Report from Dagstuhl Perspectives Workshop 25122

Climate Change: What is Computing's Responsibility?

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Abstract

This report documents the program and the outcomes of Dagstuhl Perspectives Workshop 25122 "Climate Change: What is Computing's Responsibility?" The workshop brought together global experts from computing, environmental science, and policy to explore the detrimental impacts of computing technologies on the environment, particularly with respect to climate change. These harms were considered alongside possibilities for computing technologies to facilitate climate mitigation and adaptation, as well as on balance with the social benefits delivered by computing technologies. Key topics of discussion included the role of computing in enabling a safe and just transition to a sustainable society, methodological challenges in estimating environmental impacts (beneficial and detrimental; direct and indirect), and matters of accountability and governance. Through discussions, participants converged on a vision for a paradigm shift that would align computing with climate goals, and detailed fundamental premises and commitments by computing professionals within this new paradigm.

Seminar March 16–19, 2025 – https://www.dagstuhl.de/25122
2012 ACM Subject Classification Computing methodologies → Artificial intelligence; Human-centered computing → Human computer interaction (HCI); Software and its engineering
Keywords and phrases sustainability, climate change, efficiency, supply chain management, climate modelling
Digital Object Identifier 10.4230/DagRep.15.3.113

1 Executive Summary

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The Dagstuhl Perspectives Workshop 25122, held 16–19 March 2025, convened global experts from computing, environmental science, and policy to address computing's role and responsibility in the climate crisis. Participants discussed the environmental impacts of computing technologies alongside vaunted possibilities for climate mitigation and adaptation. Through these discussions, participants converged on a shared vision of the responsibility of computing professionals within the present reality of climate crisis. This vision was articulated in a Manifesto outlining core recognitions and commitments.

Key Themes and Insights

- Computing's Role in Climate Change:
  - Computing technologies have a growing negative impact on the environment; these impacts deserve more serious consideration at all levels.

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Climate Change: What is Computing's Responsibility?, *Dagstuhl Reports*, Vol. 15, Issue 3, pp. 113–124
Editors: Vicki Hanson and Bran Knowles
Dagstuhl Reports
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

  - While there are positive environmental use cases for computing, rhetoric on the potential of computing to mitigate climate change is unsubstantiated and likely overly optimistic.
  - Computing technologies tend to amplify and accelerate; so in a society on a path towards exceeding climate targets, computing technologies are likely getting us there faster.
- Responsibility and Ethics:
  - Discussions emphasised the need for computing professionals to embrace a broader ethical responsibility that includes not only minimising harm but also prioritising sustainability and promoting systemic change.
  - Responsible computing must at the same time promote a socially just transition to a sustainable future
- Measurement and Accountability:
  - Participant experts highlighted the methodological challenges in assessing computing's environmental footprint, including direct and indirect impacts (e.g. rebound effects).
  - Calls were made for stronger professional standards, improved methodologies for assessing impacts, and greater transparency.
- Additional leverage points:
  - Participants discussed the global technology policy landscape and the need for computing professionals to actively influence regulation.
  - Promoting a paradigm shift will require a revolution in computing education.
- Producing a Manifesto:
  - The workshop culminated in the co-development of a Manifesto outlining shared commitments and principles for sustainable computing.
  - The Manifesto is intended to serve as both a guiding document for practitioners and a tool for influencing policy, advocating for transparency, repairable and reusable technologies, and prioritising the public good over profit.

Conclusions

The workshop underscored that computing is at a crossroads: it can continue contributing to the climate crisis or become a powerful agent of change. Achieving the latter requires a collective shift in values, rigorous evaluation of impacts, systemic policy engagement, and a strong ethical framework guiding innovation.

Acknowledgements

This workshop was initiated and partly funded by the ACM Europe Council [1], which promotes dialogue and the exchange of ideas on technology and computing policy issues with the European Commission and other governmental bodies in Europe.

