects explored CBM and implemented circular design. Results from these projects was a modular sign concept RE: sign designed for being able to med reused by only exchanging a printed film with the graphics. By this Accus claims that 98% of a RE.sign is reusable. Also, to use of recycled materials has been investigated. E.g with plans to use recycled Aluminum for frames. However, Accus have difficulties to source recycled Aluminium, and the hardened glass fronts are not possible to recycle. In Accus plastic sign products, Acrylic from recycled ingredients is implemented as standard.

A circular business model for signs

Accus's vision is to take control over the sign's lifecycle by providing it as a service by a subscription model, combined with maintenance and material recycling of components that became obsolete. This CBM was developed and tested on a number of pilot customers, although with challenges to get customer acceptance for a subscription instead of buying and owning signs traditionally.

Products related business risks in a CBM

The function of signs is to communicate the customer's brand identity and position. Risks for premature obsolescence, i.e before the sign is technically broken down are mostly by aesthetical changes. This could be fashion changes that might affect a brand to be considered as being less contemporary.

Also, visual wear as color fading, scratches, contamination could occur. Risks for technical obsolescence could be due to physical damages (it is not uncommon that signs are taken down by trucks turning), or fading, missing backlight. Other technical risks I related to wear of electronic drivers and LEDs, as they have a life expectancy of about 7 years(driver) x years (led). There is also a technical development with e.g digital signs as OLED on its way out on the market that offer the advantage of the changeability of the graphical content remotely.

Functional changes could be due to new dimensions for signs when buildings are being renovated and e.g., an architect specifies dimensional criteria for the signs, etc. Social changes, as new customer behavior could be about how shop owners consider existing signs and might need alternative signs for e.g. pop-up stores that are an emerging trend. Changes in legislation seldom risk signs to be obsolete, with the exception of large facade signs that might risk detaching from buildings in heavy winds.

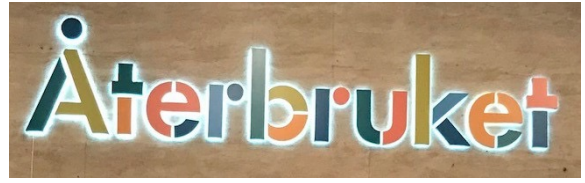


Figure1. Facade Signs that are designed with standalone physical letters or symbols representing a specific brand have only the material value left, if the graphical identity is updated, or if the brand closes shops, etc. In such a case with “single-use signs”, material recycling is the only circular alternative. However, durable materials as Aluminum can be reused for new signs. In the example above Accus has milled sign letter parts from harvest used signs, turned them into reused signs.

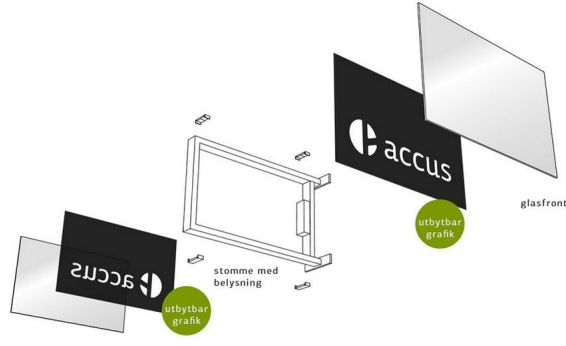


Figure2: Accus modular sign system RE: sign, with an exchangeable film representing the graphical identity of the customer. By applying a RE: sign the potential for extended lifetime increases drastically, compared with signs based on specific free-standing letters. Or traditional plastic lightbox signs, where films usually are strongly attached to the sign structure.

References:
Based on personal interviews and workshops with Accus during 2019-2021
OLED technology see e.g
https://www.lg.com/global/business/oled-signage

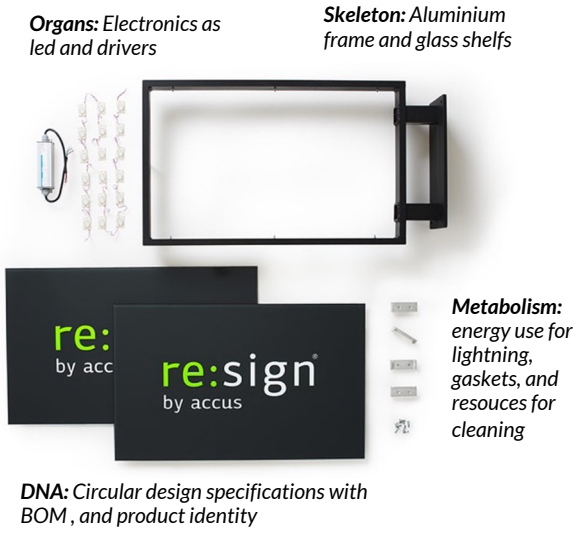


Figure 3: Accus modular RE:sign broken down in separable layers to give an overview over the PAs modularity. The Re:sign has a strict shape with hight quality materials with a potential to last for decades. However, risk for premature obsolescence can occour due to the dimensions that is not changeable, or if customer consider exchanging the graphic film as to expensive. Improving the design for easier exchangability can mitigate this.

The product architecture is built up of a supportive frame of welded Aluminium profiles, sheets of hardened glass back and fronts, an exchangeable film presenting the customer's identity. The glass covers are held in place by metal clips that are screwed to the frame. Inside is LEDs and, wiring mounted to the frame, together with an electronic -driver. The sign is mounted to the façade with screws and connected to the grid.

Depending on the height of the sign a, sky-lift could be required for cleaning or to exchange the graphical films. The planned life expectancy is 25 years, followed by a possibility to remanufacture to new like condition. However, the dimensions are fixed and the sign is only available in a fixed rectangular or circular shape.

Lifecycle Service Planning.

The components in the RE signs architecture have a different life expectancy. In a planned-for scenario, cleaning is done regularly, exchanging the sign films depending on changes at the customer. The aluminium frame and glass fronts are planned to last 25y. Led and drivers have a life expectancy of6-8 years and have to be exchanged 2 times.

