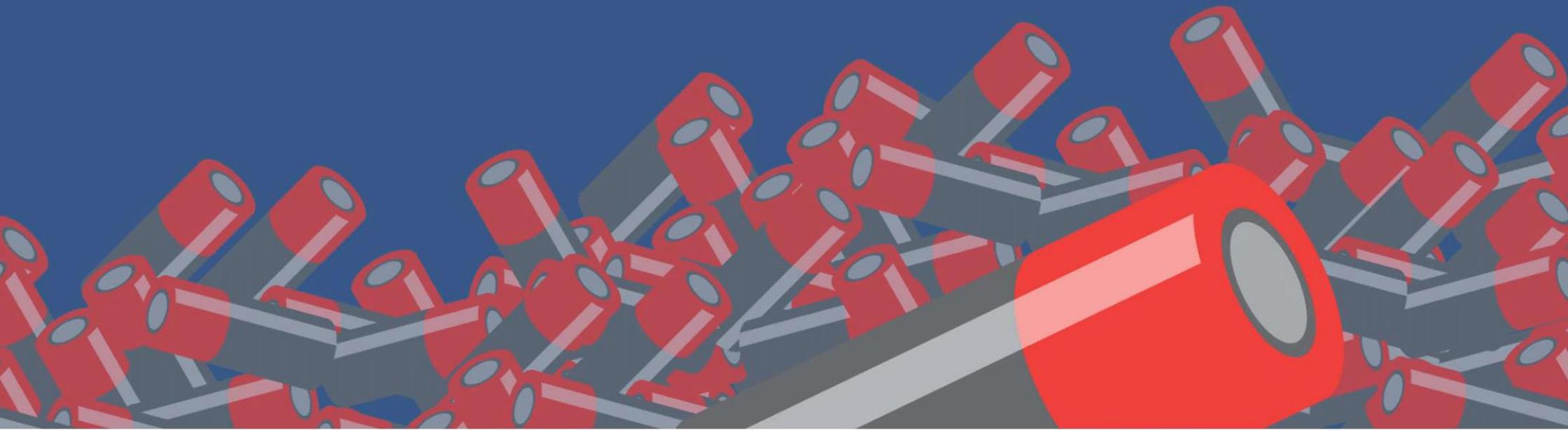




Nordic Council
of Ministers

Circularity of Batteries

Inspiration book for Consumers



Many businesses are currently exploring the countless possibilities of working with circularity of batteries and battery-driven products through new business models and improved ways of using the batteries more efficiently. Consumers can support this development via their purchases and at the same time achieve economic benefits for themselves and help protecting the environment.

In the following, we describe the principles behind circular design to better understand the following best practice recommendations.

Afterwards, we describe what you as consumer can do via your action at the purchase situation and during use of the purchased products.

How design can improve circularity and sustainability of products

Recycling is undoubtedly the strategy that receives the most attention, however, it is considered one of the least sustainable actions within the principles of circular economy – because recycling often diminishes the economic value and the energy that has been put into processing the products – and leaves just the materials. The quality of the output depends greatly on the recycling process and the amount of impurities; can components be recycled, are materials downgraded or do they keep their original quality.

To harvest more value and decrease the climate impact, we should aim for smaller

“loops”; like using fewer products by sharing the amenities we already have, e.g., sharing batteries between different products in your home or sharing the products with other people. A lot of energy goes into the production of a battery e.g., the greenhouse gas emissions of producing a battery to an electric car is about the same as the rest of the car itself. Therefore, it is important to utilise the battery as much as possible to get the lowest emission per used kWh.

Maintaining and prolonging the lifetime of batteries' keeps them out of any recycling activities in the first place. The lifespan of a product is only as long as the lifespan of the weakest component unless it is repaired. Thus, it is essential to buy products that are designed for maintenance and repair in mind, so that the broken parts can be repaired or replaced, and the product's overall lifetime can be prolonged.

Design for reuse and redistribution is a concept, where the battery can be used in a different system or by another user when you no longer need the services from the battery. This also enables products to be refurbished or remanufactured in their end-of-life and allowing them to reincarnate into a new product life.

In the following sections, we will explore some circular ways to buying, using, and disposing batteries and provide case examples of companies that have adopted circular initiatives.

