T7 Task Force Climate and Environment

POLICY BRIEF

CLEAN-IT: POLICIES TO SUPPORT ENERGY-EFFICIENT DIGITAL SYSTEMS

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Abstract

The G7 should regard the rising energy-consumption of the global adoption of digital technologies and applications as a serious threat to the world climate. Therefore setting up early warning systems to monitor the issue and raise awareness on the topic in their respective states is required. Our recommended actions for the G7 are to:

Update the engineering curriculum and require the teaching of sustainable engineering in both undergraduate and professional continuing education in all G7 states;

Significantly increase the incentives for basic and applied research across G7 states to discover methods of reducing the energy consumption of IT;

As a matter of urgency negotiate standards which could be the basis for an internationally agreed on "clean-IT label" to be required for G7 government procurement.

Challenges

Carbon footprint of digital technologies rises rapidly

During the last decades, digital technologies were celebrated as the clean counterpart to old-fashioned "dirty" manufacturing, agriculture, and energy production industries. It was believed that digital devices, products and services, due to their immaterial nature, do not contribute (or contribute very little) to global pollution by wasteful consumption of material resources and the emission of greenhouse gases. This belief is flawed. Digital devices and applications contribute significantly to the global carbon footprint. Even though neither computers, tablets and smartphones – nor even data centres – have chimneys, the amount of carbon emissions caused by digital technologies has become a threatening climate issue.

Inefficient digitalisation is about to become a major climate hazard

Already today, the total carbon emissions of digital technologies surpass those of global air traffic by a factor of two. In 2019 all air traffic combined accounted for about one billion tons of carbon emissions and 2% of overall emissions.[1] In the same year, digital technologies emitted about two billion tons, or about 4%, of all human-induced carbon dioxide.[2] Humanity is at the beginning of a massive acceleration of digitalisation on a global scale. Currently the main polluters are energy production (42%), transportation (25%) and manufacturing (19 %).[3] Depending on the progress of additional renewable energy sources and steady growth in the energy requirements of digital technologies, it is not yet clear which of these trends will prevail. It is fair to assume that since the use of digital technologies requires more energy than production that the current share of 4% will steadily rise as well and will eventually exceed the carbon emissions of transportation and manufacturing.

All data traffic requires energy. The total amount of annual internet traffic has risen exponentially during the last few years and continues to rise steeply. The International Energy Agency calculates that while in 2007 only 54 exabytes (54 billion gigabytes) of data were transferred over the internet, this amount increased by a factor of 20 in 2017 to 1.1 zettabytes (1,100 billion gigabytes). The same organisation estimates that annual data traffic will quadruple by 2022, reaching 4.2 zettabytes.[4]

Researchers at the University of Massachusetts Amherst have studied the training life cycles of several common AI models and found that the energy consumption, and therefore the carbon emissions, of developing advanced neural networks are significant. The training of one specific AI model required about 300 tons of carbon dioxide equivalents, which equals the carbon emissions of the life cycle of five cars including fuel, or 300 round-trip flights from New York City to San Francisco.[5]

Computer Scientists at the Massachusetts Institute of Technology in Cambridge show that bitcoin mining emits up to 22 megatons of CO2 annually. This is roughly equivalent to the annual greenhouse gas emissions of a country such as Jordan or Sri Lanka.[6]

Green IT is not enough

The issue of IT's growing carbon footprint has been recognised for some time now and has led to various initiatives that can be summed up under the label "Green IT". The primary focus of this movement is on the reduction of the waste of natural resources during the production and use of digital devices,[7] by using renewable energy sources and calling for "digital sobriety."[8] The US Environmental Protection Agency (EPA) and the EU Commission (in 2003) introduced the "Energy Star" label for energy-efficient ICT devices back in 1992. Despite this, the energy consumption of digital technologies continues to rise steeply. The testing schemes of the Energy Star label are not rigorous enough nor thorough enough. The increasing share of carbon emissions caused by the use of software and digital applications is not accounted for. Energy-efficient IT is a major blind spot in most of the Green IT initiatives, which focus on physical device production, not on the daily emissions occurring over the life of the device and the software it runs. The rising footprint of digitalisation is not due to the increased use of digital technology during the Covid pandemic. Covid has merely accelerated the growth in digital carbon footprint, as data from the last decades coherently shows. Therefore, it cannot be expected that the carbon footprint of digitalisation will decrease after the pandemic. Certainly, the carbon emissions of digital technologies depend on the energy sources of their production and operation and could be diminished by extensive use of renewable energy. However, there is not enough renewable energy available yet and it is also not reasonable to power inefficient computer systems with clean energy. We must design for sustainability, to use as little energy as possible. Otherwise, it would be like powering refrigerators from the 1950s with solar power and claiming that they are clean technologies: 70-year-old designs are more wasteful of energy than current refrigerators and using renewable energy alone would not make them clean. In the face of the current Ukraine crisis, which for many states is as well an energy crisis, it has become more than apparent, that it is necessary not to waste energy. It is mandatory to reduce energy consumption wherever possible to reduce well fatal energy dependencies.