Multilayered modularity and interoperability

The PA modular components are easily separable and could be divided into multilayered categories. According to figure3. Led´s, electronic drivers and interfaces are standard components.

Continuous service innovation

Today accus offer service agreements as cleaning and exchange of graphic films, and there are also plans to offer the possibility to automatically dim the sign on nights to save energy and reduce light pollution.

Cascading customer loops

Accus, has the ambition to reuse harvested complete Re.signs and if not viable, harvest values from exchanged parts. Here, metals and glass have a high value while plastics and electronics have low residual values. Here Accus are experimenting with various solutions as repurposing materials into new unique signs as in figure 1.

Financially grounded adaptivity

Accus claim that the Re:sign is not more expensive than their other signs and that the modular product design reduces labor time when exchanging graphical films, which further increases the potential for profitability when. selling the Re: sign as a service.

Suggested design improvements

The Re:sign has many strengths for longevity, such as a modular architecture with exchangeable films, a simple design with high-quality materials as anodized aluminum, and glass with predictable wear. However, the process of exchanging the graphical films today requires dismantling the sign and returning it to Accus workshop. This leads to increased costs, especially if signs are placed at heights that require skylights. Here, design improvements that simplify film exchange at the customer's location could be considered.

Summary and discussion

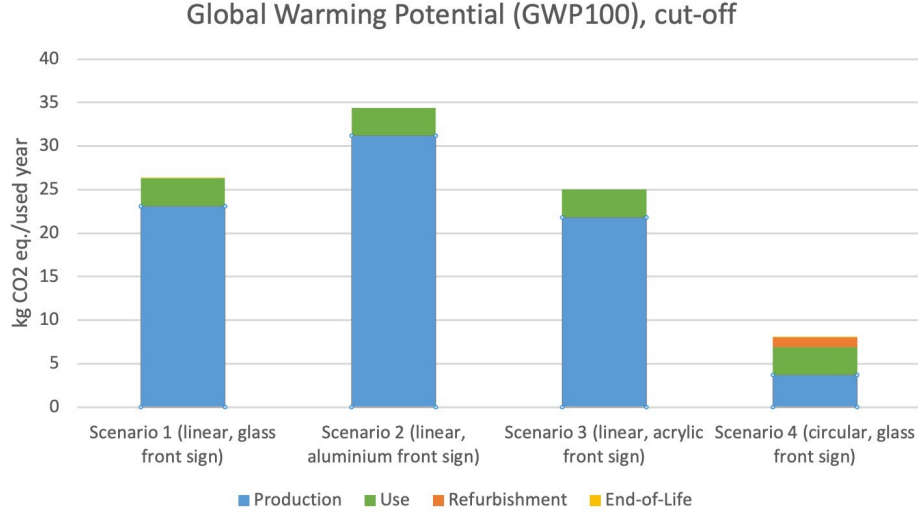
Accus ambitious circular vision and systematic work have resulted in improved organizational capabilities for CBMI and circular design. However due to a traditional purchase logic among customers, purchasing signs as a subscription seems to be a current barrier. Eventually, the buying logic in the property branch might change towards more focus on longevity for buildings and various building components. Although, even if selling products as a function by a subscription model has been argued as being the most circular solution by the CE research community, a CBM built around long-lasting products, sold traditionally but with an upgrade and buyback agreements can still lead to realizing the embedded circular potential. However, in such a CBM there is a risk over time that the original circular ideas of the product are forgotten as time goes by, and management and staff at the customers change, and keeping the customer contact and product history will be crucial to enable longevity.

Circular signs and the potential for environmental impact reductions

A large portion of a sign can be reused if the graphic can be changed, and energy use to light the sign can be reduced. In the end, large reductions in greenhouse gases can be achieved

In Accus modular RE:sign only a thin film is replaced if the sign needs to be updated with a new graphical content. Thus only 2 weight procent of embedded materials need to be exchanged when changing signs.

The effect usage in the RE:sign is only 20-30 w by using LED.
To further reduce the impact over the lifecycle accus investigates how signs could be dimmed to 30% of light capacity during nights to reduce energy usage even more.



LCA conducted by Accus with 4 scenarios, 3 linear with various materials and one circular scenario. Scenario 4 (Resign) yields reductions of over 65% compared to the standard outcome (linear)

Case study

Carried out together with Hydroware, a Swedish OEM

RI.
SE

Elevator as a service for as long as the building itself

The global elevator industry is dominated by four main firms, Otis, Schindler, TK Elevator, Kone. The rest of the market is shared between numerous smaller actors producing elevator components, installing, replacing, and doing maintenance. Competition for new elevator contracts is fierce, with usually very low margins on new sales, and with service contracts, where service and expensive exchange of components creates the main revenue streams for the OEMs. The dominant business logic among most of the larger OEMs is described as focusing on new installations and full replacements. I.e that old elevators are completely removed, existing materials scrapped, and a new elevator is installed. The dominant design logic is described as having a focus on efficient production, e.g reducing modularization in favor of combining components, and control systems that are locked to specific OEMs after installation, with an optimized lifetime a bit over the set warranty intervals for components. The expected life length for elevators installed today ranges from 20-25 years depending on intense usage and is a decrease from elevators installed from the 60s, which had a life expectancy of about 40 years and more. However, elevators can have a very long-life length and there are examples of elevators in Sweden installed in the 1930s that still operate in the 2020s. However, with described difficulties for property owners to find service firms that are willing to engage in keeping such old elevators up to date, as most service firms consider them to be obsolete and to be exchanged with new components. On p. x such an old elevator example is illustrated.

Hydroware is a Swedish manufacturing firm that since the 90s has developed and produced drive and control systems for elevators. Hydroware's core business since started 1998 has been to modernize existing elevators, by a modernization kit. Hydroware's major product segment is for hydraulic elevators that are most suitable for buildings up to 6 -7floors, with advantages as, less needed space, faster installation time, compared to the most common traction elevator installations.