The five sections cover:

- **Circular supplies** that describe circularity in the materials that go into the products.
- **Resource recovery** that describes actions that can ensure reuse and recycling of batteries.
- **Product life extension** that includes all the actions that can increase the lifespan of your battery products and components during the use phase.
- **Sharing platforms** that help to decrease the need for products by effectively sharing fewer amenities among more users.
- **Products as a service** where product ownership is never transferred to you thus supporting maintenance, product life extension, and resource recovery.

Before we go into details with the five sections, it is necessary to mention possible rebound effects, which can be a significant factor to be aware of when engaging with circular economy. Because many circular strategies increase profitability, decrease investment costs, and in general enhance convenience, they might even increase our resource dependency. For instance, the invention of LED lights that reduced energy consumption significantly also led to just more lighting being put up. Or many car sharing services promote that they reduce the total production of cars. But most consumers would not have been

driving a car before the introduction of the sharing platforms. And battery swapping technologies increases convenience of driving EVs and thus increases the adoption of EVs, however this system requires many extra batteries for the infrastructure to work.

A more general rebound effect may take place, when we reduce product costs through sharing, reusing, and recycling, what happens to the money we save? Many studies suggest that the money will be used elsewhere, increasing our consumerism and carbon footprint¹.

¹ <https://doi.org/10.1016/j.rcrx.2019.100028>

Circular supplies

If a product's scarce or non-renewable resource supply are replaced with circular alternatives, such as biobased, recycled, re-cyclable and biodegradable materials, we could improve the sustainability performance significantly. In the case of batteries this could include using recovered lithium, cobalt, or nickel in the production of new batteries or replacing synthetic glue with a biobased material.

Consumers can help the transition towards circular economy and close the loop for batteries. This will not only decrease the environmental burden of products, but also reduce the price over time and decouple the need for mining, which is hazardous for miners and often rely on child labour. Thus, the higher content of recycled materials in a battery, the less dependent is it on unsustainable sourcing and the lower climate impact.

To demand circular supplies and to push the development, consumers should look for labels and certificates on products². This includes the rate of recycled material in the product; the recyclability of the product and its packaging; worker ethics labelling; energy efficiency labels; and biobased and plastic free

production labels. An example is the industry label Eco Rating which evaluates the environmental impact of the entire process of production, transportation, use and disposal of mobile phones and provides a score from 1 to 100.

However, the number of labels can often be overwhelming, and lack of standardisation makes transparency challenging. So sometimes you might need to look up a certificate while in the store, to see what the labels entail. Figure 1 gives an overview of a few relevant labels to look for when buying battery equipped devices. In relation to the complexity of labels, consumers should demand standardised labelling systems for circular and sustainable performance of products.



Figure 1: Labels from top left; (1) Mobius Loop, (2) The Green Dot, (3) WEEE, (4) Nordic Swan, (5) IRMA, (6) SCS Recycled Content³

With few words the labels are described as the following:

1. **Mobius Loop** shows that a given product can be recycled at its end-of-life. However, this does not say anything about whether the product is made from recycled material.
2. **The Green Dot** is a European symbol, that shows that the producer of a given product has financially contributed to the collection and recycling of such products. It does not necessarily mean that their product is recyclable or made from recycled content.
3. **WEEE** is a European label that should remind consumers not to put the waste electronic in the general waste bin but go to recycling through the local recycling stations or dedicated bins.
4. **The Nordic Swan** looks at the entire life cycle of a product and indicates that this product is a better alternative over other products in terms of use of environmental performance and human health.
5. **IRMA** sets a set of rules and standards for sustainable leadership in mines, the focus is mostly on social sustainability, so it is not necessarily an indication of environmentally friendly mineral extraction.

² https://circulareconomy.europa.eu/platform/sites/default/files/carta_consumo_circolare_eng.pdf

³ <https://www.recyclenow.com/recycling-knowledge/packaging-symbols-explained>

6. **SCS Recycled Content** certifies that a company can claim a certain content of recycled material in their products.

Not only the sourcing of materials for production is important when discussing circular supplies of batteries. In the use phase of mobile devices and EVs, electricity consumption is an environmental hotspot. However, batteries are drivers of the green energy transition as they allow for more flexible consumption patterns of electricity.



Figure 2: Batteries can help driving the transition to green energy⁴

Using batteries, we can store energy when there is a green surplus and spend it when renewable sources are not producing enough electricity.

