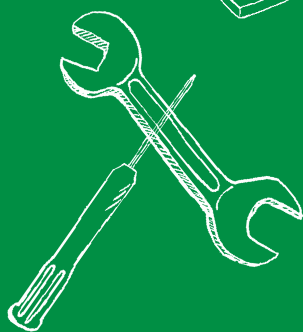
# The Life Cycle of Electronic Devices



ENVIRONMENTAL IMPACT AND THE EFFECT OF REPAIR

Funded by UiO Energy & Environment

UNIVERSITETET I OSLO

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**By moving from a linear to a circular strategy for mobile phones and laptops, the University of Oslo has the potential to reduce annual emissions (110 tonnes $CO_2$ equivalents) and significantly reduce energy demand and use of scarce minerals.**

## About this report

**Circular Energy for a Sustainable Circular Economy was a thematic research group based at the University of Oslo (UiO) and funded by UiO Energy & Environment. The main motivation for this project was the idea that repairing electronic devices was more sustainable than recycling and buying new ones. We were especially interested in the effect of repair as a measure to counter environmental impacts.**

This report will present the results of the life cycle assessments (LCAs) we implemented for two of the most common electronic devices: the laptop[1] and the mobile phone. We assessed the environmental impacts in all phases of the life cycle of these two devices: resource extraction, manufacturing, transportation, use, and end-of-life. The calculations were done in the LCA software SimaPro and ecoinvent was used as background database.

The scope of the study was the use of digital devices in Norway. This means that data for impacts from the use of electricity for charging the laptop and mobile phone was based on the Norwegian electricity mix. We also used the most common recycling procedure in Norway, which is also used by UiO.

In the life cycle assessments presented in this report, we focused on three impacts: impact on climate change, cumulative energy demand, and mineral resource scarcity.

- **Impact on Climate Change:** One of the most significant environmental challenges of our time is climate change. Emissions of greenhouse gases to the atmosphere cause elevated temperatures and extreme weather events. These emissions can stem from various activities in the life cycle, such as mining activities, production, energy, and transport. Potential impacts on climate change are expressed in kg $CO_2$ equivalents.

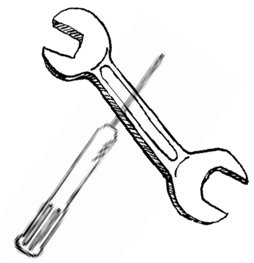
- **Cumulative Energy Demand (CED):** The Norwegian Climate Change Committee has suggested that decisions concerning the transition to a low-emission society must be based on the fact that all resources are scarce.[2] This includes energy resources. CED is an indicator for resource use which includes direct and indirect energy used throughout the life cycle of products. This means that all energy used to produce, use, treat or dispose of the electronic devices are included. It also means that the indicator not only includes the direct energy use in the products use phase, but also includes energy necessary to generate and distribute electricity. Cumulative energy demand is expressed in Megajoule (MJ). One MJ is 1 000 000 joules, and 3.6 MJ is the equivalent of 1 kilowatt/hour.

- **Mineral Resource Scarcity:** The electrification and digitalisation of society increases the demands for components and infrastructure consisting of materials with certain properties. These materials are often scarce, meaning that we have limited amounts present on earth. Increasing demand for these materials have social, environmental, and geopolitical consequences and their scarcity is perceived as a global risk to people and planet.[3] The potential impacts are quantified as kg copper (Cu) equivalents.

The impacts were calculated per year of use of the mobile phone and the laptop. We compared a linear 'no repair' strategy with the most relevant repair scenarios. By linear strategy we mean a strategy where an institution simply buys the digital products they need and discards them when they are no longer in use. We defined a circular strategy as a strategy where an institution introduces measures to repair and extend the lifespan of digital products wherever possible.

In addition, we calculated the different impacts per year for 100 and 1 000 mobile phones and laptops. This will enable institutions and companies in Norway to calculate the environmental benefits when implementing a circular, repair-based strategy versus a linear, no-repair strategy.

We end this report with a brief case study based on the UiO, an institution with 7 000 employees, as well as with data on the reduction in the impact on climate change if all Norwegians would use their mobile phone and laptop one year or three years longer.

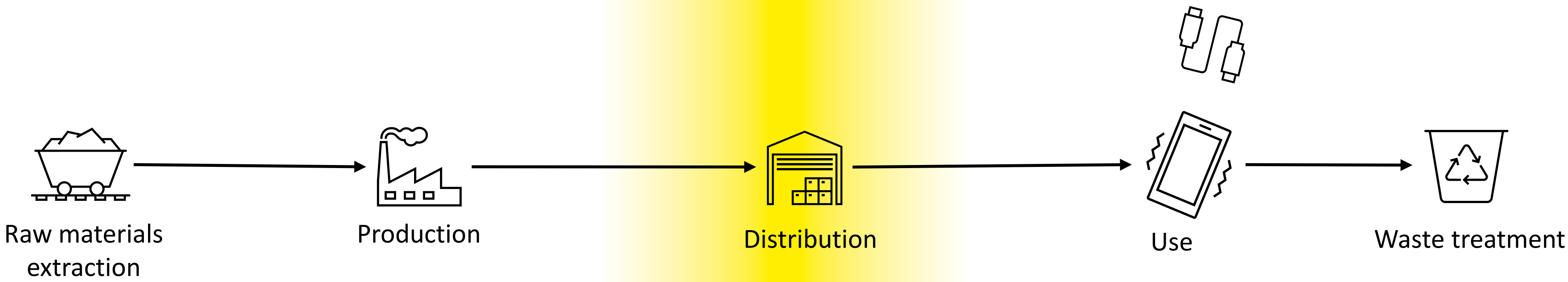


# The lifecycle of digital devices

**All electronic products we use have a similar life cycle. It starts with the extraction of raw materials, followed by production processes, assembly, transport, the use phase, and waste treatment in the end-of-life phase.**

The electronic devices we use in Norway, such as smartphones, tablets, servers, and laptops consist of more than 300 parts and have global supply chains. The raw materials are extracted in Africa, Asia, and South America. Most components are produced in East-Asia and the assembly of these products is typically done in China. The life cycle phases that take place in Norway are the use phase and end-of-life phase.

Academic research and reports by non-governmental organisations show that a wide variety of social and environmental impacts are found in the life cycle of electronics → FIGURE 1. The lifespan of digital devices is based on how they are designed (robustness, repairability), if and for how long they are maintained (software upgrades, spare parts), and how they are used. In Norway, digital devices such as smartphones and televisions are often replaced with a new one before they break down.