Photo by Hydroware

Figure1: Hydroware mainly develops and manufactures drive and control systems for hydraulic elevators. In the red cabinet, a hydraulic tank, hydraulic motor and valve block are fitted that is controlled by steering electronics placed on top. The whole assembly is usually mounted in an elevator machine room. To build a complete elevator assembly, various additional components are needed like a hydraulic cylinder, an elevator car, doors, and supporting guides that are mounted in the elevator shaft (figure 2)

Circular vision strategies at Hydroware

Hydroware's founder and majority owner had over the years seen how the main business logic in the elevator industry increasingly had resulted in many valuable components and materials just being scrapped prematurely. At the same time, the debate in the industry mainly had a sole focus on reducing energy consumption during the usage phase, excluding the impact from production and end-of-life stages. A hypothesis if extending longevity was a route that could save both resources and money started to grow and to be debated in Hydroware's top management. To explore this hypothesis of extended longevity further an LCA was conducted in 2015 showing significant potential for CO2 reductions by extending elevator usage time from 20 to 80 years. Over the years customers had responded positively to the modernization offer, and Hydroware saw an opportunity to go on step further in exploring if a functional sale offer could, be a further step towards their vision; formulated as "vertical transportation that could last as long as the building itself". That for many buildings can be much more than eighty years. Also, exploration of other circular activities as harvest exchanged components to remanufacture, more energy- efficient usage, predictive maintenance and material recycling started to emerge.

Potential for longevity for current hydraulic elevator design

The risks for premature obsolescence in current hydraulic elevator architecture are mostly related to the moving parts as the main hydraulic cylinder, valves, , together with doors, the car interior and landing panels (buttons and indicators). Also, electronics and printed circuit boards have a limited lifetime.

Occasionally, thunder and flooding's can risk to create more severe technical failures. Furthermore, visual wear of interior elements as surface colors, lightning quality, etc. poses the most aesthetical risks. The risk for functional obsolescence is mostly related to, lack of regular maintenance, introduction or phasing out of new standards. For example, as the 2g and 3g nets currently being phased out in Sweden, this will require an exchange of 2g,3g emergency phones. Such risks are associated with social obsolescence, as well as the implementation of new regulations for accessibility and safety that for old elevator installations can be difficult to meet.

Lifecycle Service Planning.

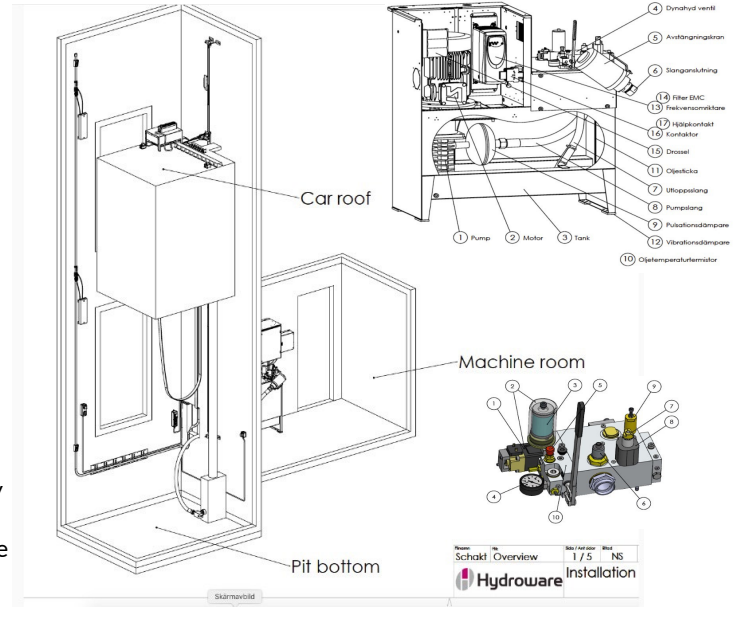
The components in the complete elevator installation have different life expectancies and maintenance needs. Components most sensitive to errors and related to elevator downtime are elevator doors, where gravel and small objects can result in doors malfunctions. Elevators usually are maintained regularly with the exchange of consumables as e.g filters and wear components. Yearly safety certification is also required, and without regular maintenance, elevators risk getting driving bans.

Multilayered modularity and interoperability

Most elevator components are modular and easily accessible. Exceptions are printed circuit boards (PCBs) in the elevator controller and BUS system, where the exchangeability of some components is limited. In the elevator industry drive and control systems that are locked to a specific OEM are common, creating barriers for maintenance personal doing troubleshooting and increased costs for property owners. Hydroware instead uses the Can open standard that enables interoperability for electronic components as control buttons, sensors, etc. Also, the elevator steering, and control system will be compatible with DC input to e.g. battery backups and solar panels, to enable a coming increase of local renewable energy systems.

Continuous service innovation

The rapid development of IoT technologies has enabled Hydroware to implement health monitoring functionality for the elevators that enable predictive maintenance. Also, service and health history can be stored and accessed, which open up for new service development based on actual individual elevator usage.



Illustrations by Hydroware

Figure 2: Overview of a complete hydraulic elevator product architecture. Including the moving parts in the elevator shaft as the elevator car and main hydraulic cylinder. Divided according to the FAD strategy for multilayered modularity they can be oriented as follows: **Skeleton***: Elevator support structure, guides, elevator car, cabinets.* **Organs;** *Main hydraulic cylinder, Electronic control system, hydraulic valves, doors, sensors, cabling.* **Metabolism:** *energy usage, hydraulic oils, gaskets, filters, and resources for cleaning.*
DNA: *Design specifications with BOM, product identity, and data about elevator health & health history.*

Cascading customer loops

Hydroware has the ambition to reuse elevator components and if not viable, harvest values from exchanged parts. Here foremost the electric motor, the main hydraulic cylinder, and drive electronics has the highest residual values. Also repurposing of used EV batteries is being explored as a way to offer new functionality in smart buildings as to help reduce electric peaks.