As more and more households invest in EVs, the energy consumption of those households is expected to heavily increase. Also, the need for

batteries is expected to grow greatly. The EV battery will often be fully charged at home at night, while smaller recharges during drives might be necessary. Aligning the recharging with availability of green and cheap energy is possible through a variety of different models.

Managed charging is where consumers subscribe to charging infrastructure, but agrees to delay the charging up to e.g., one hour⁵, which enables the energy provider to align with the grids needs and thus increase the share of green energy. Discount programmes allows for differentiated charging based on the availability of green energy. This can be controlled through internet connected apps, where your phone will receive information on current energy prices and green share while controlling the charging of your EV. Another option to purchase a stationary battery that recharges when energy is green and cheap. The battery then releases the energy to the EV whenever the customer needs it⁶.

⁴ <https://orsted.com/en/media/newsroom/news/2019/12/945369984118407>

⁵ <https://www.wri.org/insights/4-emerging-ways-pair-electric-vehicles-and-renewable-energy>

⁶ https://www.tesla.com/da_dk/powerwall

Resource recovery

Resource recovery promotes the recycling and reuse of end-of-life products through up- and recycling processes, so that the products, components, or materials can enter new product cycles. In contrast to recycling, this concept deals with innovative systems or technologies to enable the circulation and require some product redesign to improve resource recovery through design principles like modularisation and material homogeneity.

A chain is only as strong as its weakest link, and for resources to effectively circulate, consumers are one of the links that connect the whole value chain and have a great responsibility to help reducing the environmental footprint and improve social challenges in mining regions.

To ensure the recycling and circular supplies for battery production, consumers must participate in waste sorting. These are slightly different between the Nordic countries, but generally batteries should be separated from the device, taped at the poles and source separated individually. In some cases, the battery can be disposed within the electronic waste, if the battery cannot easily be removed.



Figure 3: Most consumers have old LiBs stowed away⁷

Even though lifetime extension is the most preferred circular action, batteries are still expected to degrade over time. Thus, recycling is inevitable at some point but to allow this, sorting and recycling efficiencies must be improved. According to the US Department of Energy, around 95% of LiBs on the American market, will never be recycled⁸. This is due to lack of motivation and action of consumers and policymakers, and lack of manufacturing companies designing their products for recycling.

Sorting your batteries for recycling is crucial and you should ask yourself, how many batteries you have hidden away in your drawers. Most people have around 10 LiBs tucked away, that accumulate instead of reincarnating into new products⁹. So it might be of good intention that you store your used batteries in a jar – just remember to send them to recycle frequently.

If possible, for large batteries and electronics, prioritise to deliver the product and battery back to the producer if they offer the service instead of the municipal WEEE scheme, as the manufacturer knows exactly how to dismantle their old products. Furthermore, some manufacturers even promote the recovery of their products and their valuable materials by providing a purchasing credit for consumers that hand in old products when buying a new one. Apple is doing this on many of their devices such as iPhones and MacBooks, where functioning products and components are refurbished and re-sold, while older or broken models are disassembled using automated robots for precious metal recycling¹⁰. There are many different recovery programmes like the one provided by Apple.

⁷ <https://www.mirror.co.uk/news/uk-news/unused-old-gadgets-you-sitting-13741767>

⁸ <https://everledger.io/closing-the-loop-on-portable-lithium-ion-battery-recycling/>

⁹ <https://everledger.io/closing-the-loop-on-portable-lithium-ion-battery-recycling/>

¹⁰ <https://www.apple.com/shop/trade-in>

Product Life Extension

Product life extension is a business model where companies or users seek to prolong the lifetime of products through maintaining, repairing, upgrading, and remanufacturing, thus, keeping the products or components intact for as long as possible, rather than recycling them down into their material fractions. This approach is not only environmentally viable, but from a business model perspective, the companies that master product life extension can also generate additional revenue due to extended usage of the product and consumers can save money because they only pay for the service that the product provides¹¹. The concept is often found in combination with the use of sensors and data to improve life through predictive maintenance or software upgrades. Battery management systems (BMS) is widely used to extend the lifetime of batteries through digital control of the batteries.