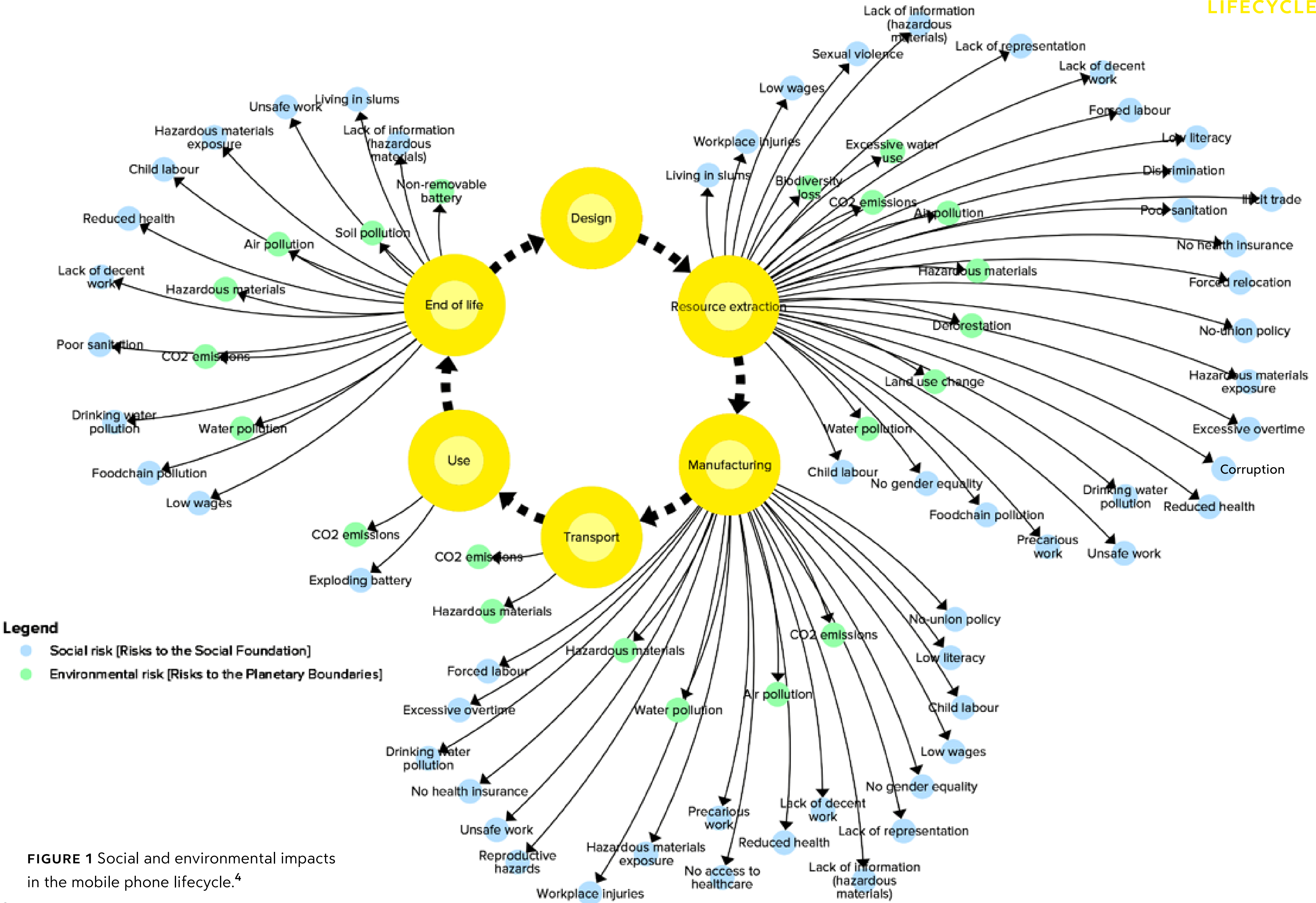



**FIGURE 1** Social and environmental impacts in the mobile phone lifecycle.[4]

## Norwegians are the second largest consumers of electronic devices in the world

Norway is the second largest consumer of electronic devices per capita in the world (in units) after the US. Norwegians purchased electronics for 42.3 million NOK in 2020.[5] The number of mobile phones sold in Norway in 2022 was 1 356 million.[6] In addition, Norwegians bought more than 1.1 million smart watches and smart bracelets in 2022 The average lifespan of a mobile phone in Norway is currently 3.2 years.[7]

## Norwegians are the largest electronic waste generators in the world

Norway generates the highest amount of e-waste per capita in the world.[8] In 2022, Norwegians generated 28 kg of electronic waste per person per year **FIGURE 2**. This was 154 000 tons in total **FIGURE 3**. About 74% of the collected e-waste is recycled and materials recovered for re-use.[9]

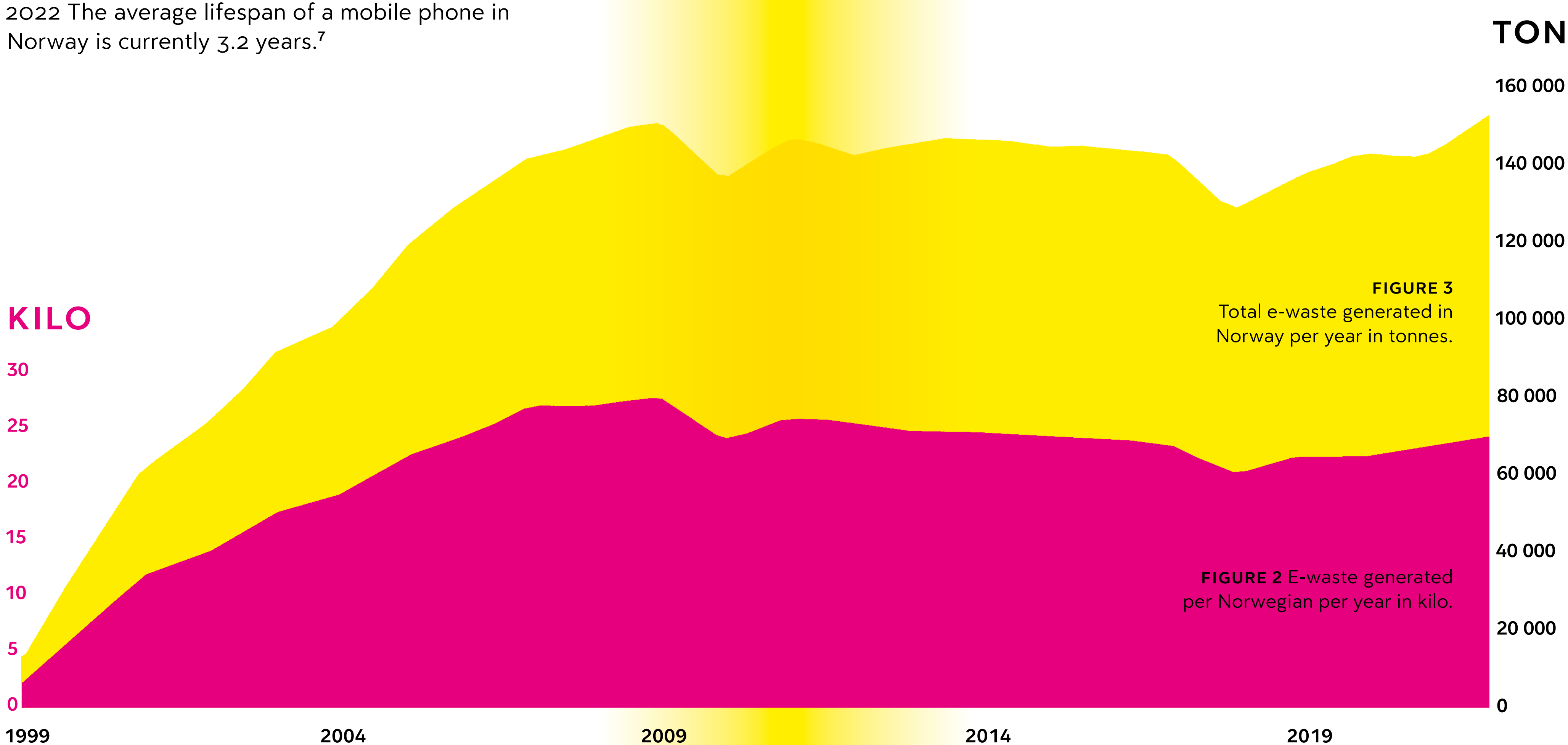



**FIGURE 3** Total e-waste generated in Norway per year in tonnes.

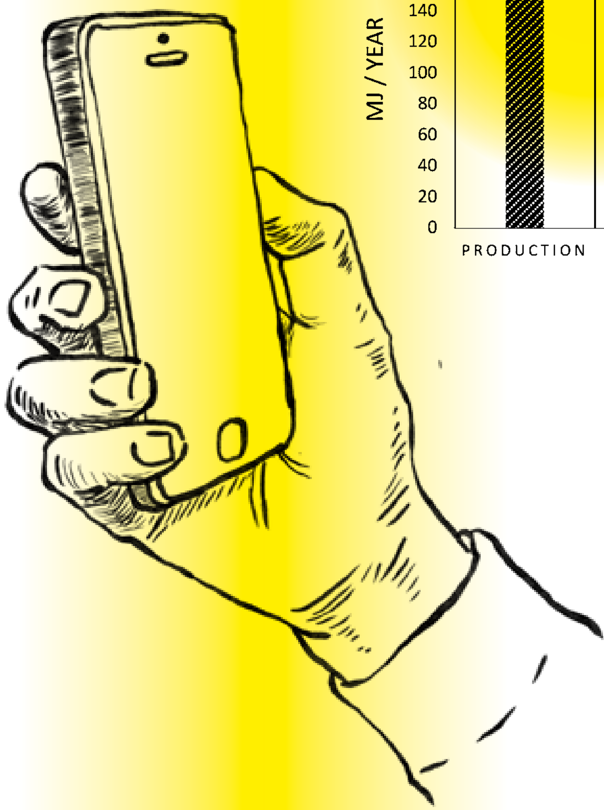
**FIGURE 2** E-waste generated per Norwegian per year in kilo.

# Environmental impact – per device per year

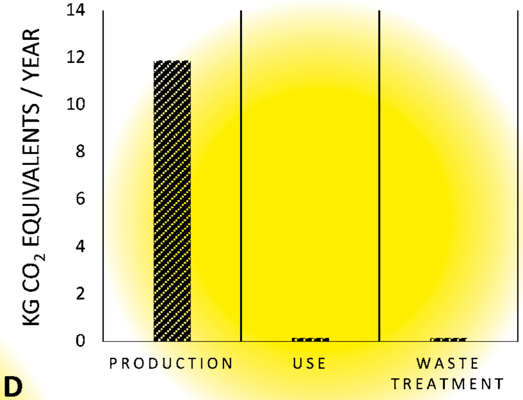
## Mobile phone

The environmental impacts from a mobile phone used in Norway are shown in **FIGURE 4**. The results are divided between the life cycle stages production, use and waste treatment. The potential impact on climate change is approximately 12 kg $CO_2$ equivalents per year, while the cumulative energy demand is 196 MJ. The potential contribution to mineral resource scarcity is 0.1 kg Cu equivalents/year.

The assessment shows that most impacts are found in the production phase of the components in the mobile phone. The component type with the largest impacts are the motherboards and circuit boards.