Financially grounded adaptivity

Based on the FAD assessment a range of more durable components has been considered, where especially high-quality doors have been considered as removing potential downtime, in combination with regular cleaning schemes. Also reconditioning or remanufacturing of hydraulic components and PCBs will be explored as ways to reduce cost

Suggested design improvements

The main suggestions for improvements are regarding, increased focus on specifying components that Hydroware is not manufacturing today to be in line with the extended lifetime, as e.g more wear resistant surface treatments on moving hydraulic parts. As well as choosing door types where the surfaces can easily be refurbished to reduce visual wear. Also, more modular and upgradable PCBs in the elevator controller and BUS system have been identified to better protect the electronics against peak currents, or other damages.

Summary and discussion

Hydroware's vision of providing an elevator as a service based on long-lasting elevator components is from a product design perspective doable based on the current product architecture. However, further in-depth explorations of identified components are needed for suggesting detailed redesign activities that can further reduce the identified risk for premature obsolescence, and thus contribute to increased profitability and realize the planned for longevity in the CBM.

The following section presents a fictive scenario of an elevator as a service from a customer and user perspective. Although partly being based on real customer data during the research project, it does not represent an actual business offering.

Background

The housing cooperative “High Five“ includes five houses in Bagarmossen south of Stockholm City. The houses built in the early 2000 s has in total ten elevators.

Over the years elevators are the area that has created many headaches for the different members of the boards. As the board members usually exchange after 2 to 5 years, documentation and keeping the information for the elevators over the years is challenging. Usually, the information about service and repairs is entered manually in a logbook, that is stored in each elevator's machine room. The current elevator, which was exchanged at the end of the 1990ies, came with a 5-year service agreement that included all maintenance and exchange of broken components.

However, when this agreement ended, problems started to emerge, as well as increased costs for service and exchange of components. As each resident had access to the phone number of the elevator service firm, many faults were reported in parallel, and the board members had difficulties understanding the many invoices for the different visits and repairs. It could be that some residents heard disturbing sounds or experienced doors or buttons not working etc. Especially, buttons became an increasing cost post, as these elevators were looked to a specifics manufacturers control system, and accordantly represented high prices as spare parts. Eventually, the board decided to make an action plan for the elevators and an elevator consultant was assigned. The consultant report concluded that all ten elevators most likely had to be replaced within five years, with an expected cost of 1 million Sek./each.

Photo by Hydroware

As the housing cooperative already had made several major investments due to earlier identified construction fraud, and upgrades as solar panels and charge points, financing elevators for 10 million would considerably increase the monthly fee, as the bank only offered an in-Blanco loan with a high-interest rate.

When the plan was proposed at the Annual general meeting, many residentials objected and the suggestion for new elevators was voted down, and the board was forced to look for alternatives. After some search, they came across one elevator OEM offering elevator as a service.

Elevator as a service offering from a customer perspective

Initially, the board members were hesitant about this offer as it was difficult to understand in detail, and there had been a tradition to purchase all new equipment, but eventually, the proposal was put forward on an extra general meeting and was accepted by the members. Many members felt that the idea of using the elevator as long as the building would stand made sense as it would save costs and reduce environmental impact.

The housing cooperative now pays for access to the elevator in contract periods of 10 years at a time, with an option for renewal for a new 10years period during the 9th year. Payment is based on a monthly fee which included and agreed uptime but excludes electricity. The monthly fee is constant for the first 10 year (except for an increase in the “stibor” interest rate) and then decreases over each following 10 year period There is no defined limit for the subscription time, with more than 80 years as a vision.

Each elevator's health and health history is monitored remotely, where errors that could lead to failures are identified at an early stage. Here regular cleaning of the car and especially the doors sills, carried out by the residents' taking turns, both reduce risks for door malfunction and save costs. The contract allows for one major yearly inspection where one elevator at a time is down during a whole day.

Conceptual proposal for an future adaptable elevator

After every 20 years, the elevator is going through a major overhaul, where the elevator car is updated, doors repainted, and the drive and control system are overviewed and requiered parts are reconditioned. Remanufactured components are used where possible. Over years new service content has been included based on needs identified by usage patterns and described needs. New functions as remote driving up, light experience “Friday disco” and a program to incentivize residents to take the stairs resulted in both stronger attachments and reduced electricity bills.

Now some residents see it as a sport to use the elevator as little as possible, giving more access to the many elderly residents, being dependent on elevators for their daily mobility. Also, used EV batteries have been installed in the elevator machine rooms, helping reduce energy peaks, at peak loads over the clock. Together with solar panels, this system also enables charging of Evs, as well as keeping the elevator up if power failures occur, with remained lightning.

Now after almost nine years of the service, the board spends very little concern over their elevators, they just run, and problems are usually solved without major downtime. They also get one invoice, have a personal contact person at the elevator company that works very well.

Image: Nick Fewings

By also working with incentives to the residentials to reduce the usage of elevators there has been a win-win regarding reduced energy usage, costs for maintenance and overhauls, as well as the availability for those residents being dependent on the elevator, i.e elderly and disabled.

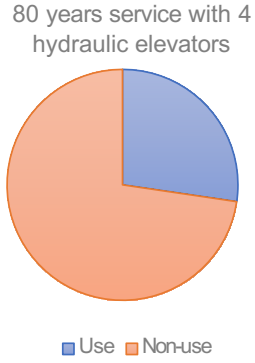
An additional benefit has also been that as the board members in the housing cooperative are being exchanged, the carry-over of information regarding the elevators has been much easier than before as all history is stored digitally at the service provider with a customer account. Before collecting information about service history and repairs and planning for new service for the elevators was usually being a time- consuming, and frustrating task for the board members.

