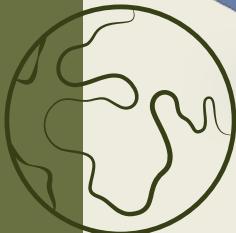




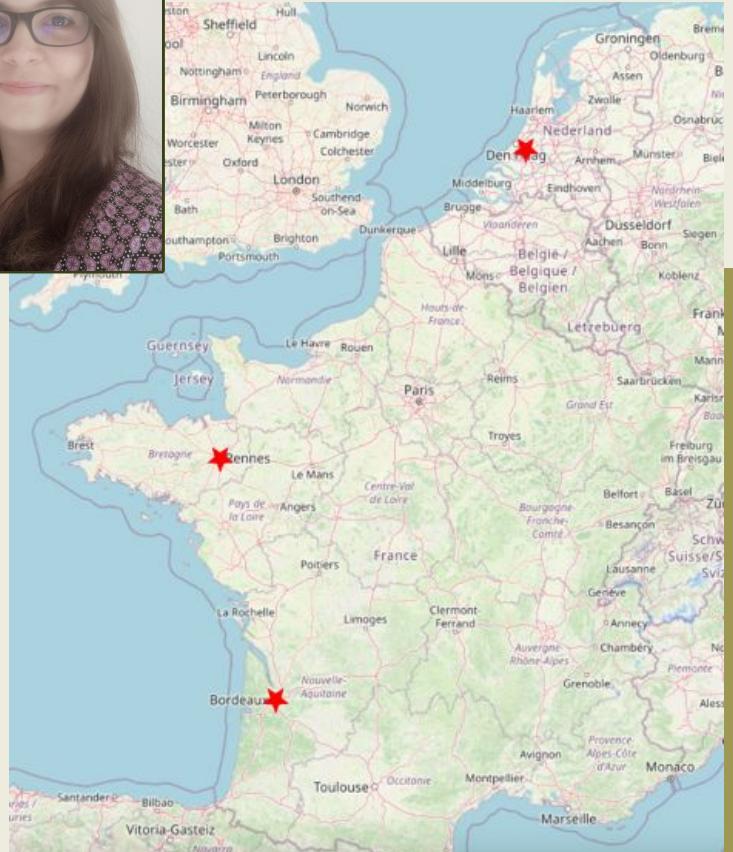
# Sustainable Software Engineering: What about Social Sustainability?





# My background

- MEng in Agronomy/Environmental Science (CS Major)
- MSc in Software Engineering
- PhD in Software Engineering (for Sustainability)
- Postdoc in (Sustainable) Software Engineering
  - TU Delft, SERG



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(Social)  
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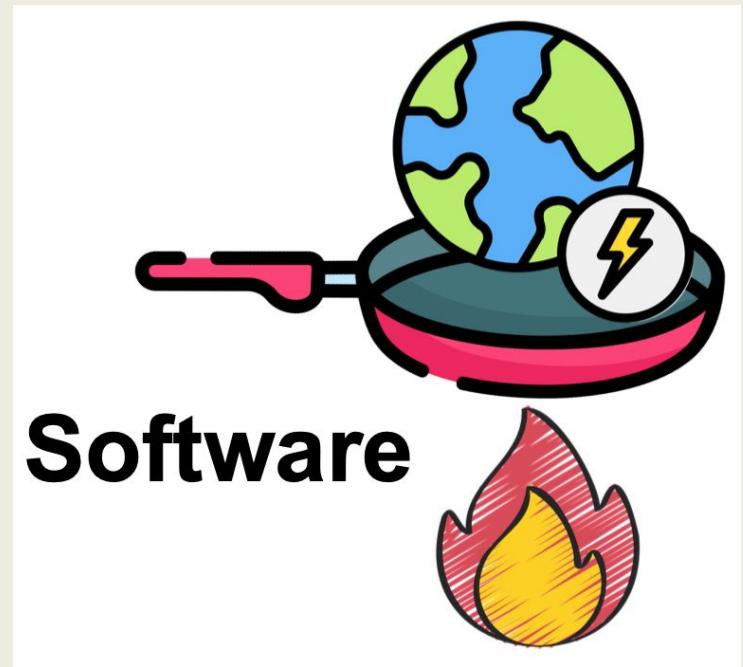
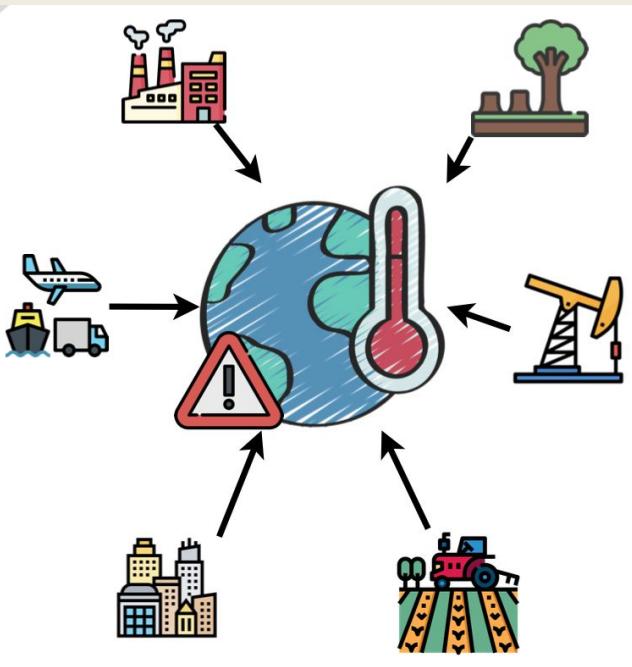