References

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3 Day 1: Understanding Computing's Responsibility

On the first day, participants worked towards establishing a shared vision of computing's responsibility in the face of climate change. In the morning, the group explored this from a climate-focused perspective. Prompted by a keynote from Mike Berners-Lee, we considered questions such as:

- *What does the climate emergency require in terms of societal change?*
- *How is computing hindering progress in addressing this emergency?* and
- *What role can computing play in realising a positive vision for the future?*

The afternoon explored the workshop's topic from a technology-focused perspective. A keynote by Vint Cerf provided a springboard for exploring questions such as:

- *How might computing critically assess new technologies?*
- *How should computing balance the drive for innovation with long-term environmental goals?* and
- *What are some levers for effecting positive change in computing?*

3.1 Keynote 1: Mike Berners-Lee

Mike Berners-Lee is the founder and director of Small World Consulting, which provides supply chain carbon metrics and management for its many clients. He has also authored a number of best-selling books including *How Bad Are Bananas?*, *The Burning Question*, and *There Is No Planet B*. His new book, *A Climate of Truth*, explains how decades of climate discussions and international conferences have failed to curb rising greenhouse gas emissions, and what this means about addressing the root causes of the climate emergency. Drawing from this latest book [1], Berners-Lee's talk outlined his understanding of why progress on climate has been limited and how society can begin to implement real solutions.

Berners-Lee presented data showing roughly exponential growth in greenhouse gas emissions over 60 years with no discernible indication that 30 years of climate COPs have had any impact on this trend. Record breaking temperatures year-on-year indicate a faster acceleration of planetary warming than had been predicted, in part due to feedbacks such as melting permafrost releasing methane. He urged participants to understand the climate crisis as part of a broader "polycrisis" that includes biodiversity loss, food insecurity, pollution, and global inequality. He highlighted plastic pollution as particularly insidious, with microplastics devastating human and ecological health.

According to Berners-Lee, we have arrived at the brink of a critical tipping point where human technological power exceeds the resilience of Earth's natural systems. Despite the urgency of this crisis, the global policy response has been ineffectual, signaling the need to approach this problem differently. A transition to renewable energy, for example, is necessary but insufficient without also drastically curbing energy demand. Reducing energy demand, in turn, requires rethinking a traditional focus on GDP growth as a measure of prosperity, which could instead be measured in terms of improved well-being, resilience, and sustainability. In this light, the implementation of a global carbon price to drive down fossil fuel consumption, shifting towards a circular economy, and redesigning products to be more durable and resusable could help arrest climate change while improving prosperity. Without these systemic economic changes, efforts to mitigate climate catastrophe are destined to fail.

The keynote also emphasised the urgent need for political and cultural change, and the role technology must play in this transition. Berners-Lee called for a renewed societal commitment to truth and accountability, in particular countering the spread of misinformation through social media and enabling increased transparency in journalism. He also stressed the importance of citizens engaging politically to push for systemic changes, and that computing technologies could facilitate this engagement.

The keynote ended by reiterating that solutions to the climate emergency exist and can be implemented so long as humanity is willing to acknowledge the truth and act decisively. Berners-Lee's call to action is for computing to foster a culture that values truth, sustainability, and responsible decision-making at every level of society.

References

1 Mike Berners-Lee. *A Climate of Truth: Why We Need It and How To Get It.* Cambridge University Press, 2025.

3.2 Keynote 2: Vint Cerf

Vint Cerf is a Vice President and Chief Internet Evangelist for Google. He is known as one of the "Fathers of the Internet" for his work on TCP/IP protocols and the architecture of the Internet. For this and his continuing work on Internet development and his efforts to increase access to the Internet for everyone, he has received numerous accolades worldwide. Notably, he is a recipient of the ACM Alan M. Turing Award. His keynote focused on the impact of developing technologies both in contributing to the climate crisis and, potentially, to providing solutions.

Cerf discussed the role of machine learning in understanding climate change through detecting complex patterns (e.g. "atmospheric rivers") and forecasting future trends. He advocated for extensive data collection on temperature changes, atmospheric conditions, and other climate variables to improve predictions and develop more effective interventions. He further stressed the need to refine theoretical models to improve their predictive power and, thus, help policymakers craft effective, targeted responses.