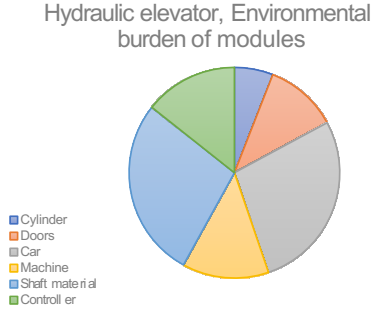
Over the year, there have been two major issues, once the basement was flooded, and once building was hit by lightning. However, due to the design with sealed components and circuit board with lightning protection the elevators were up and running after two days, and the extra costs were covered by the residential insurance. Also, power failures have been more frequent over the last years and the possibility to run the elevators on batteries has been appreciated by the elderly residents. Over the years, some members have raised concern that the costs might be higher than if buying new elevators, but as the board can show the TCO calculations for the extended longevity, this will usually end this discussion. Moreover, as many residents are being concerned about saving resources and reducing climate impact there is now a broad acceptance for the elevator as a service agreement in the housing cooperative.

References:
Based on personal interviews an workshops with Hydroware, property owners,
board members and residentials in housing cooperatives, elevator service firms and consultants during 2019-2021
Global “Elevator and Escalator Market **(2021)**
https://www.globenewswire.com.

Elevator longevity and energy/ resource efficiency

Analysis was done with existing LCAs to estimate potentials. Main assessments include identification of important modules and assessing use phase potentials. Results show potential of up to 55% reductions in environmental impact, with the existing practice of modernization representing 38%.

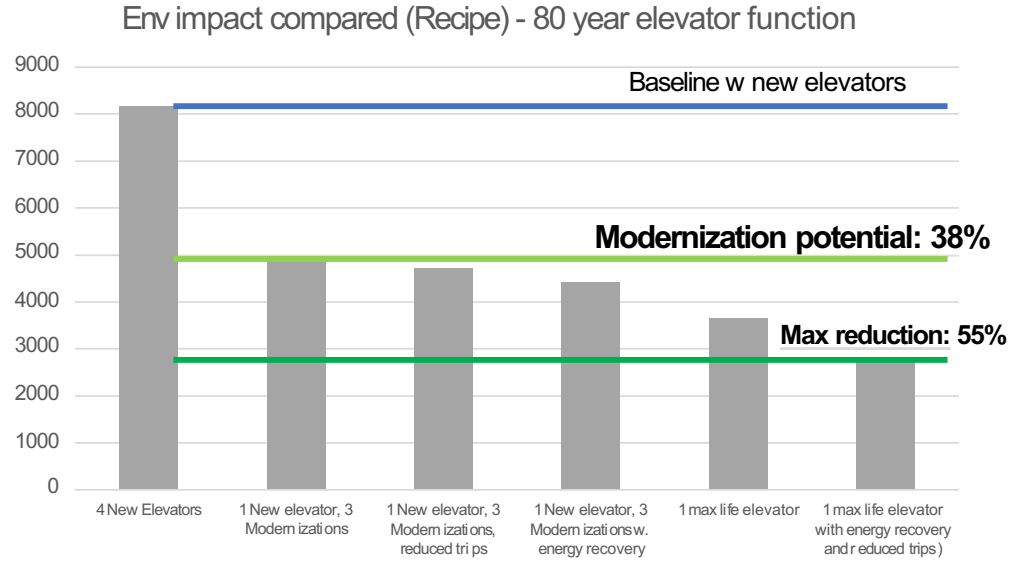




Potential related to production impacts: Determining the potential to extend product life (Use vs Non-use impacts): Impacts (including CO2 emissions) related to production of the equipment (non-use) represent a majority of the impacts resulting from 80 years of elevator function (figure below). This means that extending the use phase (instead of replacing elevators every 20 years) can mean a relatively large reduction in total environmental impact.

Key parts: Which modules represent the largest production impacts? (Hotspot analysis): The shaft material and car modules represent more than a combined 50% of the impact, with the controller, machine and door modules representing most of the remainder. Extending lives of the most impactful modules will yield the most benefit.

Estimate potential for 6 possible outcomes: Results are presented in the unit used by LCA results at hand, Recipe endpoint, a system that allows for aggregating 16 major impact categories into one measure. Recipe is used because ample breakdowns by impact categories were not available. However, the limited results for global warming potential (presented for each phase, but not for modules, nor for other analyses, like energy recovery) very strongly correlate to global warming potential results for the elevator. Results show a range of potential reductions of 38-55% compared to the base case (4 new elevators). This includes energy reductions during the use phase of up to 35%, which results in a reduction of 40,000 kwh for an elevator used in moderate use scenario for the 80-year period. Other **outcomes are generated assuming different combination of module life extension resulting from modernization and reductions in use phase impacts, resulting from reduced trips and/or energy recovery** (details on next page).



Elevator longevity and energy/resource efficiency (more explanation)

Analysis was done with existing LCAs to estimate potentials related to both non-use and use impacts. More reasoning and assumptions are found here.

Estimation related to non-use (production) impacts: Estimate potentials of modernization which allows for reuse of many parts. The table below shows an estimate of how many modules that would be needed to deliver 80 years of service if an elevator would be installed and then modernized every 20 years. Without modernization, replacements of elevators would require 4.0 of each module.

Cylinder	**4,0**
Doors	2,0
Car	1,3
Machine	1,3
Shaft material	1,3
Controller	4,0

Estimation of potential to reduce use phase emissions.

Three ways of reducing use phase impacts were identified: (1) reducing use/ reducing trips, (2) reducing standby energy and (3) energy recovery. First, reducing trips taken could be achieved by nudging building residents to take the stairs instead. This measure presents the added benefit of reducing wear and tear and increasing part longevity and is especially feasible for the primary niche of the hydraulic elevator, low-rise buildings not exceeding 10 floors. Adding messaging or symbols to nudge residents towards the stairs or even including pay-per-trip incentives to the payment logic were discussed as ways to achieve this during business model innovation.