Recycling of batteries is much in focus, but how can you make sure batteries never

become waste in the first place? Luckily, there are many ways of extending the lifetime of your devices and batteries to save money and the environment. Some of the recommendations that will be elaborated in the following section include:

- Buy long-lasting, robust products
- Maintain and repair your products – also digitally
- Look for modularity, upgradability and repairability in new products
- Buy refurbished products and resell them when you do not need them
- Give your devices a second life in a new use case

Modularity and Upgradability

Design for simple exchange of components is promoted by multiple companies already. For many mobile devices, batteries are the weakest component with the shortest lifetime due to their reduced capacity over time. In some smartphones the battery can be easily swapped without any tools when it has been worn out, as old mobile phones used to before the development of smartphones. A few

manufacturers, e.g., FairPhone¹² have implemented this ability, which enable users to easily extend the lifetime of their phones without having to pay repair shops to do the work and risk of losing the phone's warranty. See Figure 4.



Figure 4: FairPhone's website gives you guides for self-repair of most common issues¹³

¹¹ https://www.accenture.com/t20150523T053139__w__/us-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Strategy_6/Accenture-Circular-Advantage-Innovative-Business-Models-Technologies-Value-Growth.pdf, accessed 16/03/2021

¹² <https://www.ifixit.com/Guide/Fairphone+3+Battery+Replacement/125674>

¹³ <https://support.fairphone.com/hc/en-us/articles/115001041206-Fix-an-issue-yourself>

Maintain

Lifetime of batteries can be prolonged by avoiding operating in extreme temperatures (0 to 35°C) and only be stored with in cool environments, around 10-15°C. For long time storing of battery-driven devices, the battery should be half-charged and powered off. Many battery management systems, a part of the device's software for mobile devices, such as laptops, tablets, and smartphones, switch the devices off automatically if the device is overheated. It is recommended to not place your devices directly in the sun and turn them off if temperatures go above or below the recommended temperature threshold.

Another approach for consumers to prolong the lifetime of batteries can be done digitally through software interventions. In iPhones, users can see the battery health in the phone's settings and turn on optimised battery charging, as shown in the screenshot on Figure 5. This ensures that the battery is only charged to 80% at night and gives the final 20% power boost just before you wake up. This is useful, because batteries deteriorate when they are fully charged, so it should be avoided to stay too long in this phase. This feature does not exist for Android smartphones, and third-party apps cannot control and stop the charging. However, there are apps that notify Android

users to manually unplug the charging cable at e.g., 80%.

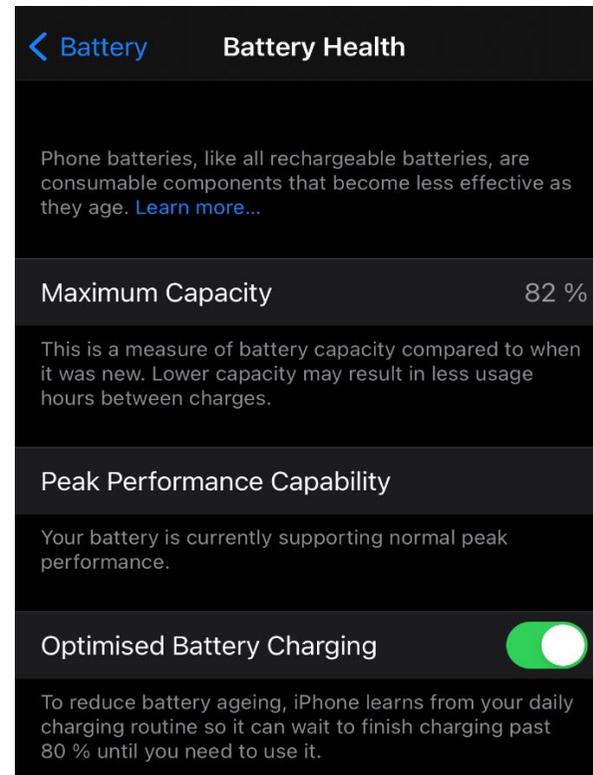


Figure 5: A screenshot from the battery health section in an iPhone

These digital solutions can be used to extend the lifetime of batteries and can be worth for users to explore both when purchasing their products but also as downloadable addons after purchase. Products come with built in Battery Management Software, which primary purpose is to protect the cells from operating

outside its safe operating conditions¹⁴. But some BMS' does also have properties that can affect the lifetime of the battery, by monitoring the condition of the battery and limiting the charging pressure. For example, Lenovo offers a digital solution¹⁵, where the charging is set to stop at 80%, as wear on lithium-ion batteries is highest when the battery is charged and used above 80% or below 5%. By only charging the battery to 80%, the battery is spared from unnecessary wear. Of course, when the users need full battery capacity, e.g., while travelling, they can still take advantage of all 100%, but it needs to be actively turned on. A similar tool is built in MacBooks, and like the iPhone technology, it analyses your daily routines and optimises charging for that.