# 01 Social Sustainability?

*What is it about?*

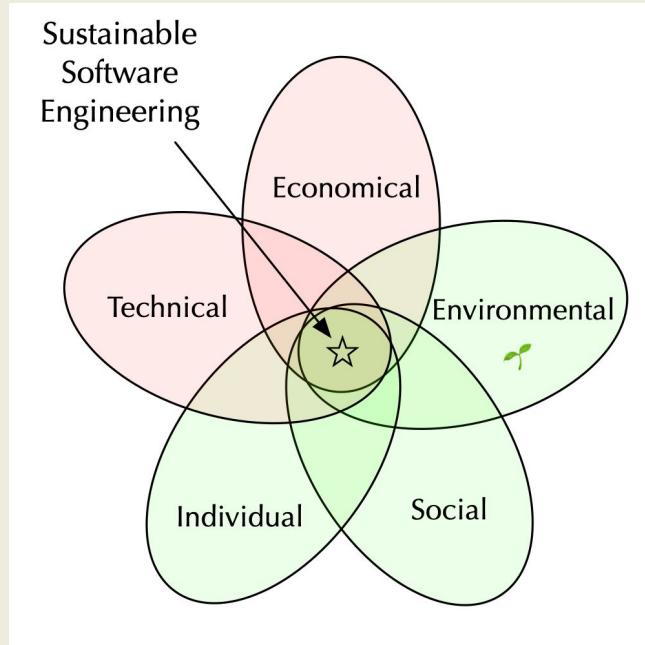
# Software is (h)eating the world!



# Sustainability & SE

*"Software Engineering (SE) has a **major role** to play in sustainability, because of the extent to which software systems mediate so many aspects of our lives." [Becker, et al., 2015]*

# (Software) Sustainability



"Software whose direct and indirect negative impacts on economy, society, human beings, and the environment resulting from development, deployment, and usage of the software is minimal and/or has a positive effect on sustainable development" [Al Hinai, and Chitchyan, 2016]

- Multi-dimension
- Intersection
- Complex

# **“Social sustainability can include anything”**

Then, what does that mean?



# Social Sustainability

"concerned with **societal communities** (groups of people, organizations) and the factors that erode **trust** in society. This dimension includes social **equity, justice, employment, democracy**, etc." [Becker, et al., 2015]

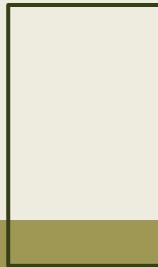
"Social sustainability may refer to a system's impact on: the individual's physical or **psycho-social wellbeing** (individual level); team cohesion and resilience (team level); organization culture (organization level); or pro-social vs. anti-social affordances (societal level)." [McGuire, et al., 2023]

"every line of code has not just financial and technical implications, but also **moral and ethical consequences**, as software services shape and inform **human behaviour**"  
[Chitchyan, et al., 2016]