Like Berners-Lee, Cerf raised alarm regarding the urgency of the climate crisis. He noted, however, that even if changes were implemented immediately to drastically reduce emissions, the climate has already altered in ways that require serious consideration of climate adaptation strategies. He suggested that computing could be particularly useful here in modeling risks and benefits of novel interventions through large-scale simulations, thereby helping to avoid unintended negative consequences. He also noted the potential for advanced computational tools to assess regional risks and guide planning.

Cerf also echoed Berners-Lee in calling for solutions to combat misinformation. Chief among these is the need for increased public education to be able to evaluate online sources and verify data. Computing could further promote fact-based climate discourse by using digital signatures to authenticate images and reports, labeling AI-generated content, and flagging informational inaccuracies.

Cerf noted the key role of industry in driving change. Acknowledging that responding proactively to climate change contributes to the long-term profitability of companies, he urged businesses to integrate sustainability into their operations (e.g. pursuing improved hardware efficiency and the use of renewable energy) before such changes are legally mandated. He also underscored the need to develop robust and adaptable technologies that can withstand disruptions that might arise from environmental or political instability to avoid catastrophic failures in critical infrastructures.

The keynote concluded by emphasising that developing effective solutions will require collaboration between environmental scientists, economists, technologists, and policymakers, and that computing can be the bridge between these disciplines through modeling, predicting, and assessing synergistic solutions. In this way, computing can help with navigating the complexities of climate change while simultaneously building the requisite infrastructure for a more resilient, sustainable future.

3.3 Discussion

The first day involved considerable discussion of computing professionals' responsibilities with respect to the climate crisis. One dimension of this responsibility is ensuring that the environmental footprint of computing technologies themselves are minimised through actively considering these impacts throughout the development process. Responsible innovation frameworks were seen as useful in guiding development of new technologies in line with environmental considerations. There was some debate as to whether existing codes of ethics, such as those put out by ACM [1] and IEEE [2], adequately address the environmental impacts of computing.

Resilient system design emerged as an important challenge for the sector. Many agreed that the field places too much emphasis on rapid iteration, often leading to unsustainable infrastructure. Participants emphasised the need to create systems that can function reliably over long periods without requiring frequent maintenance. They also stressed that overly complex systems tend to be resource-intensive, and suggested that change in the direction of simplicity would be environmentally beneficial.

Regulation was another important theme of the day's discussions. There was a suggestion that computing professionals should adopt regulatory structures similar to those in the medical field, where ethical review processes are a prerequisite for new developments. While this could ensure greater accountability for the long-term impact of technological advancements, there were as yet unresolved questions regarding the practical implications of this suggestion. There was agreement, however, about the importance of incorporating environmental and social impact assessments into all technological developments.

There was also debate about stronger regulation of specific classes of computing technologies. Technologies such as blockchain, cryptocurrencies, and generative AI were debated extensively due to their outsized environmental impacts. Discussion highlighted that impacts, both positive and negative (environmental and otherwise), are highly dependent on their specific applications and implementations, complicating any potential regulation.

Participants also discussed the importance of systemic, industry-wide change driven by policy reforms. Ensuring accountability was noted as a particular challenge, and participants explored how companies could be prevented from bypassing ethical responsibilities, as they might do through strategic public relations efforts.

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2 ACM Code 2018 Task Force. IEEE Code of Ethics and Professional Conduct – 7.8 IEEE Code of Ethics. Professional code, IEEE, 2018.

4 Day 2: Effecting Positive Change

The second day of the workshop focused on the practical matters of effecting the kinds of positive changes that were articulated the previous day. Discussions centred considerations of accountability and governance, the role of researchers and policymakers, and the influence of professional bodies such as the Association for Computing Machinery (ACM).

