Sustainable Computing Science

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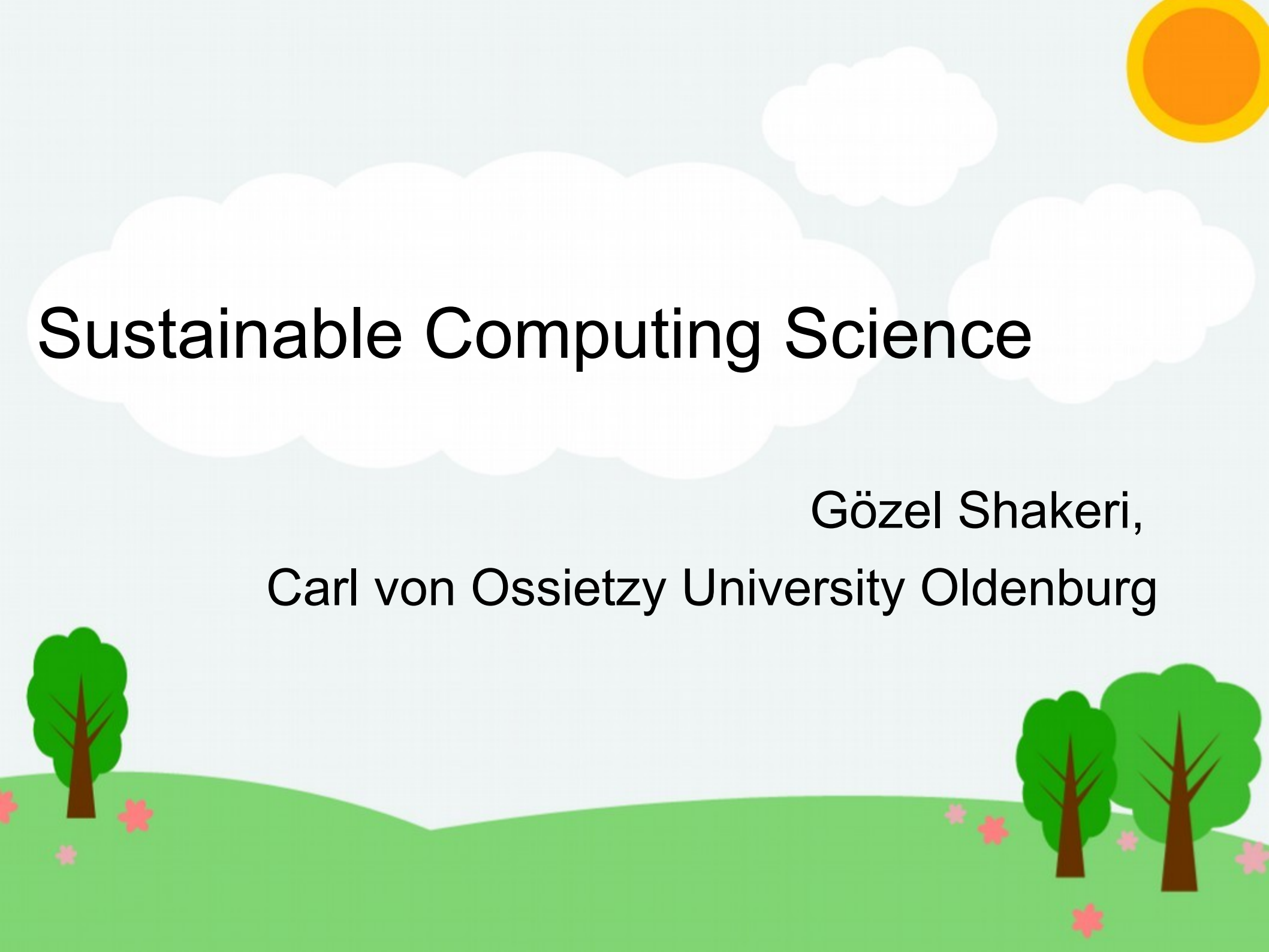
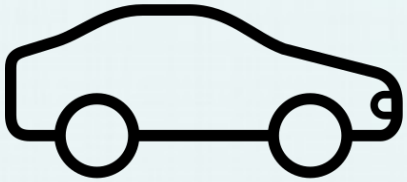
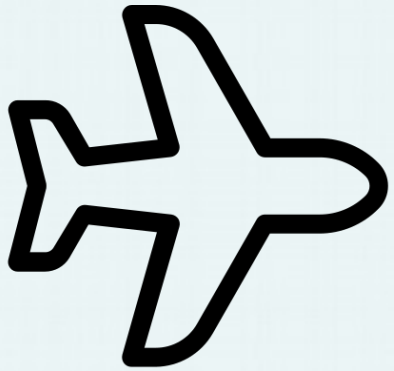
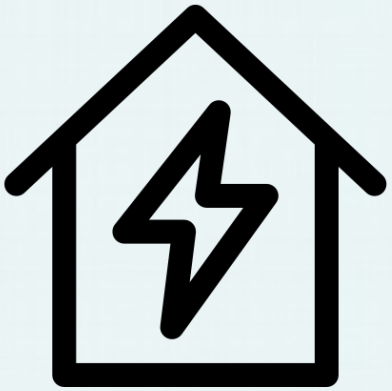
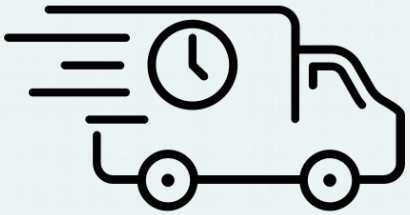