Digital sobriety is also not likely to support the quest for a carbon-free planet. Even though technologies like energy-intensive AI and blockchain applications can be banned, as recently happened in China,[9] the appropriate reaction must be nuanced to foster sustainability. Digital technologies and innovative applications are essential to decreasing carbon emissions in other sectors like energy production, manufacturing and agriculture. Reducing the use of digital technologies in those sectors would increase total carbon emissions across all sectors. Digital technologies can achieve important goals, such as accelerating recovery from pandemics like Covid-19 and promoting lifelong learning and lifelong earning on a global scale. Digitalisation is the answer to many sustainability challenges. Therefore, we must invest in research and policy to achieve more energy-efficient digitalisation. This can only be done if digital engineering follows a novel paradigm, which we call **"Sustainability by Design"**. Devices must be designed properly up front and public and engineering awareness of the digital carbon footprint and especially of the impact of wasteful algorithms must be raised. Since the use of digital technologies already represents the biggest share of the digital carbon footprint – and will continue to rise steeply – it is necessary to design algorithms to use energy more efficiently. The trade-off between precision/speed/data throughput and energy consumption must be brought into balance by making it a core principle of IT system design.

Proposals

What is "clean-IT" and "Sustainability by Design"?

With the introduction of digital applications to almost every imaginable aspect of human life, we can expect a dramatic increase in the use of digital technologies. At the beginning of the massive roll-out of such innovations, the repercussions of their use are barely tangible. However, examples from the past can guide us to not repeat our mistakes in applying new technologies.

When plastic was invented, it was a ground-breaking innovation in the field of new materials. A world without plastics would be less prosperous and innovations in many other areas would not have been possible. However, the increased use of plastics poses a threat to life on Earth today because of the high level of difficulty in recycling this material. Since the inception of the awareness campaign, less plastic is used and more importantly, more environmentally friendly, and recyclable plastics have been invented. However, had the scientists and designers behind plastic development been mindful of its potential environmental impact from the onset, we would not be facing the massive crisis of today.

However, this is avoidable with IT systems, but we can and must act now. Computer systems, which are based on the interrelationship of hardware and software, organised by algorithms, can be designed in different ways to produce the same outcome. Often unnecessarily complicated programming or computer system designs cause higher energy consumption when compared to algorithms that are more efficient. Innovative software architectures can achieve the same or only slightly lower precision or data throughput, while saving enormous amounts of energy. It matters very much to the energy consumption how algorithms and computer systems are designed.

To solve the paradox of *more from less*, new design and algorithmic paradigms must be put into practice. The principle of "**Sustainability by Design**" needs to become the very foundation of the teaching and practice of digital engineering.

The principles of algorithmic efficiency and sustainability by design are best explained by tangible examples from current research in computer science:[10]

- ***Clean Data Profiling***

  Digital applications such as many new "smart" technologies require perfectly organised mass data sets. But the larger the data sets, the more time and thus the more energy is consumed for data profiling to make the data usable. To reduce the runtime of data profiling, researchers at HPI have developed the HPI-Valid algorithm. This reduces the runtime for a specific data profiling task from many weeks to a couple of seconds, saving an immense amount of energy.[11]

- ***Energy-Aware Computing***

  Data Centres are at the heart of digitalisation. Cloud applications, streaming, complex simulations – everything runs in data centres. The ever-increasing energy consumption that results is a significant contributor to our global carbon footprint. Current research suggests that data centres can use heterogeneous computing resources to decrease the energy consumption of a computation task by a factor of 10 if the right computation problem is routed to the right computation resource.[12]

- ***Energy-efficient Deep Neural Networks***

  Deep Learning Neural Networks are a game changer in the field of Artificial Intelligence. However, deep learning algorithms consume a vast and constantly growing amount of energy during training and execution. Energy can be saved by lowering the complexity of AI models. By setting rounding data values in AI models, it is possible to sacrifice only 5% of precision, but to achieve about 95% of energy saving required for an AI computation.[13]

Implementation

How can the G7 implement policies to reduce the carbon footprint of digitalisation?