The morning session focused on methodologies for measuring the environmental footprint of computing technologies and some of their strengths and weaknesses. Keynotes by Vlad C. Coroamă and Emma Strubell provided a basis for discussion on what oversight might look like if the computing sector were to coordinate efforts towards improved climate responsibility. The afternoon session began with a keynote by Tom Romanoff which prompted discussion on opportunities for influencing global technology policy.

4.1 Keynote 3: Vlad C. Coroamă

Vlad C. Coroamă is the founder of the Roegen Centre for Sustainability (Zurich, Switzerland) and affiliated researcher and lecturer with the TU Berlin, Germany. His research revolves around the relation between computing and the environment. He contributed both methodologically and with concrete assessments to understanding the environmental impact of ICT. Today, his main research interest lies in exploring the mechanisms through which computing can save resources, energy and emissions, and how to best exploit this potential, while understanding and avoiding the counteracting rebound effects.

The environmental effects of computing are numerous, multifaceted and intertwined. Various taxonomies for their conceptualisation have been proposed. This presentation used one of the simplest conceptualisations, which distinguishes between direct effects, beneficial indirect effects and detrimental indirect ones [1].

Focusing on indirect effects, the presentation started by presenting the typical bottom-up estimation process, as deployed in several of the current assessment methodologies. For the example of teleworking [2], these steps are:

- First, identifying impact avoidance mechanisms (e.g., less commute, less office energy).
- Then, the baseline impact is estimated in a counterfactual without the computing service (i.e., the environmental impact of traditional commuting).
- The third and fourth step estimate the savings per usage for each mechanism identified in step 1 and the adoption rate of the service, respectively.
- Finally, the overall beneficial effect is computed as the sum over all mechanisms of the mechanisms effect per instance times the adoption rate.
- Usually as a mere afterthought, rebound effects (and the negative indirect effects they trigger) are mentioned but not assessed.

In its second part, the presentation discussed some of the flaws and limitations of this paradigm:

1. The ontologically uncertain set of mechanisms yielding indirect effects, and the epistemically uncertain assessment of those that are known.
2. The “chronic potentialitis” [3] of such assessments, which typically lie in the future and their occurrence is almost never validated in hindsight.
3. The plethora of different types of rebound effects that exist and can outweigh the positive indirect effects.

4. The difficulty in estimating the hypothetical baseline/counterfactual, often leading to its overstatement, which consequently also yields an overstated positive effect.
5. Possible time boundaries for indirect effects: When they become part of the socio-technical regime [4], should these effects no longer be considered additional?
6. The possibly difficult boundary between rebound effects and economic growth: Are rebound effects merely one mechanism of economic growth, and if so, should they be counted as indirect effects of computing at all?

To address some of the first 4 limitations, the final part of the presentation argued in favor of top-down assessments such as quantitative systems dynamics or input-output analyses. As opposed to bottom-up assessments, they can set the system boundary arbitrarily wide and thus account for the subtle and hard-to-grasp mechanisms as well. For top-down assessments, however, causal links are hard to establish, so they miss some of the explanatory power of bottom-up analyses. A hybrid approach deploying both might thus be called for.

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3 Vlad C. Coroamă. The chronic potentialitis of digital enablement, 2024.
4 Frank W Geels. The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental innovation and societal transitions*, 1(1):24–40, 2011.

4.2 Keynote 4: Emma Strubell

Emma Strubell is the Raj Reddy Assistant Professor in the Language Technologies Institute (within the School of Computer Science) at Carnegie Mellon University. Strubell's research focuses on advancing machine learning and natural language processing methodology and measurement in order to promote environmentally sustainable development and deployment of AI. work has been recognised with a Madrona AI Impact Award, best paper awards at ACL and EMNLP, and in 2024 they were named one of the most powerful people in AI by Business Insider.

Modern AI approaches, powered by deep learning and large language models (LLMs), have the potential to accelerate progress by augmenting human intelligence in our efforts to overcome urgent societal challenges such as climate change. At the same time, training and deploying these increasingly capable models comes at an increasingly high computational cost, with corresponding energy demands and environmental impacts. This presentation characterises the complex relationship between AI and the environment through the lens of LLMs, with a focus on describing what we know about AI's direct environmental impacts.