Secondly, energy used during standby represents a large part of total energy use. In settings with low-frequency use, standby energy represents a majority of energy demand. In settings with more frequent use, the energy used during trips represents the majority. Naturally, incentives focused on reducing trips would best target high frequency use settings. While reducing stand-by energy is a natural target, no immediate solution was identified. That being said, if energy would be recovered and stored (such as in battery storage) that energy could at least be used to cover some of the standby demand. Energy storage could also offer emergency power and could reduce peak loads, two features that would be attractive to some customers. However, we don't estimate the potential of such a solution.

Here, for purposes of estimating total potential of FAD outcomes, we use a previous LCA, which estimated that energy demand could be reduced by around 25%. In addition, we assume 25% reduction of trips in the scenarios shown in the chart below. We assume this to yield a 12.5% total energy reduction due to an at least equal energy demand from standby energy. Results are presented in the unit used by the LCA results at hand, Recipe endpoint, a system that allows for aggregating 16 major impact categories into one measure. Recipe is used because ample breakdowns by impact categories were not available. However, the limited results for global warming potential (presented for each phase, but not for modules, nor for other analyses, like energy recovery) very strongly correlate to global warming potential results for the elevator.

Outlook

Promising exampels of design for durability, flexibility & adaptability

TRL 9. Actual system proven through successful mission operations.

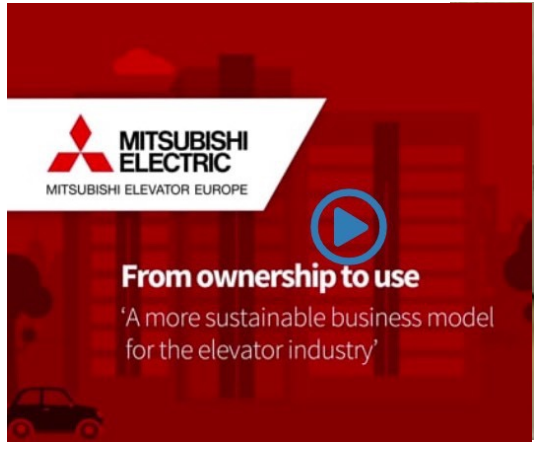
Elevator-as-a-service, M-USE

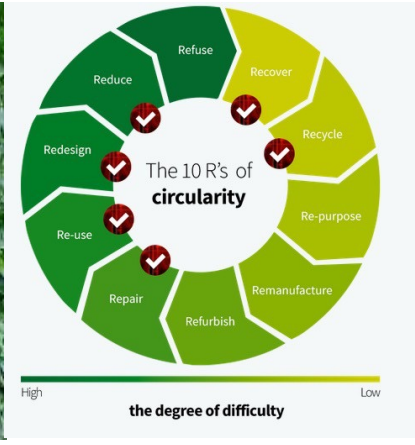
Mitsubishi Electric has in the Netherlands offered elevators as a service since 2017, under the name M-use, offering property owners a “worry free” access to elevators for a monthly fee. The planned for usable life is 50 years, in line with the planned for life of commercial buildings in the Netherlands, that is divided i two twenty years lease periods. Plus a ten years optional period.

During the lease periods Mitsubishi claim the legal ownership of the elevator shaft and all elevator components. Service and upgrades are included with only one planned maintenance stop every year. Customers can either pay a monthly fee without any upfront investments, or a down-payment that reduces the monthly fee. The M-use agreement is only available for new installations, where Mitsubishi can install the suitable components that meets customer requirements and extended longevity. The M-use elevators are monitored where malfunctions can be remediated before major failures occur, reducing costs, downtime and inconvenience for property owners and their tenants.

The elevator as a service offering was first developed in 2012 , in combination with the building of the Park 2020 near Schiphol airport, with the aim to contribute to a circular economy by implementing C2C principles. Even if environmental benefits was in the forefront when starting, the financial benefits today is the main driver, and with over hundred installations, the M-use offering has been a success than contributes significantly the turnover.

In the M-Use , Mitsubishi have control over the whole value chain, including contacts with the end customers. However, compared to the dominant business logic for the dominant firms in the elevator industry, the M-use differs much regarding planned for product longevity and responsibility for the installed materials.





Circular business logic

- Customers buy access to the function worry free vertical transportation
- Less bound capital for customers than buying elevators
- An objective to increase margins by lowering maintenance costs
- Stable revenue streams over a long time, creates a stable business
- MITSUBISHI owns the whole value chain
- Possibility to reach new customer segments that previously chose low price competitors

Circular design logic

- Elevator components optimized for the planned for functional life
- Components designed to be exchangeable and reusable
- Health and health history of elevators are monitored by IoT
- Material passport keeping track of embedded materials

Potential for environmental reductions

- Extended longevity reduces CHG
- Cascading usage of components
- Material recycling is done when no usable life is left in components

References:
Based on personal interview with Mitsubishi during June 2020
PARK 20|20 , A Circular Economy Business Model Case,
Zwart et al., (2014)
https://www.mitsubishi-elevators.com/m-use/

TRL 9. Actual system proven through successful mission operations.

Product longevity for smartphones, Fairphone

The telecom industry, with consumer electronics as smartphones represent one of the fastest growing waste streams of E-waste. In Europe incentives to force manufactures to prolong product life has been implemented in France, with was preceeded by law suits against Apple and Samsung for planned obsolescence. During 2021, German government are proposing that manufacturers should keep smartphones updatable for up to 7 years. The response from the branch organization is 2 years!

Fairphone is a Dutch company with ambitious goals to change the way smartphones are made throughout the whole value chain by designing long-lasting phones with “fair” and recyclable materials and reasonable working conditions for those working in the value chain. Fairphone started in 2010 with a campaign about conflict minerals. Since then, they have promoted transparency in their operations and marketing. By making their supply chain visible, Fairphone wants to initiate a discussion about where its consumer products come from, what raw materials it uses, and how the phones are made. Fairphone 2, released in 2016, was claimed to be the world’s first modular and fair smartphone and has been sold in many countries.