02

## The need to invest(igate)





# Why?

- Sustainability = intersection of dimensions.
  - Need for overview / holistic view
  - Trade-off
- Climate change / civilisation preservation
- Pragmatic incentives: EU Corporate Sustainability Reporting Directive (start 2024)
- Developers want to address sustainability in software development
  - No full understanding
  - But no tools

*"Notion of social sustainability is hugely important in the society at large, as evidenced by standards and research" [Al Hinai, Chitchyan, 2016]*

*"The software professionals still have very little awareness of these topics and even less practical engagement with them."*

# Gaps

## Sustainability is Stratified: Toward a Better Theory of Sustainable Software Engineering

Publisher: IEEE

Cite This

Sean McGuire ; Erin Schultz ; Bimpe

### Sustainability design in requirements engineering: state of practice

Authors:  Ruzanna Chitchyan,  Christoph Becker,  Stefanie Betz,  Leticia Duboc,  Birgit Penzenstadler,

 Norbert Seyff,  Colin C. Venters [Authors Info & Claims](#)

- Less sustainability research in SE than other fields
- Non-empirical (position papers)
- Software products rather than processes
- Rarely addressed holistically
  - Focus on env sust => energy efficiency
  - Technical sustainability
  - “Social factors are sometimes considered important but never addressed systematically”
- Methodology / Tool support lacking

*“There is still a significant lack of metrics to measure the sustainability in individuals and social communities, mainly as a result of sustainability actions in technical and environmental dimensions. We still need to connect these dimensions to understand how sustainability benefits people” [Venters, et al., 2023]*



# 03 Challenges

# Challenges



## Complexity

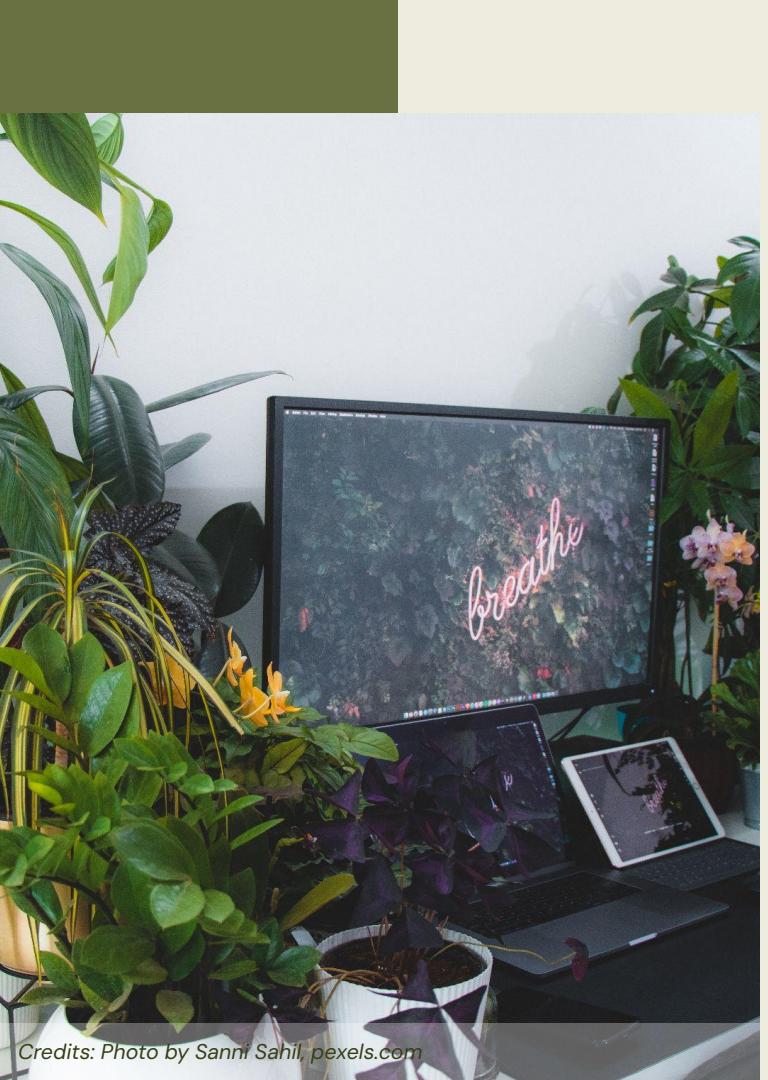
How to model such complexity wrt software sustainability?

## Expertise

People that can understand the different point of views, with diverse backgrounds.