Carbon Footprint … ?

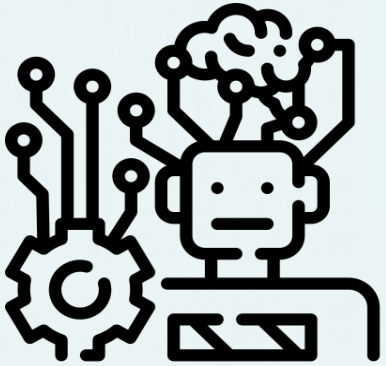




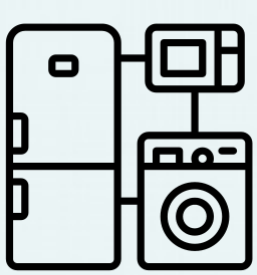
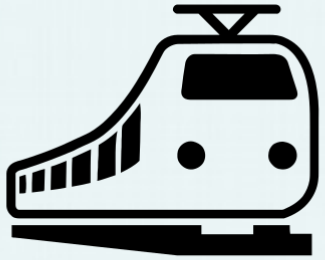




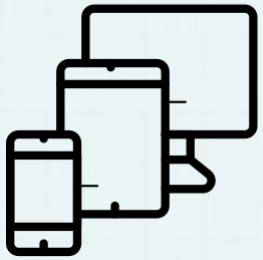
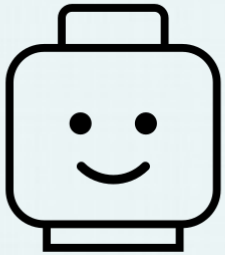
Carbon Footprint … ?



Computing is Ubiquitous





[1] Gupta et al., 2019, Chasing Carbon: The Elusive Environmental Footprint of Computing