The presentation begins by establishing some high level metrics for how much we know that AI is emitting in terms of direct GHG emissions, versus how much we should in fact be curbing those emissions. While there exist many potential environmentally beneficial applications of AI, such as energy optimisation, materials discovery, and policy analysis, many these benefits have yet to be demonstrated in practice while the negative environmental impacts are already quite clear. At the same time, AI's energy consumption is growing, despite targets to reduce emissions due to ICT (including AI data centre emissions) by 50%

by 2030 [1]. Self-reported GHG emissions from major tech companies are rising significantly due to the increasing development and deployment of generative AI such as LLMs [3, 2, 4], which are resource intensive during model development (training) and use (inference). While training is the most well-studied phase of the AI model lifecycle where data is most readily available, inference likely makes up the majority of AI energy use, and rapidly growing due to recent methodological trends such as DeepSeek.

The presentation then shows that estimates of data centre energy usage vary widely, and argues that this stems from a lack of available data. There is a need for greater transparency from major tech companies regarding their energy use and emissions to improve assessments of direct impacts. There is also a need for better benchmarking tools, following from first steps via the AI Energy Score project [5], to measure and compare the energy efficiency of different models, and to better understand alignment between AI methodology, capability, hardware, and energy requirements.

The talk explores in more detail in what ways AI directly impacts the environment (primarily: GHG emissions, water consumption, and waste production), and how those impacts arise (examples: fossil-fuel based energy powering data centres, evaporative cooling to cool hardware in data centres, and mineral extraction for hardware.)

The presentation advocates for the importance of mitigating AI's direct impacts. The current, unsustainable, trajectory is a consequence of prioritising computational scaling over improved efficiency, or environmental sustainability. This could be spurred through enforcement of stricter emissions and energy-use guidelines, such as a carbon tax. The talk ends by calling for collaboration between policymakers, researchers, and industry leaders to put AI on a sustainable trajectory.

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4.3 Keynote 5: Tom Romanoff

Tom Romanoff is the ACM Director of Policy. In his career he has led AI policy research and issued recommendations adopted in NIST governance, White House Executive Order requirements, and US legislation. He launched AI101.org to educate and inform congressional staff on AI background and issues. He has also directed research and developed recommendations on topics including cybersecurity, privacy, technology's role in climate change mitigation, content moderation, data privacy, digital divide issues, and competition in the technology sector.

Romanoff's keynote provided an overview of the global regulatory and legislative landscape, current policy challenges, and reflections on strategy for effective advocacy in technology policy discussions, e.g. by organisations such as ACM. He noted that governments are investing billions in AI research and development for strategic advantage. They are also taking different approaches to regulating AI in different regions, with the US taking a market-driven approach with a slow roll-out of safeguards, the EU implementing stricter regulations such as the AI Act, and China prioritising AI efficiency and large-scale deployment, focusing on AI-driven infrastructure and national security applications. This has led to global regulatory fragmentation, hindering progress in curbing AI's environmental impacts.

Romanoff identified several challenges in AI governance as it relates to climate change. The first, echoing Strubell, is the lack of transparency around AI models and their environmental impacts. Another is the influence of corporate interests in shaping AI policy and the resulting prioritisation of profits over ethical considerations. To address these challenges, he advocated mandating transparency and developing clearer, and more proactive (rather than reactionary), AI accountability frameworks; greater involvement of independent experts in influencing policy; and development of mechanisms to ensure compliance and assess long-term policy effectiveness.

The remainder of the keynote explored strategy for influencing technology policy. He recommended pursuing both insider and outsider strategies, i.e. establishing relationships with policymakers while simultaneously adding pressure through media influence. He also stressed that materials presented to policymakers must be backed by robust data to enhance credibility and framed in an accessible manner to be consumed by busy staffers; and that they are strategically timed to coincide with policy cycles and current priorities. This often means being ready to respond to calls for comment at short notice. He ended by providing some insights into the ways ACM currently works to influence policy, and how workshop participants could leverage these mechanisms to amplify the group's manifesto.