## Community?

No established community as such yet?  
ICT4D (Information and Communications Technologies for Development)



# 04

# Confer Env Sustainability

# What's in progress

- Adding the env sustainability perspective on SE practices
  - Metrics
  - Methods / Assessments (LCA)
  - Empirical studies / exploratory
- Education (Courses)
  - SLR on
  - Sustainable SE (TU Delft, Master degree)  
[https://luiscruz.github.io/course\\_sustainableSE/2023/](https://luiscruz.github.io/course_sustainableSE/2023/)
- Dedicated venues

## Sustainability in Computing Education: A Systematic Literature Review

A.-K. Peters, R. Capilla, V. C. Coroamă, R. Heldal, P. Lago, O. Leifler, A. Moreira, J. P. Fernandes, B. Penzenstadler, J. Porras, C. C. Venters

Research shows that the global society as organized today, with our current technological and economic system, is impossible to sustain. We are living in the Anthropocene, an era in which human activities in highly industrialized countries are responsible for overshooting several planetary boundaries, with poorer communities contributing least to the problems but being impacted the most. At the same time, technical and economic gains fail to provide society at large with equal opportunities and improved quality of life. This paper describes approaches taken in computing education to address the issue of sustainability. It presents results of a systematic review of literature on sustainability in computing education. From a set of 572 publications extracted from six large digital libraries plus snowballing, we distilled and analyzed the 90 relevant primary studies. Using an inductive and deductive thematic analysis, we study 1) conceptions of sustainability, computing, and education, 2) implementations of sustainability in computing education, and 3) research on sustainability in computing education. We present a framework capturing learning objectives and outcomes as well as pedagogical methods for sustainability in computing education. These results can be mapped to existing standards and curricula in future work. We find that only a few of the articles engage with the challenges as calling for drastic systemic change, along with radically new understandings of computing and education. We suggest that future research should connect to the substantial body of critical theory such as feminist theory of science and technology. Existing research on

# Some examples of work

- Context Awareness
- Adaptation
- Trade-off
- Approximate computing
- Useful & Usable (Gail Murphy)

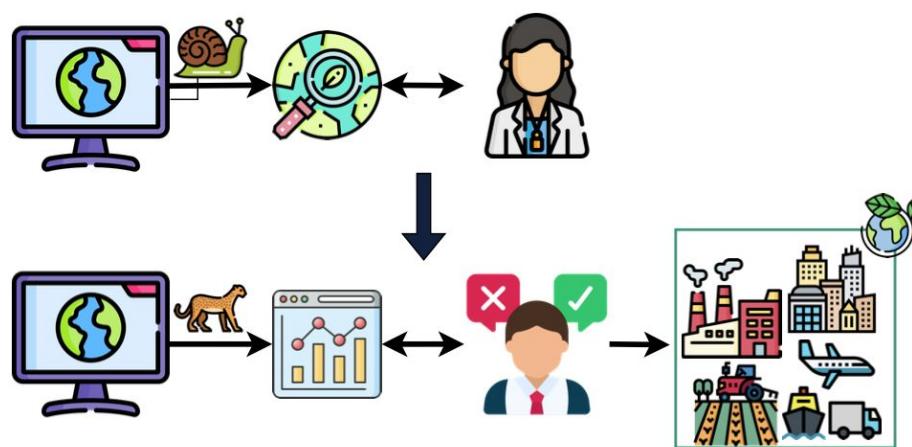


*"most real-world software is embedded in a social context, and that changes in the software and the world affect each other." [Becker, et al., 2025]*

# Approximate Computing for Sustainable Decision-Making

## Loop Aggregation for Approximate Scientific Computing

[June Sallou](#)✉, [Alexandre Gauvain](#), [Johann Bourcier](#)✉, [Benoit Combemale](#)✉ & [Jean-Raynald de Dreuzy](#)



