Sustainability

Recommendations for IT Sustainability

Validated life-cycle models for computing

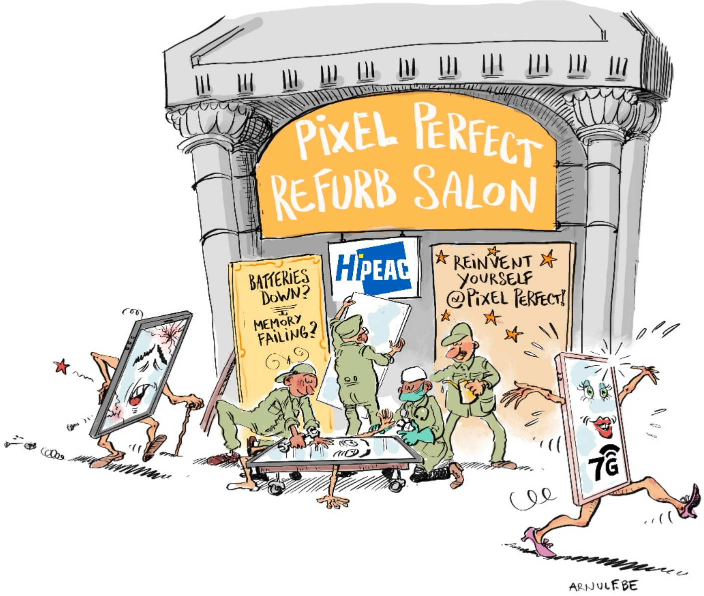
The information technology (IT) community should further develop validated life-cycle models for its own products and services. These models should comprehensively account for the total environmental impact of the production and disposal of the product, commonly known as embodied emissions. This includes the impact of mining, water usage, the use of chemicals in production, and end-of-life processing.

In addition, the model should also estimate operational emissions. This information should be included in a digital product passport (DPP) containing information about the environmental impact comparable with the information on pre-packaged food products or power-efficiency information on household appliances. This information will help consumers to make informed choices about sustainability. The digital envelope of a device should be able to return this information to e.g. an orchestrator to enable it to select the services that optimize the sustainability requirements specified by the owner of the orchestrator.

Sustainability-focused design methodologies and business models

Detailed life-cycle models will help designers make the most effective eco-design decisions. To be effective, design tools should automatically include the environmental impact of the components and technologies used in the design, without putting the burden on the designer. Incorporating repairability, reusability, recyclability, and end-of-life processing considerations from the beginning of the product development process will also lower the environmental impact of the final design.

Inevitably, reducing the environmental impact of a product will have an impact on companies' business models. Designing products that last longer will reduce sales of new products and hence lower the profitability of the company. This can only be mitigated by developing new business models, based on extra services: maintenance, repair, disposal, … up to completely replacing the ownership of hardware by a service contract. The goal should be to bring services to the market with the least environmental impact possible (which in practice means with the least amount of hardware, and the lowest power consumption).



Introduction

Life-cycle assessment (LCA) is an analysis technique that provides tools and frameworks for measuring and managing the environmental footprint of products and services. An LCA analyses the impact of the complete life cycle (cradle-to-grave), from raw materials extraction, via manufacturing, transportation, and usage, to waste disposal. It measures the cumulative environmental effect of the whole life cycle.

It is crucial to consider the complete life cycle to avoid a situation in which a footprint reduction in one phase is cancelled out by a footprint increase in another phase, in the worst case leading to an increase in the total footprint. An LCA is a complex analysis because of the complexity of digital products and services, which are built from components that are sourced globally, all of which need to be analysed to determine their combined environmental footprint.

Another difficulty with an LCA is that the post-production impact (i.e. after it leaves the factory) is difficult to model because it depends on the use and disposal, and that these two aspects are difficult to model because they are controlled by the user. Obviously, a car that is used as a taxi will have a larger operational footprint than a car that is only used occasionally, but at the same time, the total environmental impact per kilometre driven may be lower for the taxi. A fridge that ends up in a landfill will have a different environmental footprint to one that is properly recycled.