CLIMATE CHANGE




CUMULATIVE ENERGY DEMAND

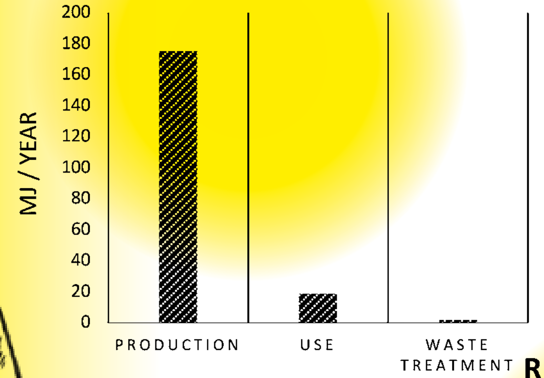
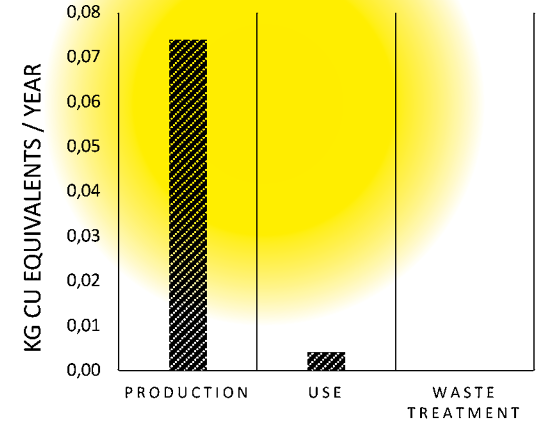


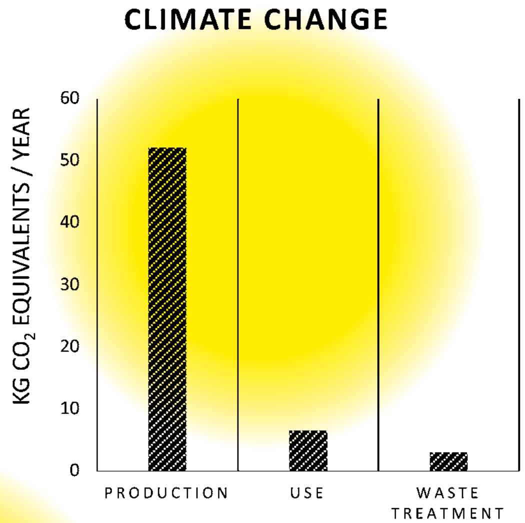

**FIGURE 4**
Environmental impacts in the life cycle of a mobile phone per year of use in Norway

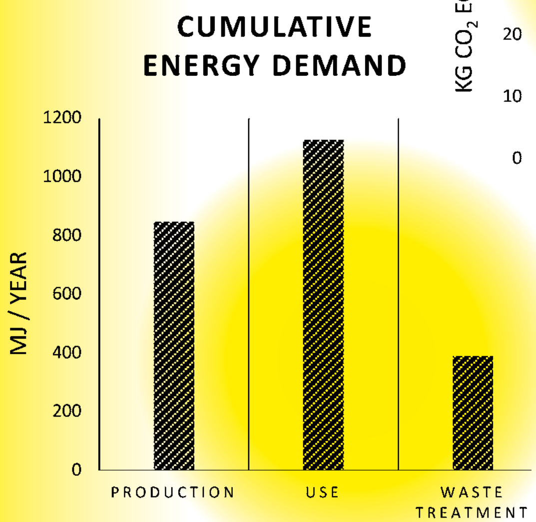
MINERAL RESOURCE SCARCITY



## Laptop

A laptop with a life span of three years results in a potential impact on climate change of approximately 62 kg $CO_2$ equivalents per year. The largest contributions are from the production of the components in the laptop, specifically the motherboard. The cumulative energy demand of the laptop is estimated to be 2 364 MJ/year or 657 kWh. This is mainly due to the electricity consumption in the use phase. The potential contribution to mineral resource scarcity is 1.25 kg Cu equivalents/year, where the largest impact is from gold in the circuit boards **FIGURE 5**.



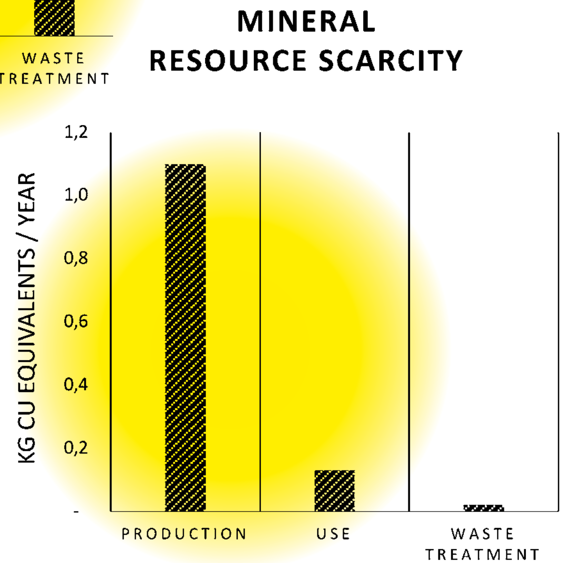
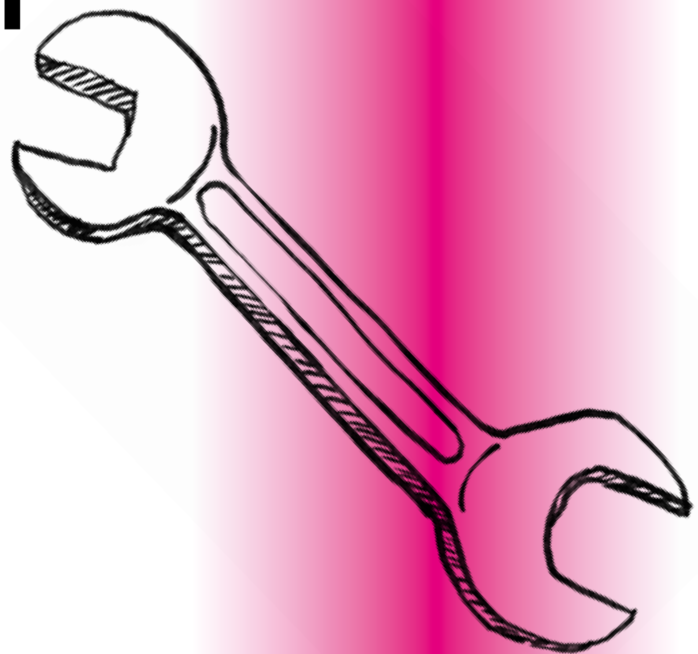




**FIGURE 5** Environmental impacts in the life cycle of a laptop per year of use

# The effect of lifespan extension through repair



**As the production of the components in the digital devices represent a significant share of the overall impacts, repair is an important strategy to extend the use phase and reduce the need for extracting new materials and producing more components. The potential reductions in environmental impacts from repair will be dependent on how long the use phase of the product can be extended and what kind of activities or new components are required to obtain the desired functionality.**

## Mobile phone

The most common causes of defects for mobile phones are broken display (37%) or weak or broken battery (34%).[10] In the figures below, three different scenarios are compared: a no repair scenario where the phone is sent to recycling after 3.2 years (the current average lifespan of a mobile phone in Norway) and two repair scenarios: One where the screen is replaced after 3.2 years, and one where the battery is replaced after 3.2 years. The repair is assumed to increase the life span of another 3.2 years. The results are shown per year of use.

### IMPACT ON CLIMATE CHANGE

- Repair by replacement of the screen improves the climate impacts by 5 kg CO2 equivalents/year of use, a reduction from 12 to 7 kg CO2 equivalents/year of use.
- Repair by replacement of the battery improves the climate impact with 6 kg CO2 equivalents/year of use, a reduction from 12 to 6 kg CO2 equivalents/year of use.

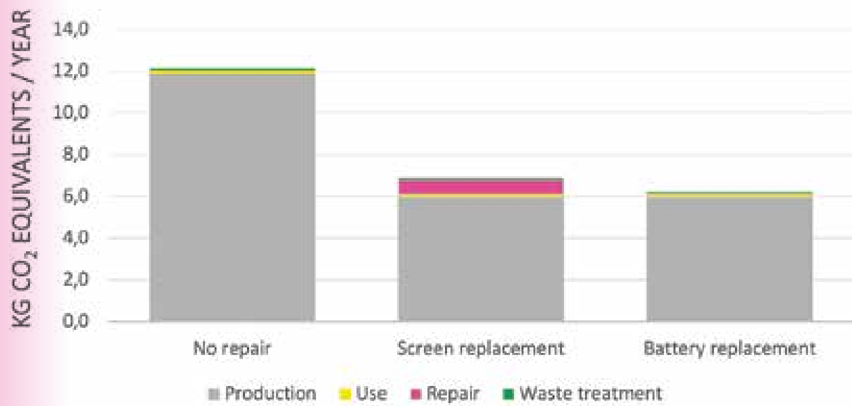



**FIGURE 6** Potential impact on climate change from use of one phone during one year for three different repair scenarios

### IMPACT ON CUMULATIVE ENERGY DEMAND

- Repair by replacement of the *screen* improves the CED by 78 MJ/year of use, a reduction from 196 to 118 MJ/year of use.
- Repair by replacement of the *battery* improves the CED by 87 MJ/year of use, a reduction from 196 to 109 MJ/year of use.