# Approximate Computing for Green AI

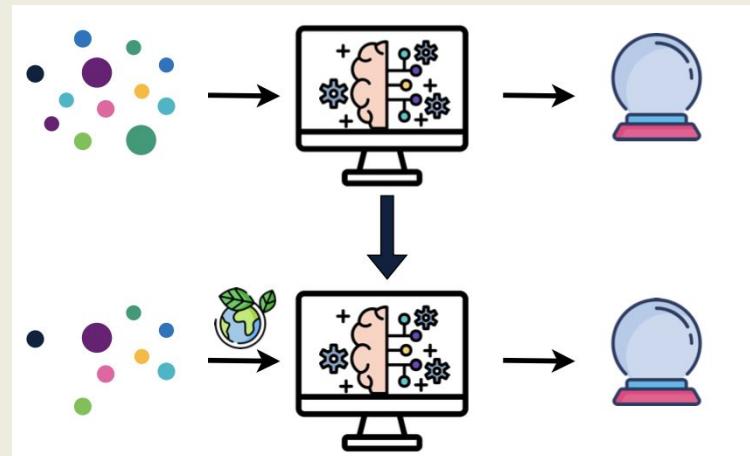
## Data-Centric Green AI An Exploratory Empirical Study

Publisher: IEEE

Cite This

PDF

Roberto Verdecchia ; Luís Cruz ; June Sallou ; Michelle Lin ; James Wickenden ; Estelle Hotellier [All Authors](#)



# Sustainable Adaptation of AI models

Retrain AI Systems Responsibly! Use Sustainable  
Concept Drift Adaptation Techniques

Lorena Poenaru-Olaru\*, June Sallou\*, Luis Cruz\*, Jan S. Rellermeyer †, Arie van Deursen\*

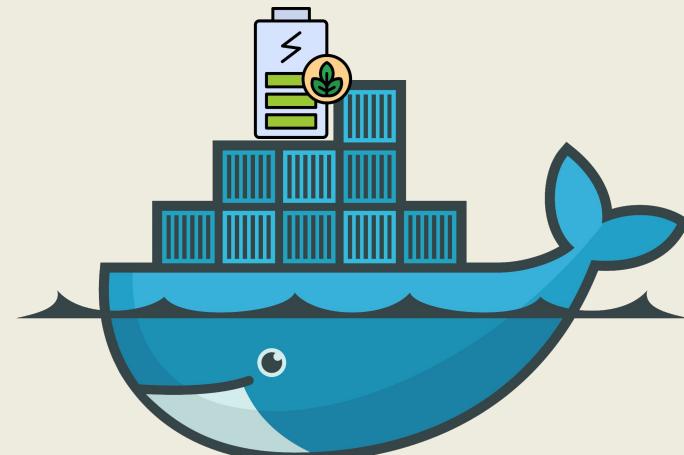
\*Software Engineering, TU Delft, Netherlands

†Dependable and Scalable Software Systems, Leibniz University Hannover, Germany

L.Poenaru-Olaru@tudelft.nl, j.sallou@tudelft.nl, L.Cruz@tudelft.nl, rellermeyer@vss.uni-hannover.de, arie.vandeursen@tudelft.nl

# Software Containerisation

Master thesis: "The impact of base image selection on the energy efficiency of containerized applications"



docker

# Digital Twins for Sustainable SE

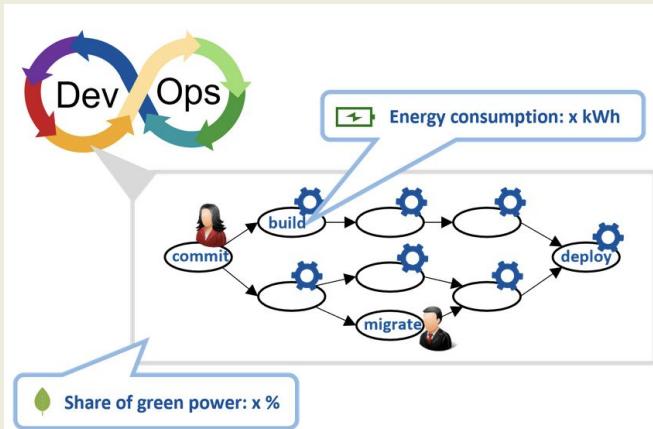
## Digital Twins for Sustainable Software Systems

Publisher: IEEE

Cite This

PDF

Malte Heithoff ; Alexander Hellwig ; Judith Michael ; Bernhard Rumpe [All Authors](#)



Master Thesis Project:  
<https://www.se-rwth.de/theses/MA.sustain.bpmn/>



# 05

# Transfer to Social Sustainability

# Just do it!

- Start small but dream big
- Exploratory
- **Empirical!**
- Add another layer / perspectives to what is already done (technical sustainability)