Because most consumers do not understand how modern products are built and how services actually work, it is almost impossible for them to assess their environmental footprint. Even for experts, it is difficult to predict the environmental footprint without doing a detailed analysis, and such an analysis regularly leads to counterintuitive conclusions (e.g. that replacing a working device by a more power efficient device is seldom better for the environment than continuing to use the less power-efficient device).

The difficulty in fully understanding the real environmental impact of our actions, and the fact that a thorough LCA sometimes leads to counterintuitive conclusions leads to confusion in the general public, especially when they learn that the behaviour that they thought was beneficial for the environment turns out to be ineffective, or even harmful in some cases. This confusion provides fertile ground for environmental sceptics to convince the public that sustainability is a scam and to use social media to amplify their messages. It also makes it more difficult to detect greenwashing.

What about climate change?

From the scientific view, there is no doubt that the current global environmental footprint is too high for the carrying capacity of the planet, as illustrated by the yearly earth overshoot day `[EarthOvershoot]`. The world uses in seven months everything the planet can regenerate in one year. The remaining five months, we are depleting the planetary resources. The EU overshoot day was 3 May 2024, meaning that the EU uses in four months everything the EU can regenerate in one year.

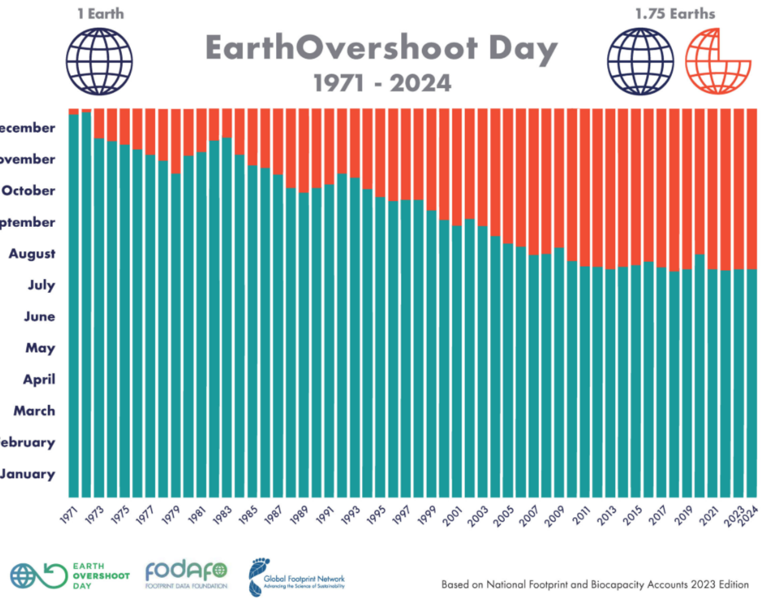


Figure 1: Earth overshoot day 2024 was 1 August 2024

One can disagree on the root causes: overconsumption, overpopulation, inefficiencies, … but not on the effects which are observable: climate change, loss of biodiversity, … If not mitigated, science predicts that there will be serious implications for the future generations.

The most important action humanity can take to stop climate change is to reduce the emissions of greenhouse gases (GHG). The most important ones are carbon dioxide (CO_2) (caused by the use of fossil fuels, deforestation, …), methane (caused by livestock, oil and gas extraction, …), nitrous oxide (caused by fertilizers, fossil fuels, industry, …) and fluorinated gases (caused by industrial processes, cooling, electronics manufacturing, …).

CO_2 has the highest contribution due to its sheer volume, but the other gasses are much more potent GHGs, and the electronics industry is a source of fluorinated-gas emissions. To simplify the maths, all GHGs are commonly expressed as their equivalent in CO_2 emissions, called CO_2e. This is convenient but also misleading, in the sense that techniques to extract CO_2 from the air, like planting trees, work for real CO_2, but does not work for the CO_2e that is caused by e.g. methane.