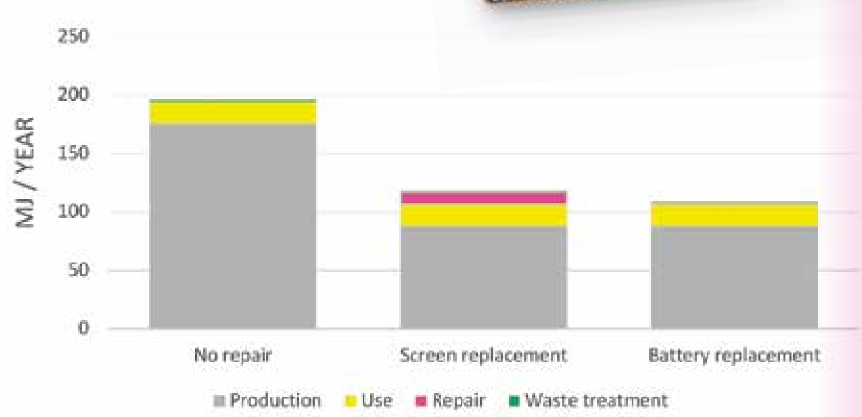



**FIGURE 8** Potential impact on cumulative energy demand from use of mobile phone during one year for three different repair scenarios

### IMPACT ON MINERAL RESOURCE SCARCITY

- Repair by replacement of the *screen* improves the mineral resource scarcity impact by 0.04 kg Cu/year of use, a reduction from 0.08 to 0.04 kg Cu/year of use.
- Repair by replacement of the *battery* improves the mineral resource scarcity impact with 0.03 kg Cu/year of use, a reduction from 0.08 to 0.05 kg Cu/year of use.

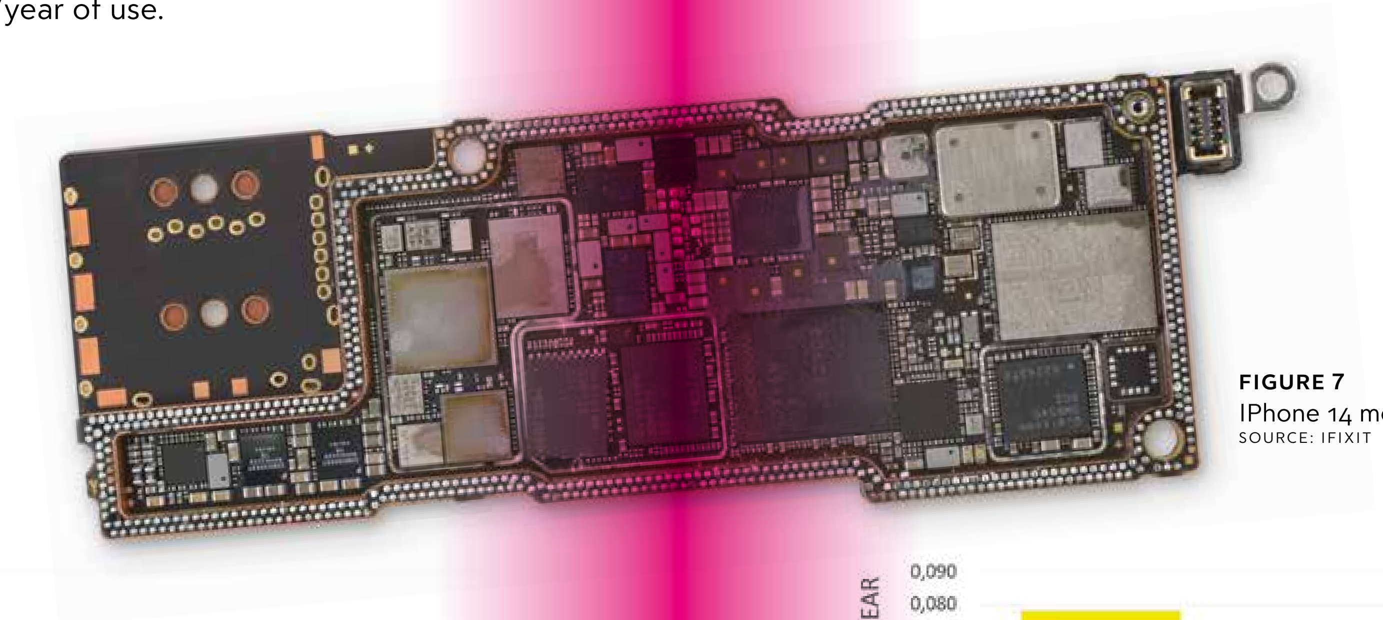


**FIGURE 7**
IPhone 14 mother board
SOURCE: IFIXIT

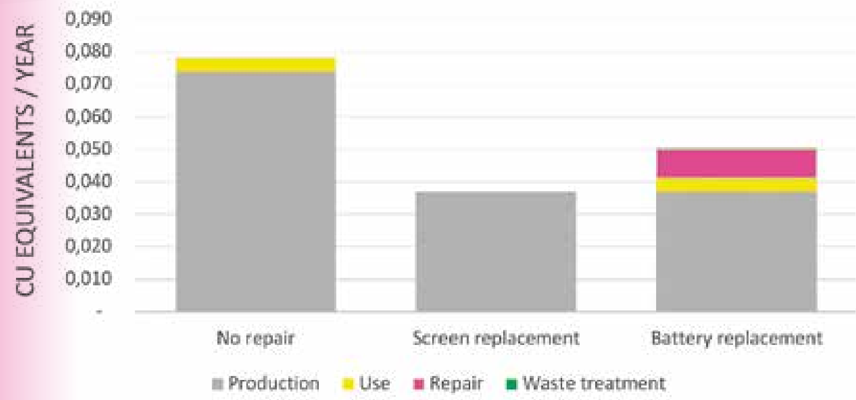



**FIGURE 9** Potential impact on mineral resource scarcity from use of mobile phone during one year for three different repair scenarios

## Laptop

Common causes of defects for laptops are overheating, noise, a liquid spill on the keyboard, weak or broken battery, broken motherboard, and broken hard disk drive. We have looked at three repair scenarios that include the replacement of a broken component by a new component: battery, motherboard, and hard disk drive. We assumed repair will extend the lifespan with another 3 years, which reduces the impact per year of use of the laptop as follows.

**FIGURE 10**
Laptop hard drive
SOURCE: WIKIPEDIA



### IMPACT ON CLIMATE CHANGE

- If a broken *battery* is replaced to extend the laptop's lifespan, the potential impact on climate change is improved with 28 CO2 equivalents/year of use, a reduction from 62 to 34 kg CO2 equivalents/year of use.
- Repair by replacement of the *motherboard* improves the climate impact with 18 kg CO2 equivalents/year of use, a reduction from 62 to 44 kg CO2 equivalents/year of use.
- Replacement of the *hard disk* improves the climate impact with 26 kg CO2 equivalents/year of use, a reduction from 62 to 36 kg CO2 equivalents/year of use.

This means that repair of the laptop can reduce potential impacts on climate change with between 28% and 44% per year, dependent on which component breaks down and needs to be repaired to extend the laptop's lifespan.

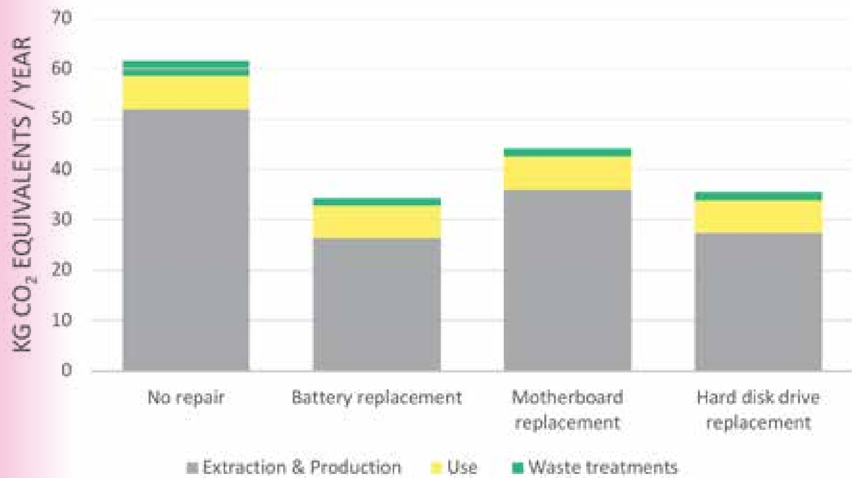



**FIGURE 11** Repair scenarios of a laptop – reductions in climate change impact

## IMPACT ON CUMULATIVE ENERGY DEMAND

- If a broken *battery* is replaced to extend the laptop's lifespan, the potential impact on cumulative energy demand (CED) will improve with 599 kg MJ/year of use, a reduction from 2 337 to 1738 kg MJ/year of use.
- Repair by replacement of the *motherboard* improves the impact on CED with 440 MJ/year of use, a reduction from 2 337 to 1 897 MJ/year of use.
- Replacement of the *hard disk* improves the impact on CED with 568 MJ/year of use, a reduction from 2 337 to 1 769 MJ/year of use.