# Ideas / Perspectives



**Definition of  
Social  
Sustainability**

**Social  
Sustainability  
metrics**

**Digital Twins for  
SE Social  
Sustainability**

**Impact of  
Generative AI on  
Social  
Sustainability**

**Perception of  
Software  
Sustainability /  
Stakeholder  
Involvement**

**Trade-off  
between Env,  
Social, and  
Technical  
Sustainability**

# Ideas / Perspectives



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# Ideas / Perspectives



Definition of  
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Social  
Sustainability  
metrics

Digital Twins for  
SE Social  
Sustainability

## Emotions and Perceived Productivity of Software Developers at the Workplace

Daniela Girardi, Filippo Lanubile, Nicole Novielli (Corresponding author), Alexander Serebrenik

## Emotion Analysis in Software Ecosystems

Nicole Novielli, Alexander Serebrenik

# Ideas / Perspectives



**Definition of  
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# Ideas / Perspectives



Definition of  
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sustainability

Social  
Sustainability  
metrics

Digital Twins for  
SE Social  
Sustainability

## Current Trends in Digital Twin Development, Maintenance, and Operation: An Interview Study

Hossain Muhammad Muctadir, David A. Manrique Negrin, Raghavendran Gunasekaran, Loek Cleophas, Mark van den Brand, Boudewijn R. Haverkort

# Ideas / Perspectives



Definition of  
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Sustainability

# Ideas / Perspectives



## Cross-Language Plagiarism Detection: Methods, Tools, and Challenges: A Systematic Review

Miguel A. Botto Tobar (Corresponding author), Mark G.J. van den Brand, Alexander Serebrenik

**Impact of  
Generative AI on  
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Sustainability

# Ideas / Perspectives



## Opportunities and constraints of women-focused online hackathons

Lavinia Paganini, Kiev Gama, Alexander Nolte, Alexander Serebrenik

Impact of  
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Sustainability**

# Ideas / Perspectives



## Breaking bad? Semantic versioning and impact of breaking changes in Maven Central: An external and differentiated replication study

Lina Ochoa (Corresponding author), Thomas Degueule, Jean Rémy Falleri, Jurgen Vinju

Impact of  
Generative AI on  
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# Conclusion

## Expertise

### Opportunities

- Understanding
- Framework
- Metrics
- Practices
- **Empirical /**  
Implementation studies
- Reglementation

## Complexity

### Multidisciplinary

- Complementary perspectives
- Trade-off
- Complexity
- Useful & Usable

## Community?

### We need you!

- Expertise needed!
- Let's start the conversation. :)

*"In summary, we need a renewed set of metrics properly combined that can estimate sustainability in the different dimensions but also how these dimensions connect to each other in order to address several SDGs." [Venters, et al., 2023]*

# References

- McGuire, Sean, et al. "Sustainability is stratified: Toward a better theory of sustainable software engineering." 2023 IEEE/ACM 45th International Conference on Software Engineering (ICSE). IEEE, 2023.
- Chitchyan, Ruzanna, et al. "ICSE '16: Proceedings of the 38th International Conference on Software Engineering Companion." Sustainability design in requirements engineering: state of practice. Association for Computing Machinery, 14 May. 2016, pp. 533–42, doi:10.1145/2889160.2889217.
- Becker, Christoph, et al. "Sustainability design and software: The karlskrona manifesto." 2015 IEEE/ACM 37th IEEE International Conference on Software Engineering. Vol. 2. IEEE, 2015.
- Al Hinai, Maryam, and Ruzanna Chitchyan. "Engineering requirements for social sustainability." ICT for Sustainability 2016. Atlantis Press, 2016.
- Venters, Colin C., et al. "Sustainable software engineering: Reflections on advances in research and practice." Information and Software Technology, 11 Aug. 2023, p. 107316, doi:10.1016/j.infsof.2023.107316.



# Thanks!

Do you have any questions?

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# Trade-off between Accuracy and Energy Consumption in AI Training

## Uncovering Energy-Efficient Practices in Deep Learning Training: Preliminary Steps Towards Green AI

Tim Yarally\*, Luís Cruz\*, Daniel Feitosa<sup>†</sup> June Sallou\*, Arie van Deursen\*

\*Delft University of Technology, The Netherlands - timyarally@hotmail.com, { l.cruz, j.sallou, arie.vandeursen }@tudelft.nl

<sup>†</sup>University of Groningen, The Netherlands - d.feitosa@rug.nl