In 2019 Fairphone 3 was launched, which Fairphone was the worlds first smartphone that could be upgraded, by an exchangeable camera module, battery pack and speaker module with improved features. In Ifixit reparability score Fairphone 3 got 10/10 . There is also a 3+ edition launched where existing customers could get the latest upgrades or new customers get the latest model, with the aim to keep main parts in existing phones for longer

The camera module in model 3 was deliberately designed to allow exchange, and the physical interface with few connectors further make exchange feasible also for consumers themselves to exchange. However, as the chipset, the brain in the smartphones is not possible to upgrade Fairphone phase a challenge to keep phones up to date if. To further illustrate this the shift to the 5G communication protocol , has required Fairphone to develop a new model; 4, that has the same objective for longevity but now in line with this new communication speed.

Image: Ifixit.com

Image: Fairphone.com

Image: Fairphone.com

Fairphone is one of the case studies where we follow their challenges in developing and selling a circular product during this research project. Fairphone offers customers a smartphone designed for at least five years of life, and with ambitious goals to change how smartphones are made throughout the value chain. Their Model 3 is modular and where it is easy for the users themselves to replace broken components. Some components such as the camera module can also be upgraded.

Circular business logic

- A competitive price point for smartphones
- Upgradeable modules instead of exchanging to a new product
- Low margins on spare parts, and exchange/repair instructions for free
- Building a strong community of dedicated users
- Stable revenue streams over a long time, creates a stable business
- Paying living wages for subcontractors in value chain

Circular design logic

- Modular design
- Components designed to be exchangeable and reusable
- Material passport keeping track of embedded materials
- Use of recycled minerals and plastics

Potential for environmental reductions

- Extended longevity reduces GHG
- Possibility for material recycling of exchanged components or phones
- Material recycling is the last

References:
Based on personal interviews with Fairphone during 2020
https://www.ifixit.com/News/43623/fairphone-3- plus

TRL 9. Actual system proven through successful mission operations.

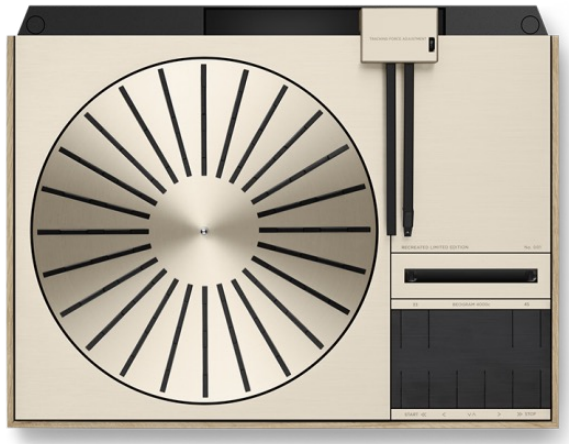
Exploring value preservation, Bang & Olufsen

Bang & Olufsen (B&O) has a long heritage regarding classic design and longevity. Many B&O products can last for decades, with products carried over through generations, and B&O has a strong user community with dedicated fans.

Many products have over the years become iconic with, high residual values on the second-hand market. In 2020, when the company turned 95 an exploration about value preservation/ improvement was carried out by buying back B&O Beogram 4000 turntables manufactured and sold in the 1970ies. These products were then remanufactured by B&O and upgraded to the latest technical standards and visual qualities, together with documentation about the history. The remanufactured products were sold in a limited edition in 2020 at a good margin and have since increased even more in value on the second-hand market.

The project was initiated from B&O design by customer research about trends for sustainable, post-pandemic living, in combination with internal B&O roadmaps for increased circularity for tackling E-waste, etc. Together this formed the ground for the project's two desired outcomes; 1: to challenge consumer behavior regarding product newness, and 2: to change actual customer behavior in practice by identifying willingness to pay for used B&O products.

The used products were disassembled, and the visual Aluminium surfaces were, refurbished, re-grinded, and anodized. New visual elements as a wooden frame and new finishes were added. The remanufacturing process was enabled by a high degree of modular design in the original product architecture, that also, in the 70ies had room for upgrades in form of a pre-amplifier, enabling upgraded connectivity to modern speakers.



Circular business logic
- High price with a promise of longevity
- High residual value of embedded components

Circular design logic
- Careful redesign updates based on the original design ideas about timelessness and upgradability
- Modular design, where components easily can be exchangeable and reused
- Components originally optimized for longevity

Potential for climate/environmental reductions
- Extended longevity has a significant potential to reduce GHG & E-waste
- Cascading usage of components saves energy & resources in the reman process

References:
Based on a personal interview with Bang & Olufsen in October 2021
https://www.bang-olufsen.com/en/us/speakers/beogram-4000c

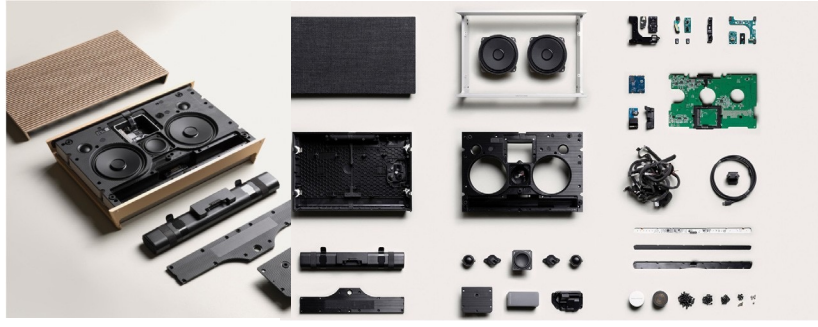
TRL 9. Actual system proven through successful mission operations.

Future proof design, Bang & Olufsen

The Beosound Level is a wireless, mobile speaker for streaming audio that was launched in 2021. The design team at B&O was inspired by their previous work with the Beogram 4000c and wanted to take further steps on their circular roadmap. The main design criteria for the Beosound Level was to create a modular future-proof product architecture, where some components are accessible for the users to exchange themselves, as the batteries and exterior panels that can change the visual appearance, while others are only available for repair shops. The main processor had been designed deliberately to run on 50% of its capacity to give room for future software upgrades that might require more capacity. The electronic components are specified for a life length of 10 years, and beyond. For most of the components, this will not be an issue.