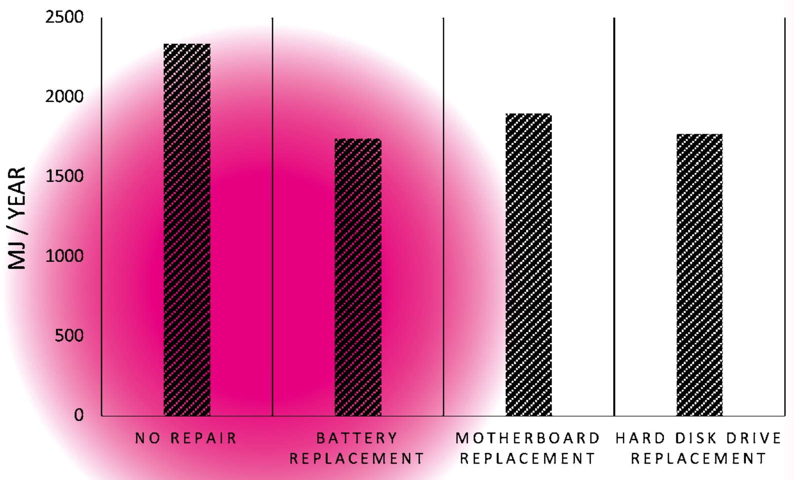



**FIGURE 12** Repair scenarios of a laptop - reductions in cumulative energy demand

## IMPACT ON MATERIAL RESOURCE SCARCITY

- If a broken *battery* is replaced to extend the laptop's lifespan, the potential impact on material resource scarcity improves with 0.5 kg Cu equivalents/year of use, a reduction from 1.1 to 0.6 kg Cu equivalents/year of use.
- Repair by replacement of the *motherboard* improves the impact on CED with 0.2 kg CU equivalents/year of use, a reduction from 1.1 to 0.9 kg Cu equivalents/year of use.
- Replacement of the *hard disk* improves the mineral resource scarcity with 0.5 kg Cu equivalents/year of use, a reduction from 1.1 to 0.6 kg Cu equivalents/year of use.

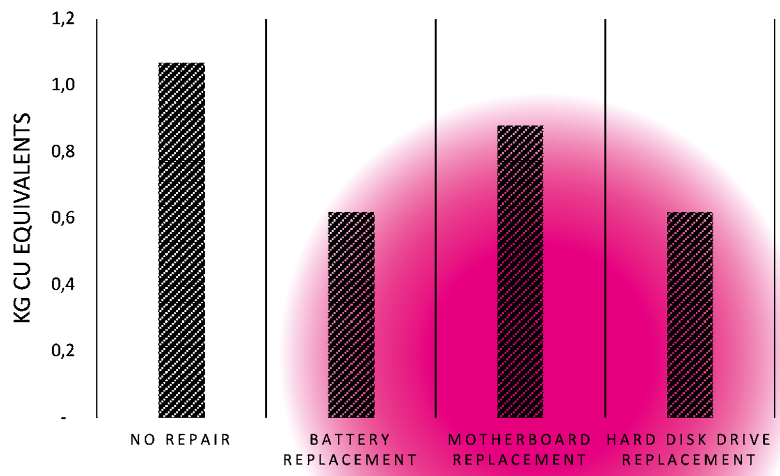
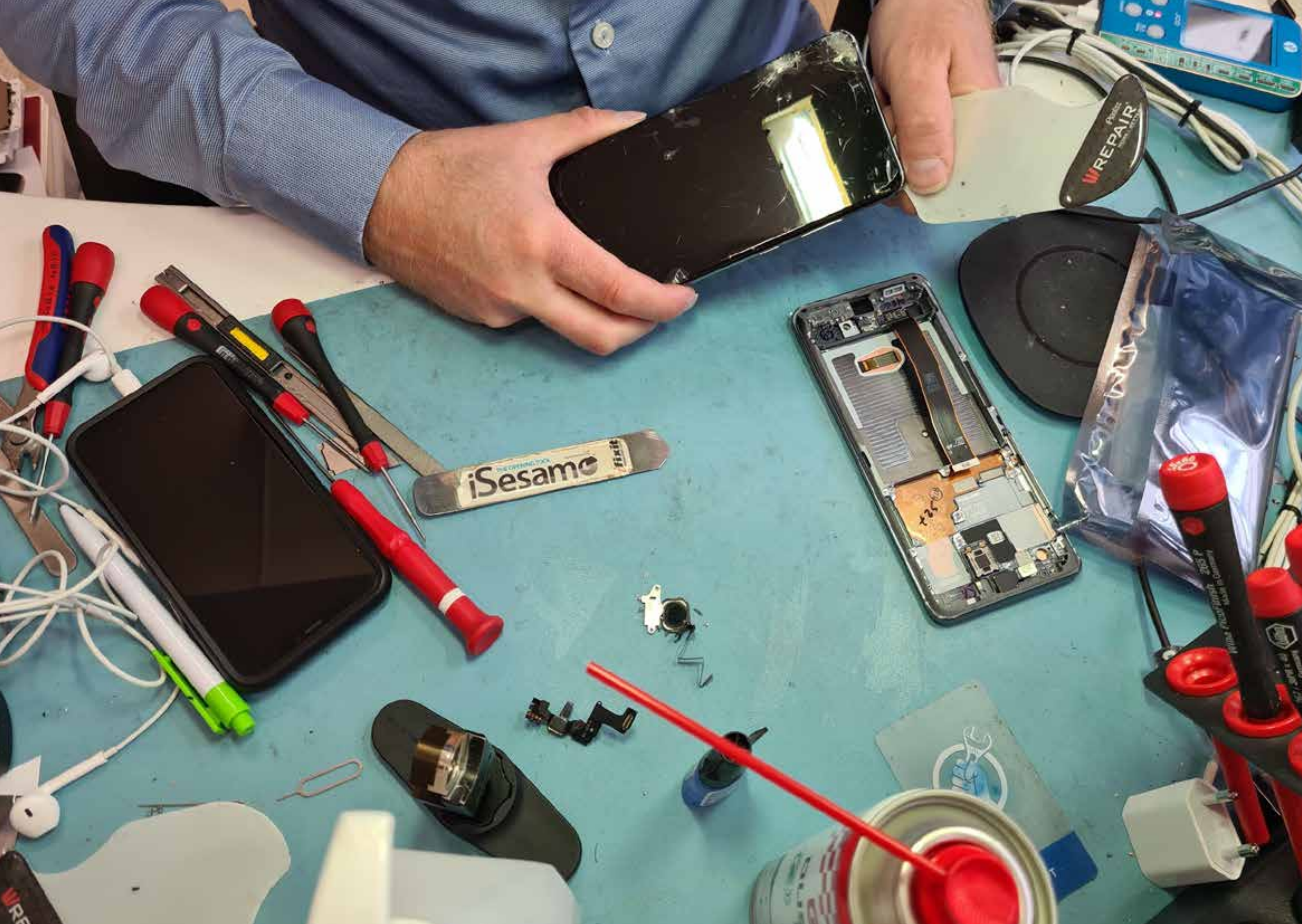



**FIGURE 13** Repair scenarios of a laptop - reductions in materials resource scarcity


iSesamo
REPAIR

# From a linear to a circular strategy

**What are the positive environmental impacts if an organisation wants to consider implementing a circular, repair-based strategy? We used the data we found for the mobile phone and laptop and calculated the impacts for 100 and 1 000 devices per year. This will enable organisations to calculate the environmental gains when implementing a repair-based strategy.**

For the mobile phone we assumed that 34% of the phones was repaired because of broken battery, 37% was repaired because of a broken display. For the remaining 29%, we assumed that 14% could not be repaired and 15% did not require replacement of components to extend the lifetime.

For the laptop, we assumed that 16,4% was repaired because of a broken battery, 21.2% was repaired through motherboard replacement, and 16.9% was repaired through hard disk drive replacement. For the remaining 45.5%, we assumed that 22% could not be repaired and 23.5% required a different repair or did not need a repair.