According to international agreements, emissions should be cut by 45% by 2030, compared to 2010 levels, and the world should reach net zero by 2050. Unfortunately, despite all our efforts of the last 20 years, global GHG emissions are still increasing, albeit at a lower rate than 20 years ago. With current commitments, the emissions in 2035 will hardly be lower than the emissions in 2020, and the gap between the path towards net zero emissions in 2050 is quickly widening.

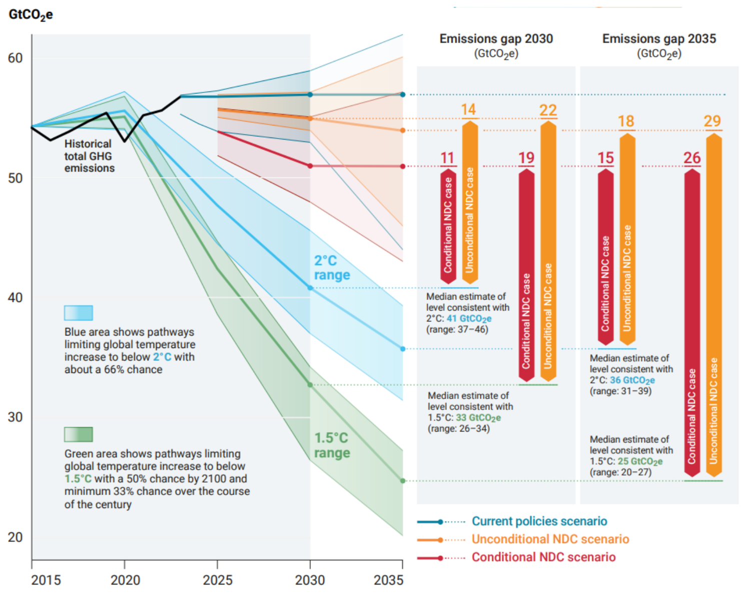


Figure 2: Global total GHG emissions in 2030, 2035 and 2050, and estimated gaps under different scenarios (unconditional national determined contribution (NDC) scenario = current committed efforts). Conditional NDC: contributions that are conditional, i.e. they depend on factors that are unsure like the passing of laws in local parliaments.

Given the fact that the early emissions reduction would normally consist of low-hanging fruit, there is little hope that decarbonization will be easier in 2035 than it is in 2025. The fact that the newly elected president of the US will actively promote fossil fuels until 2030, along with the quickly growing energy consumption by AI data centres in the US, might slow down the emission reductions in the coming years.

Authors like Vaclav Smil `[VaclavSmil]` argue that fast decarbonization of the global economy over the next 25 years is unlikely because the world is built of concrete and steel, both of which require a huge amount of energy to produce, and for which there are currently no economically viable alternatives that can be scaled up to the required volume. In addition, industry needs the molecules of fossil fuels in the chemical industry to produce e.g. plastics and fertilizer, two other cornerstones of modern society. Furthermore, major industrial capital investments often have a time horizon of two decades. Hence, fossil fuel-based industrial facilities that are built today will still be in use in 2045. The conclusion is that, given that it took more than a century to build a fossil fuel-based industry, it is very unlikely that it can be reconverted into a fossil-fuel-free one in two decades.

What about the IT industry?

Obviously, the IT industry also contributes to the global GHG emissions. The most widespread comparison is that the emissions of the IT sector are comparable with those of aviation (2%). This comparison suggests that the IT industry is a polluting industry and devastating for the planet.

Given the importance of IT in the modern world, one could also say that it is ‘only 2%’, and the IT industry helps the other industries to reduce emissions (optimized processes, cleaner transportation, less business travel, …). The fact is that (i) we do not know for sure whether this 2% is high or low compared to the benefits of using IT, and (ii) we do not know how and by how much the footprint of the IT-industry could be reduced without losing its main economic and societal benefits. Furthermore, it is dangerous to make any statement about concrete situations without first making a solid LCA about it to make it evidence based. Extrapolating from similar situations is tempting, but no two situations are identical and only an LCA analysis can provide certainty.