However, the communication module has deliberately been designed to be upgraded if new communications standards for streaming will be introduced over the usage time. Software upgrades will be done through the smartphone app that controls the speaker. To further support B&Os aims for longevity, Beosound Level comes with a 5-year warranty and software features that enable the products to be upgraded through the BEO app and with possibilities to do remote health checks. Spare parts will be available in repair kits. The sound can also be adapted to optimize the sound quality, based on how the speaker is positioned, and if moved between different locations. Enabled by embedded sensors.

Compared to other similar consumer electronic products the Beosound Levels, the potential for additional functional life will probably be much longer, as many electronic products with built-in batteries are affected by battery depreciation, and new technological standards being implemented driving them to be obsolete. From an OEM perspective, the availability of critical electronic components over time is also crucial to keep products in use, and previously B&O has done "last–time" buys of critical components to put in stock. However, in the case with the Beosound Level, B&O teamed up with some new subcontractors in the automotive industry that were used to supporting OEMs with spare parts for decades. Moreover, the Beosound Level is the first Cradle to Cradle-certified consumer electronic product and is described as an in-depth learning process that gave the B&O development organization new knowledge regarding circular criteria and challenges in their existing value chain. In addition, it contributed to further developing the C2C certification process.



Circular business logic
- High price with a promise of longevity
- Embedded values in the produced product have a high residual value
- Prepared for new service offerings by a software roadmap
- Prepared for being offered as a service
- Long time agreement of suppliers of components and close collaboration with providers of operating systems (Apple & Google)

Circular design logic
- Components optimized for longevity
- Modular design and those with the highest risk of becoming prematurely obsolete are exchangeable
- Multiple connectivity standards, both wireless and by hardwire
- Health and health history can be remotely monitored
- Water protected according to (IP54)
- Use of recycled plastics, wood, and wool

Potential for climate/environmental reductions
- Extended longevity has a significant potential to reduce GHG & E-waste
- Cradle to cradle certification restrict usage of problematic substances and enable material recycling

References:
Based on a personal interview with Bang & Olufsen in October 2021 https://www.bang-olufsen.com/en/us/story/cradle-to-cradle-certification
https://www.c2ccertified.org/products/scorecard /beosound-level-bang-olufsen-as
https://www.architecturaldigest.com/story/a-bang- olufsen-speaker-designed-to-take-on-the-e-waste- dilemma-launches

Vehicle design for longevity, Riversimple

Riversimple is a startup company I the UK dedicated to change the environmental footprint for passenger cars and to disrupt the traditional business and design logic compared to incumbent automotive OEMs. Their first model (the RASA) is being is pilot tested (in 2021) with real customers and is a Fuel Cell electric vehicle (FCEV), built around a modular carbon composite skeleton with exchangeable exterior polymer panels. The planned for life length is 20years and beyond. Main reasons for choosing hydrogen technology is to reduce the environmental impact from batteries, and the RASA model use supercapacitors instead of traditional Lion batteries, reducing weight and need of charging times. Compared with a a Smart electric, the RASA only weight 654Kg, which is approx. 400kg less.

The design logic at Riversimple is described as being continuous where improvements to vehicles being produced will be made over time., e.g exterior body shapes.

Riversimple's business logic is built around keeping ownership of and selling their vehicles as a service where customers pay a monthly fee for personal mobility including fuel, and harvest revenues over a long usage time Using CFC was also a deliberate choice from an investment perspective as the traditional way to produce car bodies in pressed steel requires volumes of approx. 1million units over a production life cycle of 7 years to reach break even. While, according to Riversimple, producing in CFC only requires a volume of 10.000 units.

Hugo Spowes, CEO of Riversimple started the company in 2007 based on his research about disruptive innovations in history, in combination with Amory Lovin's research about the role of FC to mitigate climate emissions. The vision is to design the whole system instead of only focus on the vehicle itself. And Riversimple is building an innovation center to further drive circular initiatives .

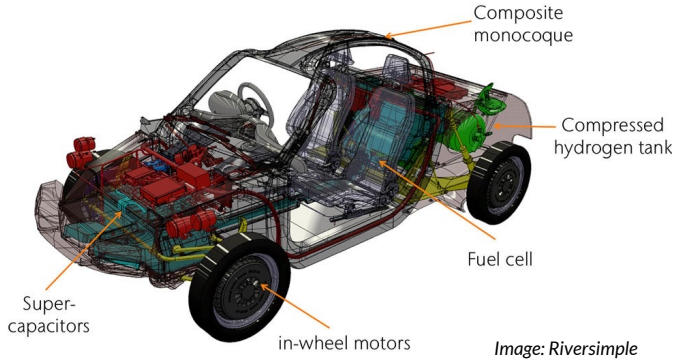


Image: Riversimple

"We are not interested in the end of the pipe solutions, we are interested in changing the system. *We see that the Business Model affects everything and we try to design the whole system instead of only some of the pieces. In the incumbent industry everyone only optimizes their bit."* *Hugo Spowes CEO of Riversimple*

Circular business logic
- Providing product as a service, custumers pay for worry free acess including fuel
- Hypothesis that customers primarly care about reliability & predictable costs than the year model of vehicles
- High value materials to be used for longer
- Prepared for new service offerings by a software updates
- Distributed production

Circular design logic
- Components optimized for longevity 20+ years
- Modular design with exchangable components

Potential for environmental reductions
- Extended longevity offers potential for reducing GHG
- Circular materials ?
- Lightweight
- FC technology and supercapacitors offers resource efficiency if renewable energy is used for Hydrogen production

References:
Based on a personal interview with Riversimple CEO in June 2020 https://www.riversimple.com/
https://www.theengineer.co.uk/riversimp le-to-launch-new-circular-economy- centre/