## One hundred devices

Estimated reduction of impacts when moving from a linear to a circular strategy for an institution with 100 employees, assuming all employees have one mobile phone and laptop each:

**TABLE 1** Impact **reductions** for 100 mobile phones and 100 laptops (per year of use)

| | CLIMATE CHANGE KG $CO_2$ EQV | CUMULATIVE ENERGY DEMAND MJ | MINERAL RESOURCE SCARCITY KG CU EQV |
|---|---|---|---|
| PHONES | 486 | 7 154 | 3 |
| LAPTOPS | 2 000 | 45 624 | 48 |
| **TOTAL** | **2 486** | **52 778** | **51** |

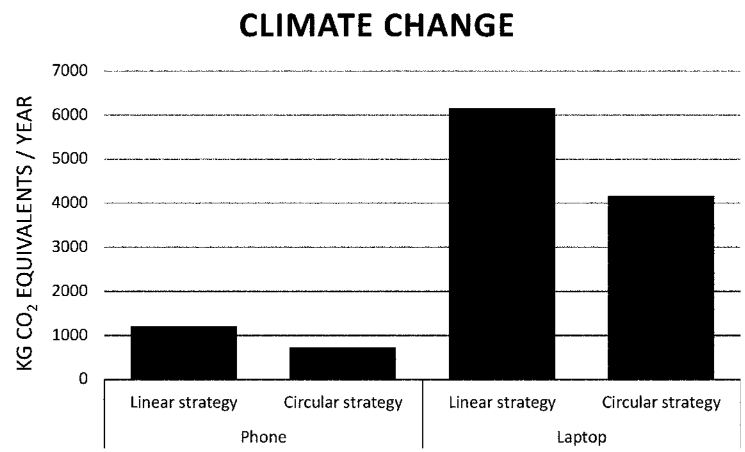



**FIGURE 14** Effect of two different strategies on climate change (100 employees per year)

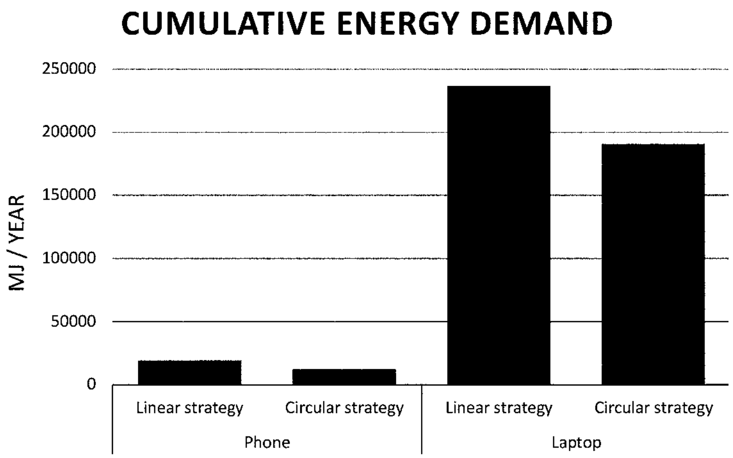



**FIGURE 15** Effect of two different strategies on cumulative energy demand (100 employees per year)

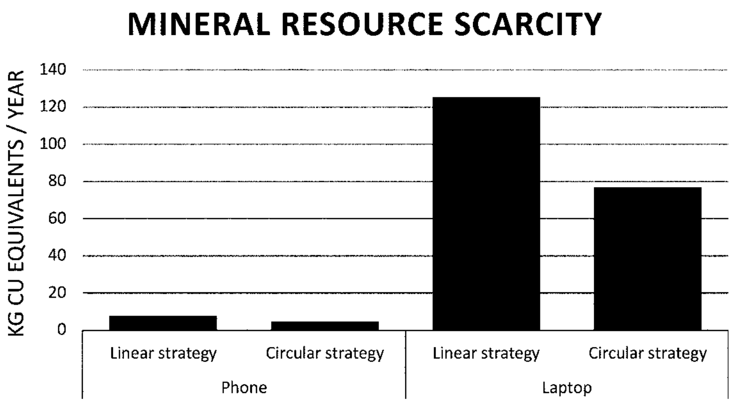



**FIGURE 16** Effect of two different strategies on mineral resource scarcity (100 employees per year)





## One thousand devices

Estimated reduction of impacts when moving from a linear to a circular strategy for an institution with 1 000 employees, assuming all employees have one mobile phone and laptop each:

**TABLE 2** Impact **reductions** for 1 000 mobile phones and 1 000 laptops (per year of use)

| | CLIMATE CHANGE<br>KG $CO_2$ EQV | CUMULATIVE ENERGY DEMAND<br>MJ | MINERAL RESOURCE SCARCITY<br>KG CU EQV |
|---|---|---|---|
| PHONES | 4 860 | 71 539 | 30 |
| LAPTOPS | 19 996 | 456 241 | 483 |
| **TOTAL** | **24 857** | **52 7780** | **513** |