4.4 Discussion

A major theme of the second day was the growing trend toward regulating of AI. The European Union's AI Act was discussed as a key example of such efforts, with participants exploring its implications for technology companies inside Europe and beyond. Of concern was the apparent pattern of big tech firms using their lobbying power to shape regulations to suit their financial interests. A noted corporate strategy was framing AI as a necessary tool for progress, even progress on environmental issues, while downplaying its various negative impacts. The lack of transparency, e.g. regarding data usage and carbon emissions, was seen as enabling overly positive framings of AI. Aware of the challenges in measuring AIs' environmental impacts, participants proposed creating standardised benchmarking tools to help with assessment of energy consumption. Participants also explored various strategies for mitigating AIs' energy consumption, including developing more efficient algorithms, optimising model architectures, and exploring alternative computing paradigms such as neuromorphic computing. There was some discussion of incentives for industry leading a transformation along these lines, given that rising costs of AI infrastructure may make large-scale models financially unsustainable in the long run, even potentially catalysing a new "AI winter".

The other major theme of the day was an exploration of the role of computing professionals in influencing policy. It was broadly agreed that researchers and industry experts should take a more proactive approach to influencing policy. This was seen as critical given that policymakers lack the technical knowledge needed to craft effective policies. Strategies for policy engagement were explored at length. Those noted as especially relevant were capitalising on opportunities for providing expert testimony and publishing research on AI's impacts, but also included advocating for policies that promote transparency and sustainability, collaborating with advocacy groups, and educating the public on the long-term consequences of AI-driven energy consumption.

5 Day 3: 19 March 2025

5.1 Manifesto Development and Long-Term Vision for Computing

On the final day, participants worked toward developing a Manifesto, outlining key values and responsibilities for the field. The session consisted largely of full-group discussion, with participants debating audience, structure, content, and specific wording for the Manifesto, with all involved in co-writing a draft.

One of the key debates was whether the Manifesto should primarily address computing professionals, policymakers, or both. Some suggested a tiered approach, including different recommendations for individual developers, corporations, and policymakers, thus allowing for a more nuanced and actionable set of guidelines. The group decided for a more general approach that represented the core commitments of those in attendance, but potentially building on the Manifesto in ways that targeted different audiences.

While not explicitly referenced in the final Manifesto, the concept of "doughnut economics" [1] was used as a reference point to guide conversations around boundaries. The consensus, in line with this economic model, was that technological development must operate within environmental boundaries while also meeting basic societal needs. As for environmental boundaries, participants stressed that the Manifesto should draw attention to the issue of electronic waste, discouraging planned obsolescence and encouraging the development of repairable and reusable technologies.

Another source of debate was the question of whether computing has more potential for harm or for good when it comes to the issue of climate change. A shared concern was the tension between the profit motives for big tech and issues of public interest (e.g. sustainability), and agreement that our Manifesto ought to advocate strongly for prioritising public interest.

The environmental impacts of large-scale AI continued to be an important focal point for discussion. There was significant unease amongst participants about the unchecked expansion of AI – not only in terms of the environmental impacts of this expansion but also in terms of social impacts, e.g. on labour markets. The notion of mandating that AI developers conduct environmental impact assessments before deploying new models was explored in terms of its practical implementation, e.g. who scrutinises these assessments, who might oversee approvals, and how would this be coordinated given geopolitical tensions? The group conceded significant challenges, while agreeing that the Manifesto should nonetheless endorse transparency.

Participants also stressed the importance of using research to inform policy and ensuring that professional organisations, such as ACM, actively advocate for ethical computing policies. This became an important theme within the resulting Manifesto.

The final half hour of the workshop was dedicated to exploring next steps, including avenues for amplifying the impact of the Manifesto or otherwise shaping technology policy. A number of practical steps were identified, including various outputs that could reiterate the Manifesto for different audiences.

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1 Kate Raworth. *Doughnut economics: Seven ways to think like a 21st century economist.* Chelsea Green Publishing, 2018.

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