Given the complexity of an LCA analysis, some organizations publish general recommendations, such as those published by [Ericsson]:

- Use your smartphone or other ICT devices longer before upgrading
- Make sure you recycle or reuse ICT equipment
- Consume digital services on smaller devices
- Charge the batteries with electricity from renewable sources
- Avoid buying more ICT devices than you have time for (pass unused devices on)
- Show your suppliers that their footprint matters to you
- Buy your digital devices and services from companies that have Science based Targets
- Use ICT services that help to reduce carbon emissions

These may help some high-level decisions, but they won't help somebody deciding which smartphone to choose in a shop. Furthermore, they are not quantitative, and do not allow estimates of what the difference in emissions is.

To give a few examples: few people are aware that a non-rechargeable battery requires 100 times more energy to produce than the energy it stores, that mobile devices can cause up to 10x more emissions to produce than the operational emissions over their entire life cycle (which explains that keeping a power inefficient one is often more sustainable than replacing it with a power efficient one), that five ChatGPT questions consume the same amount of energy as stored in a fully charged iPhone 15 battery.

This leads to two recommendations:

Validated lifecycle models for computing

A first recommendation is that the IT community should develop validated life-cycle models for its own products and services. The life-cycle models should not be contested (hence "validated") and be developed by sustainability experts based on solid scientific evidence. These models should comprehensively account for the total environmental impact of the production and disposal of the product, commonly known as embodied emissions. This includes the impact of mining, water usage, the use of chemicals in production, and end-of-life processing.

In addition, the model should also estimate operational emissions, which obviously depend on the usage of the product and the environmental impact of the energy used. This information should be included in a digital product passport (DPP) containing information about embodied energy, operational energy, mining, water usage, and chemical impacts comparable with the information on pre-packaged food products or power efficiency information on household appliances. This information will help consumers to make informed choices about sustainability.

For digital products (IT services), the product should be able to return this information to the user. This will allow e.g. an orchestrator to select the services that optimize the sustainability requirements specified by the owner of the orchestrator. For services, this information might also be dynamic: the service request during the day might have a lower impact than during the night if the carbon intensity of the energy consumed was lower during the day. Obviously keeping track of all this information will have an environmental cost itself too, and it will be important to prove that the environmental benefit of keeping track of it exceeds its environmental cost.

Sustainability-focused design methodologies and business models

Once the life-cycle models are available, and the environmental impact of product and services has been modelled, designers can optimize their designs to lower the environmental impact. They can do this to make their products more environmentally friendly, to make them more attractive to customers who care about the environment, or to make them compliant with local regulations.

The detailed life-cycle models will help the designer to make the most effective design decisions, and to ensure that environmental impact is one of the design criteria to optimize. This is already common practice in the building industry where designers routinely base their designs on low-carbon construction materials, which in turn has stimulated innovation in companies that produce construction materials.

Questions which should be very easy to answer include e.g. whether it is better for the environment to power a device with a battery, or with an adaptor from the grid, whether adding an extra cache level in a computing system is better or worse for the environment, and whether executing a workload at the edge is environmentally better than execute it in a cloud data centre. Such questions can only be answered by a solid LCA, and the answer will depend on the usage, the location and the domain in which the technology is applied.

To be effective, design tools should automatically include the environmental impact of the components and technologies used in the design, without putting the burden on the designer. Incorporating repairability, reusability, recyclability, and end-of-life processing considerations from the beginning of the product development process will also lower the environmental impact of the final design.

Inevitably, reducing the environmental impact of a product will have an impact on companies' business models. Designing products that last longer will reduce sales of new products and hence lower the profitability of the company. This could be mitigated by marketing: products that last longer can also be sold at a higher price point.

Furthermore, new services could be built around the life cycle of a product: maintenance, repair, disposal. Such services might create opportunities to build a loyal relationship between the vendor and the customer; when the product is beyond repair, the vendor can immediately propose replacing it, and hence not lose the customer to the competition. The computing industry could learn from industries that already work like this (cars, household appliances, heating and cooling systems, alarm systems, …).

Another option is to no longer sell the hardware, but a service based on the hardware. This leads to a high startup cost, but a stable revenue stream afterwards. In any event, the computing industry will have to change its business models to become sustainable.

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