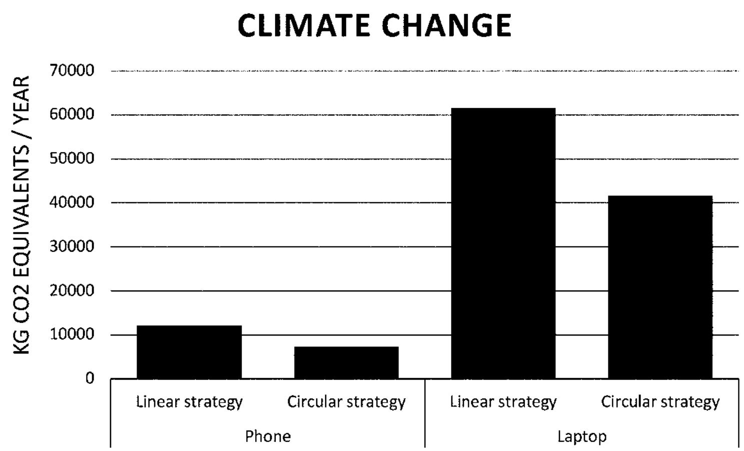



**FIGURE 17** Effect of two different strategies on climate change per year (1 000 employees)

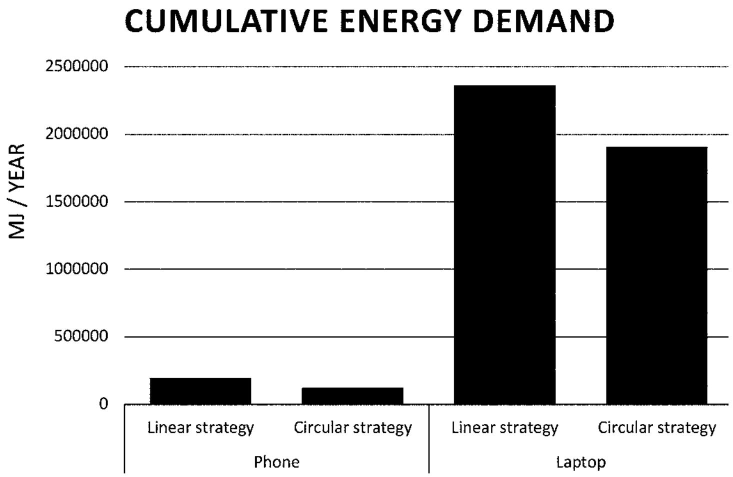



**FIGURE 18** Effect of two different strategies on cumulative energy demand per year (1 000 employees)

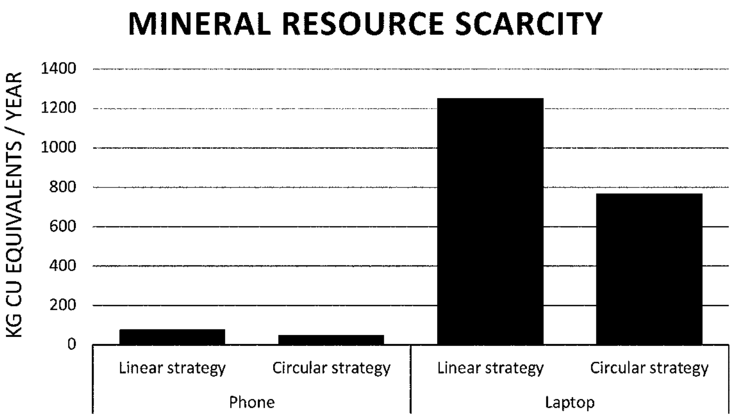
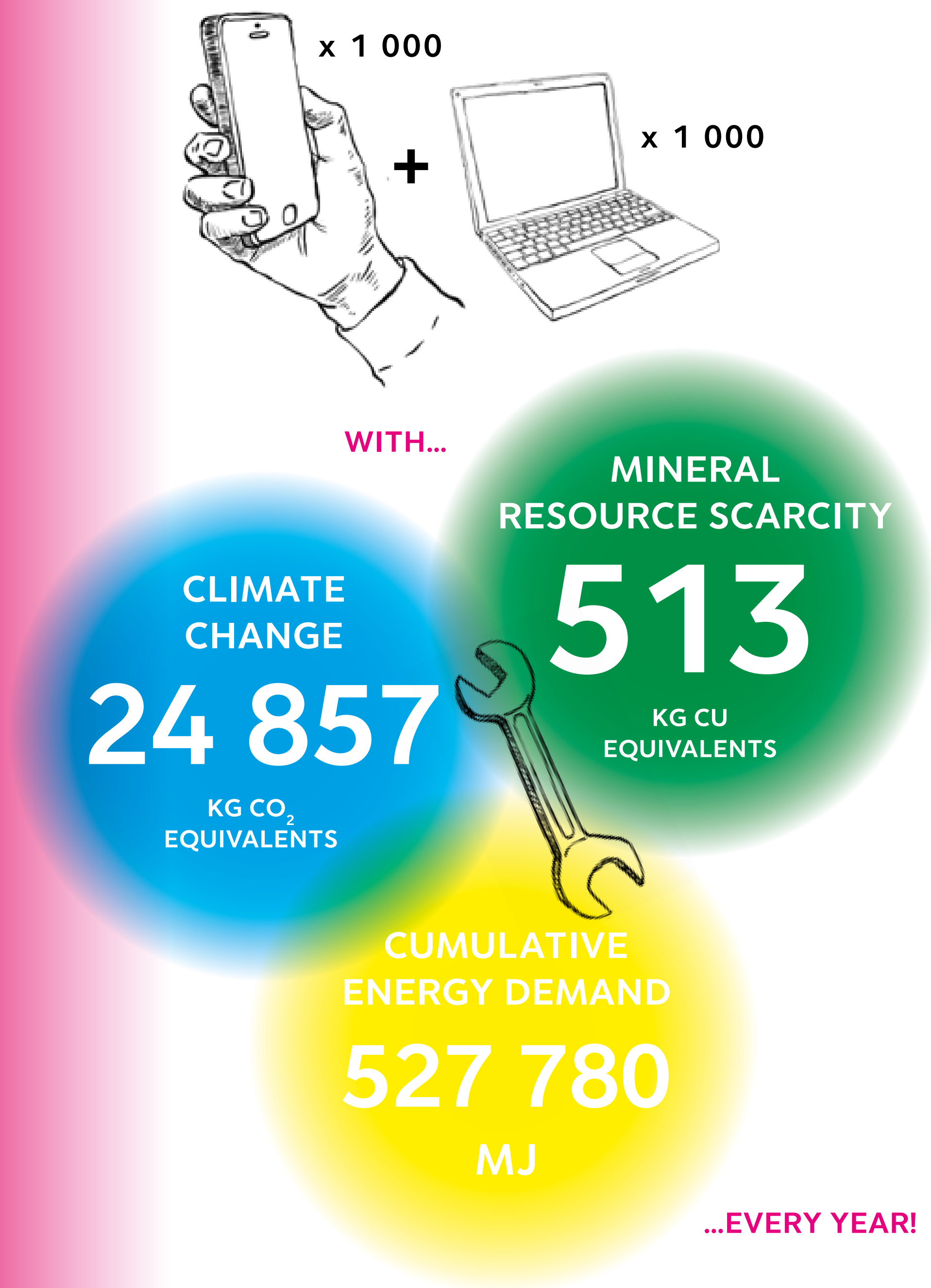



**FIGURE 19** Effect of two different strategies on mineral resource scarcity per year (1 000 employees)



## A REPAIR-BASED STRATEGY WILL REDUCE THE IMPACT OF...




**...EVERY YEAR!**

# University of Oslo

**Since 2022, the University of Oslo (UiO) has a comprehensive Climate and Environmental Strategy that governs all units of the university.[11] Since 2018, it also maintains greenhouse gas (GHG) accounting. In 2022, the UiO reduced its emissions with 8% compared with 2018, the first year they started the climate accounting. This decrease is mainly the result of a decrease in travel and energy consumption.**

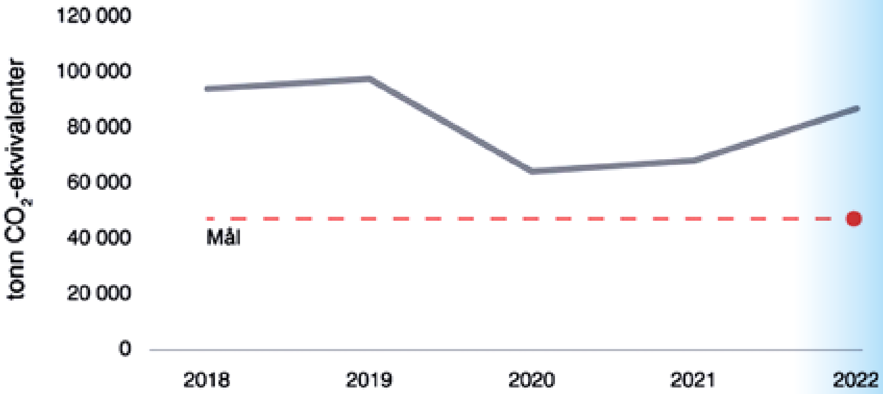



**FIGURE 20** UiO's total emissions from 2018 to 2020. The red line shows the overall goal for 2030.[11]



CASE STUDY

The UiO has as its goal to reduce its emission by 50% in 2030 (**FIGURE 20**). The GHG account show that the emissions are not decreasing fast enough to reach this goal.[12]

## The UiO sustainability goals for 2030

The UiO has set goals for six categories of sources of possible unsustainability and where sustainability gains can be achieved ↓ **FIGURE 21**. In this limited case study, we wanted to find out how the repair of electronic devices can contribute to the decrease in the university's emissions. Repair will delay buying new devices by extending the lifespan of existing devices.


**FIGURE 21** UiO's sustainability goals for 2030.[11]

The University of Oslo consists of more than 110 faculties, departments, centres, support units, libraries, and museums. While there is a central IT support unit, departments and centres procure their own digital devices. This makes it very difficult to find out how many laptops, desktop computers, servers, routers, mobile phones, etc., are in use. The University employs about 7 000 people. In this case study we assume that 5 000 employees have a laptop serviced by the UiO and 1000 employees have a mobile phone serviced by the UiO.

## Environmental gains through repair

Moving from a linear to circular strategy for mobile phones results in the following reductions per year → **TABLE 3**:

- Climate change: a reduction of 4.9 tonnes CO2 equivalents
- CED: a reduction of 72 GJ, which corresponds to approximately 20 000 kWh
- Mineral resource scarcity: a reduction of 30 kg copper equivalents





### Moving from a recycling to a repair scenario for laptops results in the following reductions per year:

- Climate change: a reduction of 100 tonnes $CO_2$ equivalents
- CED: a reduction of 2 352 Giga Joules (GJ), which corresponds to approximately 634 000 kWh
- Mineral resource scarcity: a reduction of 2.4 tonnes copper equivalents

**TABLE 3** Reductions through repair in kg per year (laptops and mobile phones)

| | CLIMATE CHANGE KG $CO_2$ EQV | CUMULATIVE ENERGY DEMAND MJ | MINERAL RESOURCE SCARCITY KG CU EQV |
|---|---|---|---|
| PHONES | 4 860 | 71 539 | 30 |
| LAPTOPS | 99 982 | 2 281 206 | 2 416 |
| **TOTAL** | **104 842** | **2 352 745** | **2 447** |

Moving from a linear to a circular strategy for phones and laptops, the University of Oslo has the potential to reduce the annual impacts by 110 tonnes $CO_2$ equivalents, 2.44 tonnes copper equivalents and save 2 353 GJ which corresponds to approximately 654 000 kWh.

# What can organisations do?

## Get to know your inventory

If you consider adding repair of IT equipment to your sustainability strategy, you need up-to-date information about your organisation’s IT inventory:

- How many devices do you have
- How long have they been in use?
- What is the reason when they break down and are no longer functioning?

This knowledge enables your organisation to explore how IT equipment can be used longer, thus postponing the procurement of new equipment. It also supports the calculations of improved environmental impacts as a result of repair and lifespan extensions.

## Procurement of repairable electronic devices

To make the repair of digital devices a feasible option in the transition to a more sustainable organisation, it is advisable to procure devices that are designed to repair.

iFixit, the online platform providing free repair manuals for a wide variety of products, maintains repairability scores for mobile phones, laptops, and tablets ↓ **FIGURE 22**. It also provides repair guides for a large number of digital technologies, such as different brands and models of servers, laptops, smartphones, headphones, and desktop computers.