Climate change is a threat that cannot be tackled by the efforts of single countries and single companies alone. It is a global phenomenon. In addition, the fact that digital technologies and services impact societies all over the world without regard to borders underscores the necessity for coordinated action. The G7 can lead by example, and working closely with the G20 can develop the early warning systems[14] to address much unnecessary and avoidable energy consumption by IT.

Currently, nations with the highest valuation global IT companies are the main contributors to the carbon footprint of digitalisation through their ubiquitous digital platforms and services. By introducing new computer systems for the global market, they effectively set the technological standards in cyberspace.

Because of this the G7 need to deal with the issue of reducing the carbon footprint of digitalisation from two directions: At the beginning of the product development cycle, with requiring beginning and mid-career engineers learn Sustainability by Design; And during the sales cycle with a clean-IT label so all buyers can make informed decisions. Energy-efficient algorithms and digital architectures can be implemented without regard to national interests. On the contrary, energy-efficient computer systems are able to boost economic development as well as preserve the climate. Therefore, clean-IT could be an international topic and discussed by global competitors, generating benefits for all sides.

Furthermore, computer systems and mobile applications are increasingly created by people who live in both developed and developing countries. Standards for sustainable computer systems therefore need to be discussed and implemented globally led by the G7 and the G20. International institutions such as ITU and IEEE can be facilitators of measures to reduce the footprint of digitalisation. However, they do not have the power to enforce international agreements on education, research, innovation and environmental policy. The G7 is uniquely the body that needs to begin a coordinated effort with the G20 to set national policies among the G7 countries, by example first and the G20 countries provide the next set of national policies that improve the energy efficiency of computer systems to contribute to the long-term low greenhouse gas strategies agreed upon at previous COPs.

Specifically, we make **3 recommendations** for policies to reduce the global carbon footprint of computer systems:

1. *G7 member states should take up the issue of "sustainability by design" and the state of energy consumption of computer systems in their working group on "Saving the Planet", and operate regional networks of community digitalisation labs to assess the current state as "Early warning systems" and together share and apply knowledge to accelerate the implementation of sustainable digital technologies. The permanent working group within the G20 summits should gather information on the topic, produce policy recommendations on how to reduce the carbon footprint of computer systems design and usage and follow through to implement in every G7 and G20 country.*

2. *G7 member states should lead the way in establishing and coordinating incentives for research and public education in energy effective algorithms. Trade-offs in performance and energy consumption must be incorporated in the digital engineering curriculum. To this end international research centres for the assessment of the digital carbon footprint should be established to make informed decisions on economic, social, and environmental policy.*

3. *G7 member states should update their software procurement guidelines towards energy-efficient software solutions in a coordinated manner. The adoption of innovative technologies and novel societal paradigms needs to be supported by politics and public administration. To certify energy-efficient software the G7 member states should establish an internationally recognised clean-IT label for sustainable computer systems. Internationally recognised quality labels and standardisation can play a major role in promoting widespread awareness and penetration of sustainable software in public and private enterprises. Especially in computer systems, it is hard to distinguish whether products and services are sustainable due to heterogeneous hardware infrastructures, a mix of different software solutions and individual use of IT. Common standards therefore need to be put in place first in the G7, then the G20, and thereafter all countries in the world.*

Endnotes

[1] ATAG 2019.
[2] The Shift Project 2019.
[3] Statista 2018.
[4] IEA 2017.
[5] Strubell et al. 2019.
[6] Stoll et al., 2019.
[7] OECD 2009.
[8] The Shift Project 2019.
[9] Kharpal 2021.
[10] A large collection of examples of clean-IT solutions in different domains of digitalisation can be found at the clean-IT Forum. open.hpi.de/channels/clean-it-forum
[11] Birnick et al., 2020.
[12] Plauth et al., 2020.
[13] Bethge et al 2019.
[14] Early warning systems, 2019 - https://climate-adapt.eea.europa.eu/metadata/adaptation-options/establishment-of-early-warning-systems

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