On your Windows computer you can get a printed battery performance report by opening Windows PowerShell, and type `powercfg /batteryreport /output "C:\battery-report.html"` into the window and press Enter to run the command. Your computer has now generated a report and placed it on the C: drive. It gives you info like the current capacity, health of the battery and cycles count.

¹⁴ <https://news.inventuspower.com/blog/what-is-a-battery-management-system-bms> , accessed 16/03/201

¹⁵ <https://support.lenovo.com/us/en/solutions/hto69687-easy-ways-to-extend-your-battery-life-ideapadlenovothinkpad-laptops>

Some computers have also in the battery management software a possibility to see the battery health, see Figure 6.

For your EV it is recommended to mostly use the AC charging instead of the super chargers. Furthermore, it is recommended to use the battery between 20-90%, and only fully charging it when you need that extra distance¹⁶.

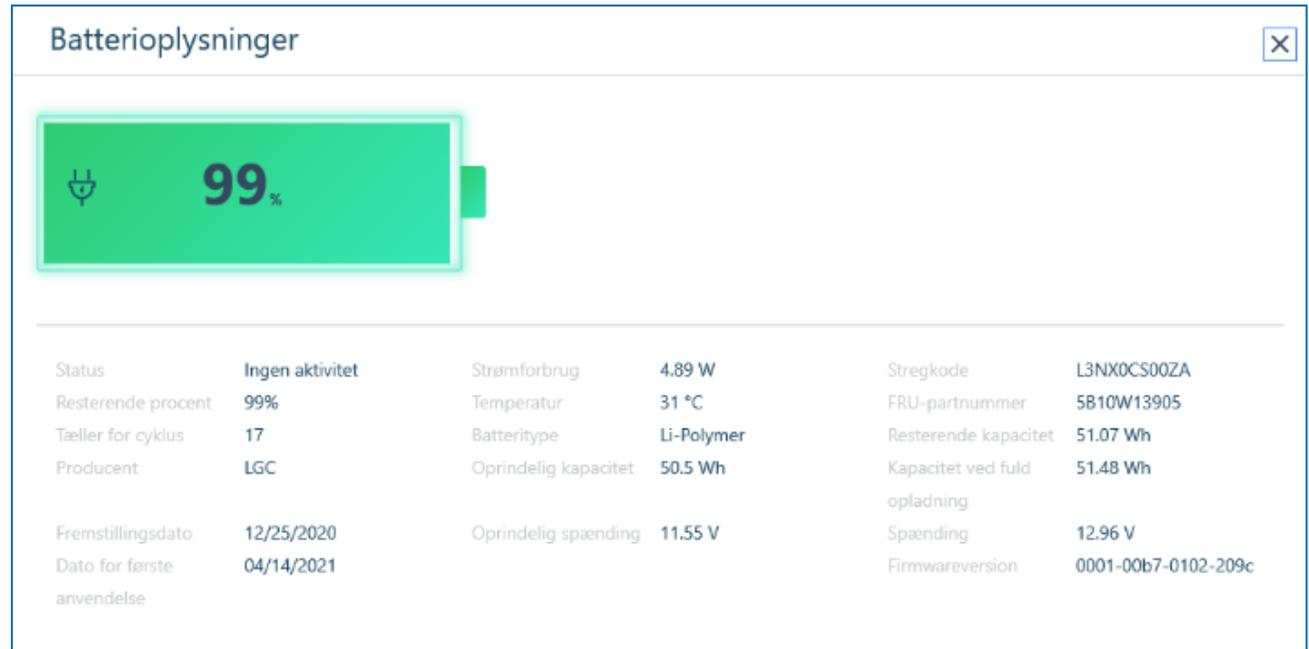


Figure 6: A screenshot from Lenovo's battery health info

¹⁶ <https://www.volvocars.com/dk/v/cars/recharge/charging>

Sharing platforms

A sharing platform is an efficient circular business model, where products are shared between multiple users. The model requires a platform to control, manage and rent out all the products to maximise operation time and utilisation of the products, thus minimizing the needed number of products. However, many examples of today's sharing systems are run by companies that share third party products, which are not specifically designed for sharing. To harvest the full potential of such business model and increase the lifespan of the overused product, they must be optimised for sharing, like improved robustness, increased traceability and monitoring through sensors and data logging.