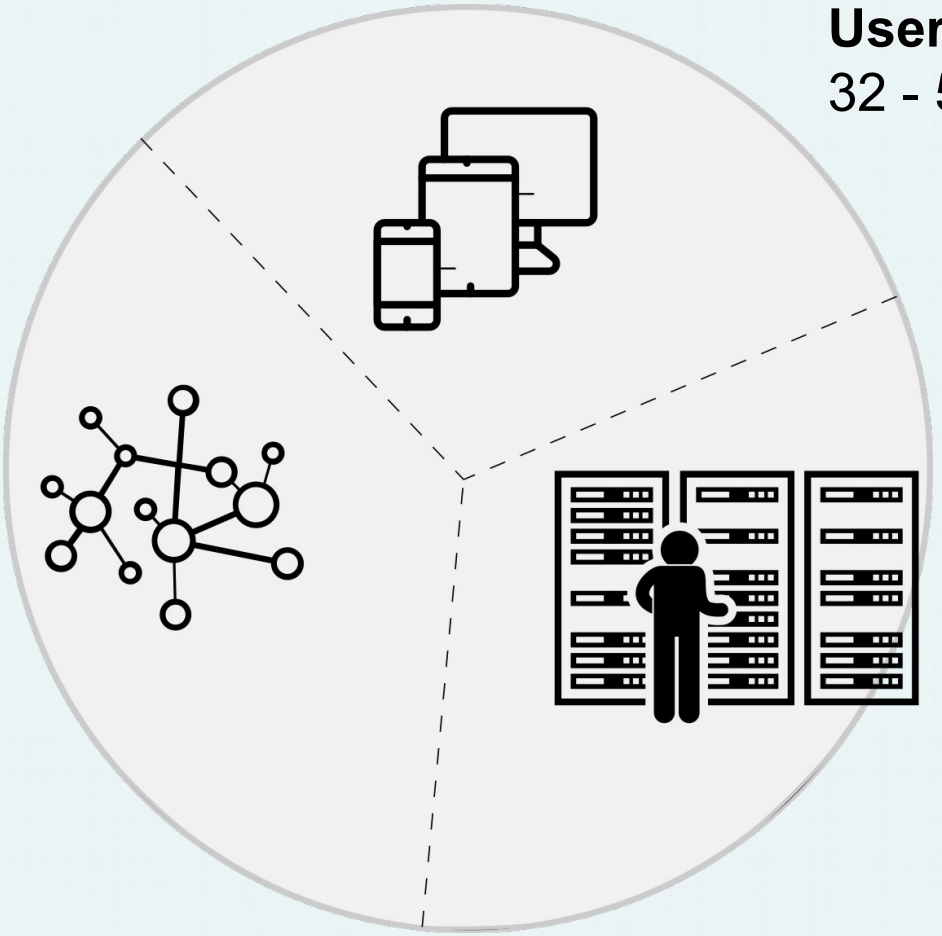
Information & Communication Technology's (ICT) impact

- Global Energy Consumption [1]:
  - Today: 5%
  - 2030: 7%
- Global Greenhouse Gas (GHG) emissions [2]:
  - 2 - 4%
  - aviation: 2%

- [1] Gupta et al., 2019, Chasing Carbon: The Elusive Environmental Footprint of Computing; [2] Freitag et al. 2021, The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations.