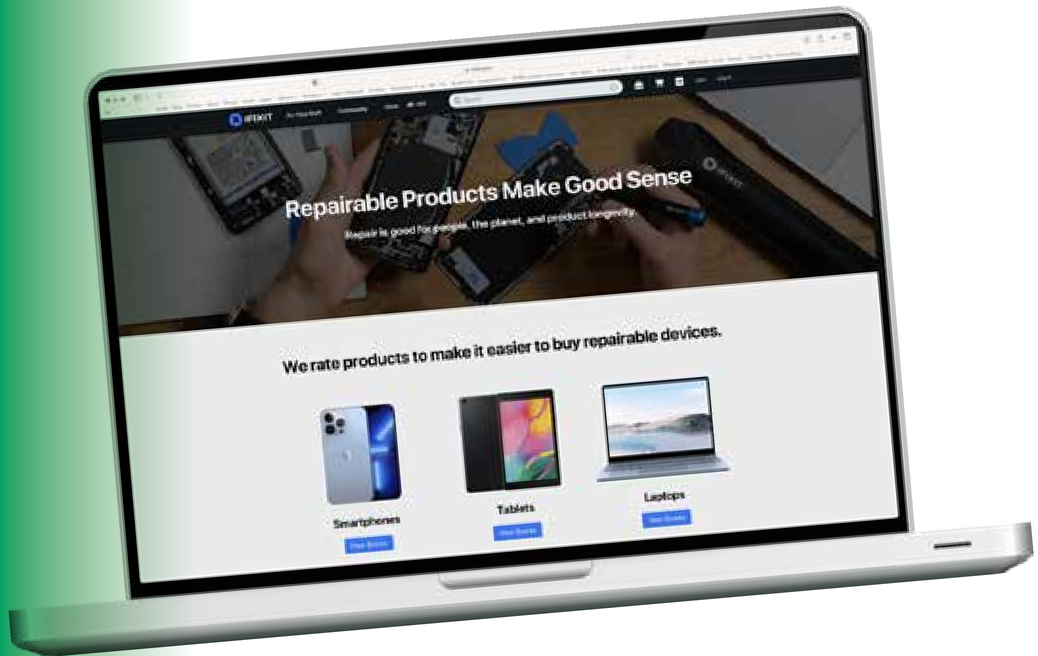
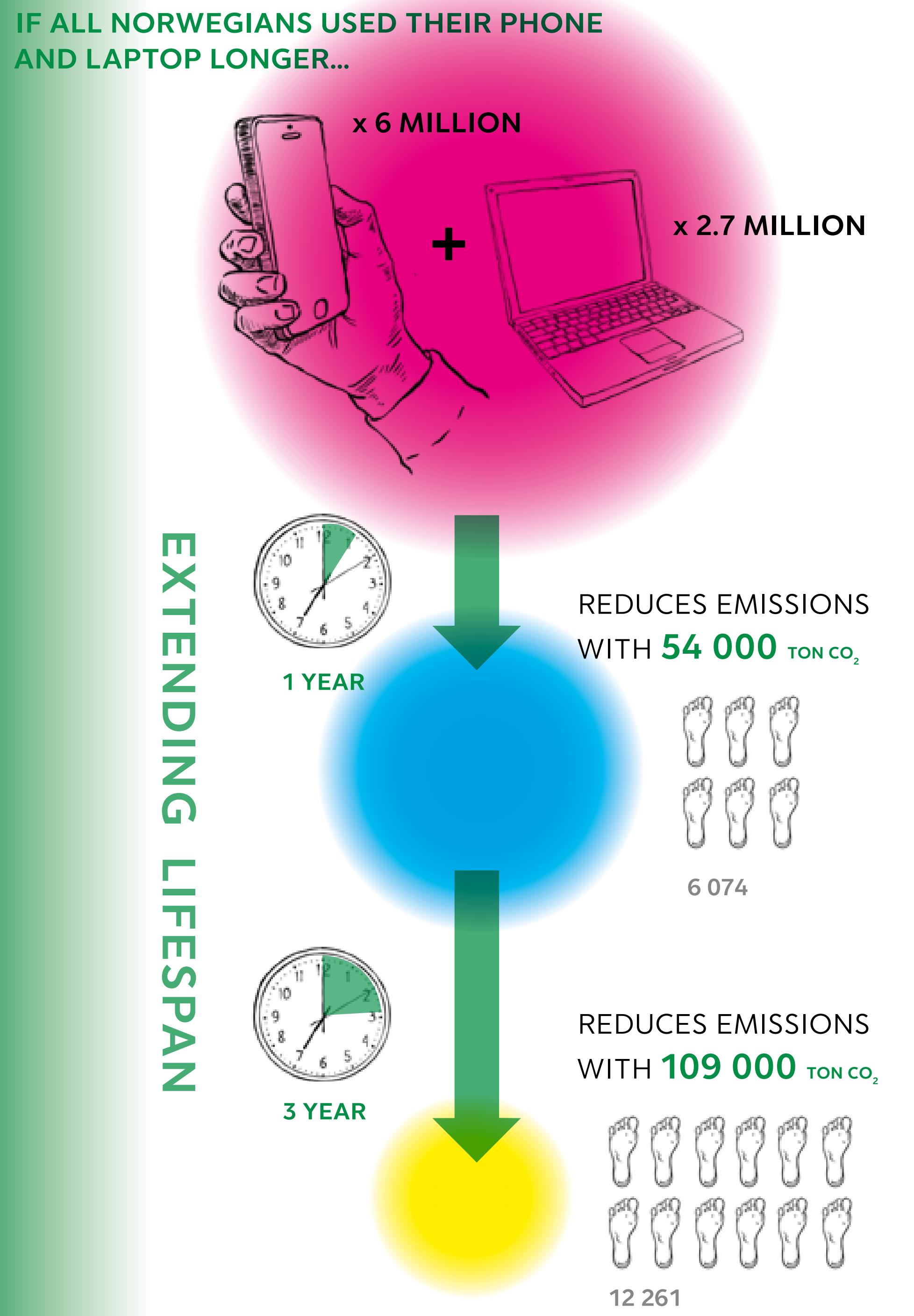



**FIGURE 22** iFixit.com repairability scores

# What can you do as an individual?

**Do you want to reduce your contribution to climate change? If all Norwegians were willing to use their electronic devices longer, we could make a real difference. There are almost 6 million mobile phones in use in Norway. Many devices do not go out of use because they are defect, but rather due to slightly reduced functionality or the urge to buy a more updated product.**

If we could extend the lifespan of all these phones with 1 year on average, we would save around 17 000 tonnes $CO_2$ equivalents per year ↓ FIGURE 23. That is the same as the amount of $CO_2$ equivalents generated by 1 912 Norwegians in a year – based on 8.89 tonnes $CO_2$ equivalents per capita per year.[13] If we could expand the lifespan of all these phones with 3 years, we would save around 35 000 tonnes $CO_2$ equivalents per year. That is the same as the amount of $CO_2$ equivalents generated by 3 937 Norwegians in a year.



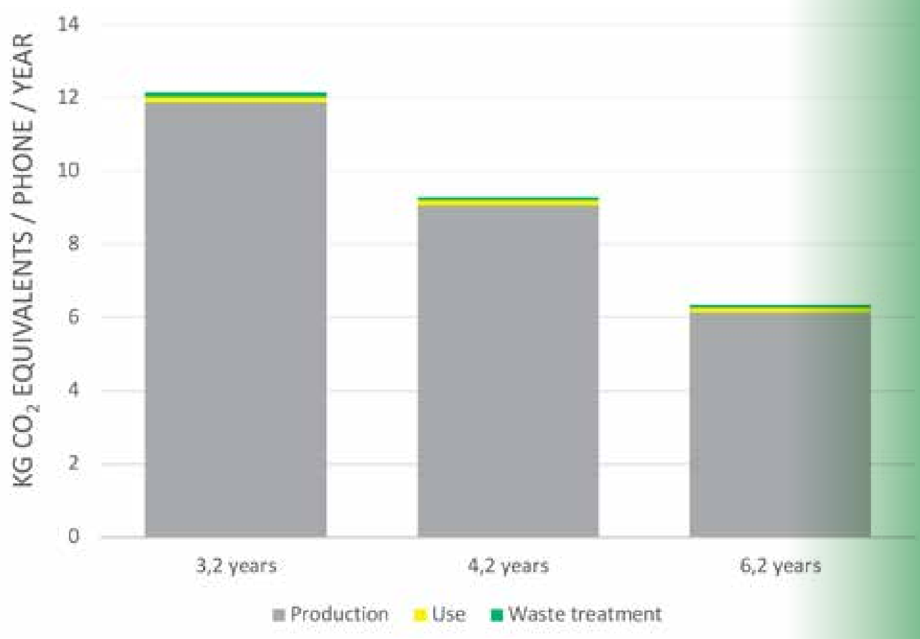



**FIGURE 23** Extending the lifespan of a mobile phone with 1 and 3 years (average lifespan is 3.2 years in Norway)

The same is true for laptops. There are about 2.7 million laptops in Norway.[14] We assume they have an average lifespan of three years. If we extend their lifespan with 1 year, would save approximately 37 000 tonnes $CO_2$ equivalents per year. That is the same as the amount of $CO_2$ equivalents generated by 4 162 Norwegians in a year – based on 8.89 tonnes $CO_2$ equivalents per capita per year.[13] If we could expand the lifespan of all these laptops with 3 years, we would save approximately 74 000 tonnes $CO_2$ equivalents per year. That is the same as the amount of $CO_2$ equivalents generated by 8 324 Norwegians in a year.

If we all would use both our mobile phone and laptop one year longer, we would reduce our emissions with 54 000 tonnes, which is the same as the amount of $CO_2$ equivalents generated by 6 074 Norwegians in a year. If we all would use both our mobile phone and laptop three years longer, we would reduce our emissions with 109 000 tonnes, which is the same as the amount of $CO_2$ equivalents generated by 12 261 Norwegians in a year. ■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