Value benefits for end users include improved geographical access at cheaper prices for short term uses e.g., renting an e-scooter rather than buying one, and having 24-hour access to the service from every corner in the city. Some sharing platforms have evolved to include "sharing of sharing platforms", such as carpooling in Uber and Lyft, where not only idle time of cars are improved but also maximization of seat capacity in the vehicles.

Another way of reducing the climate impact of our devices is by sharing products between

multiple users so that fewer products are needed to satisfy the same amount of people. This removes the upfront purchasing cost and limits the total production of batteries. An additional advantage is the effective use justifies always having the battery fully charged.

This concept is especially great for amenities that you only use occasionally, such as drilling machines, hedge trimmers or lawn mowers. For city residents cars and e-scooters can be accessed the same way in case you do not want to own one full time.

Husqvarna's digital tool shed, allows customers to rent professional equipment, through an app. The shed is placed at different locations that are accessible 24/7. Similarly, in Copenhagen a concept called NaboSkab allows neighbours to share things like power tools in smart lockers. The concept has been evaluated by the Danish EPA as a solution to reduce resource consumption¹⁷, and is intended for local communities such as an apartment block.

There are a variety of mobility sharing platforms such as Donkey Republic, Lime, ShareNow, Green Mobility, and KINTO. One thing to be aware of when using sharing platforms, is to consider potential rebound effects. Often sharing platforms will brand themselves as sustainable because they reduce



Figure 7: Naboskab, a locker to share amenities between neighbours¹⁸

resource consumption. However, sometimes they create a need that was not there before. Such as the availability of e-scooters that is currently competing with normal bikes, that most Scandinavians own anyway. Also, consider if the environmental cost of the sharing platforms' infrastructure is more impacting than the alternative, i.e., what about the energy and resource consumption for the digital sheds?

¹⁷ <https://naboskab.dk/mst/>

¹⁸ <https://naboskab.dk/category/produkter/>

Product as a Service

Product as a service is a model that seeks to improve the efficiency and shift the motivation for resource efficiency by delivering the value as a service rather than selling the asset to the customer. The model requires a deep understanding of the customers' needs and shifting to a contract-based service delivery.

An example outside the battery topic but still a relevant illustrative example is "pay-per-lux" from Philips that sell access to lighting in office buildings, but

they do not sell the actual bulbs. The customer agrees to buy "lighting within work hours in a 3000 m2 office building" and pay a specified price for that service. Philips installs their LED bulbs and take over the energy bill for lighting. Philips now have an economic incentive to improve energy efficiency as much as possible, maintaining the bulbs, and if the customer ends the contract for any reason, Philips can re-install their bulbs in other customers' office buildings.

The business models can vary in the product-to-service ratio, meaning that one business model can be either full service with little or no

product ownership, like in the pay-per-lux example, or involve mainly product ownership with a small service add-on including guarantee, support agreements, upgrade agreements or monitoring software.

For many products, leasing is a convenient, economic, and environmentally better performing option. The ownership and responsibility for repair is placed at the manufacturer or reseller and you, as a consumer, does not need to worry about unexpected bills or big upfront costs. Because the responsibility is placed at the manufacturer, you will often find that parts are better quality, the product is easier maintained thus fewer breakdowns compared to if you own a product.

When leasing a product, you support many circular strategies such as improved reuse, refurbishing and recycling of products and product life extension, thus reduced resource consumption. Acquisition costs of battery driven products are sometimes up to double as high compared to petrol or cabled options. As leasing diminishes the up-front costs, you can often get access to electric and mobile options without having to find a lot of money to begin with.

There are many examples of products as a service in the battery driven industry. In Denmark, Volt is leasing out mobile batteries, mainly for festival guests, where you continuously can swap a drained battery for another one that functions. In this way, you can easily recharge your devices on the go¹⁹. See Figure 8.

However, it is important to note that product as a service is not necessarily a more sustainable option, as they sometimes require more resources to function or might even increase our resource demand as customers now have easier access to new products without the upfront investment.



Figure 8: Volt Batteries on a Danish festival²⁰

¹⁹ <https://www.getvolt.dk/>

²⁰ <https://www.roskilde-festival.dk/da/years/2020/news/volt/>

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Nordic co-operation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland, and Åland.

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