ICT’s Carbon Footprint

User Devices
32 - 57%



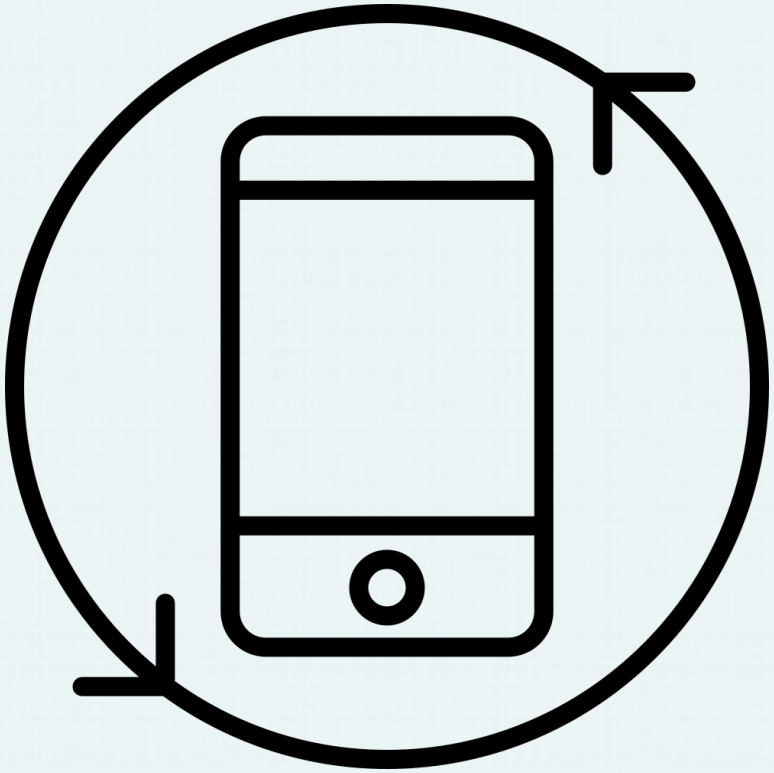
Networks
22 - 35%

Data Centres
18 - 41%

[1] Freitag et al., 2021, The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations; [2] Lannelongue et al., 2021, Green Algorithms: Quantifying the Carbon Footprint of Computation; [3] Gupta et al., 2019, Chasing Carbon: The Elusive Environmental Footprint of Computing.

Hardware's Carbon Footprint

Recurring Operations



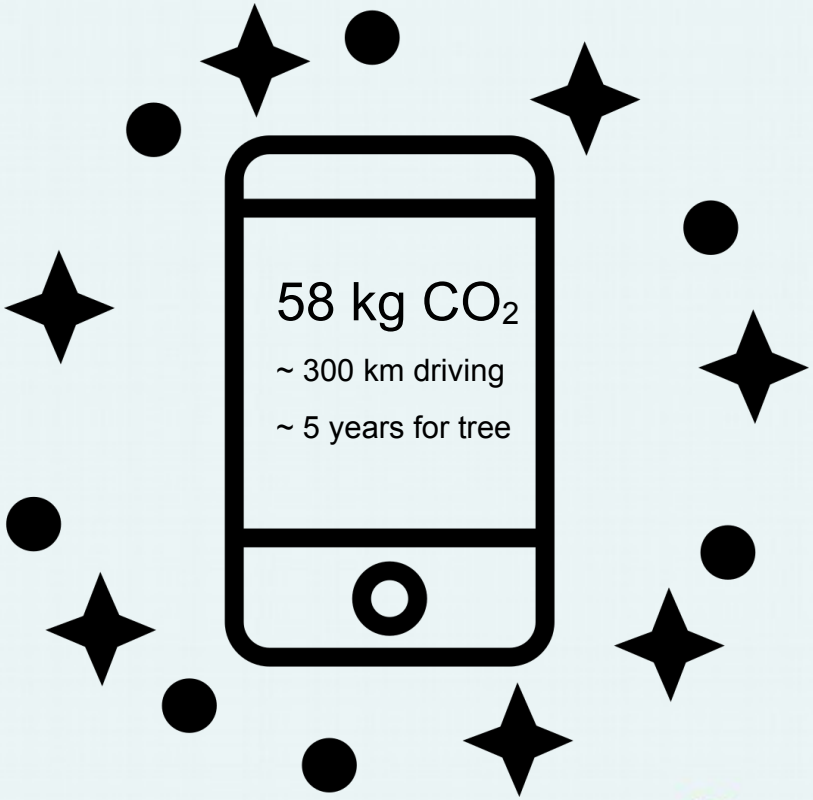
One-time Operations

[1] Lannelongue et al., 2021, Green Algorithms: Quantifying the Carbon Footprint of Computation; [2] Gupta et al., 2019, Chasing Carbon: The Elusive Environmental Footprint of Computing.

Hardware's Carbon Footprint

1st year: 25%

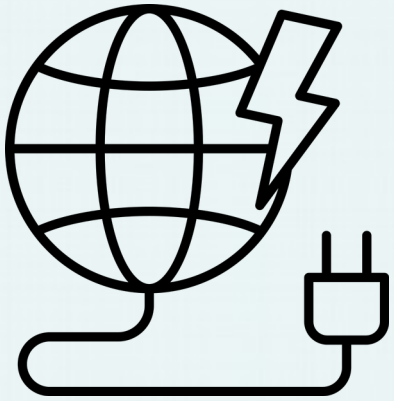
75%



[1] Mike Berners-Lee, 2020, How Bad are Bananas? The Carbon Footprint of Everything, ISBN: 9781788163811

To Recap

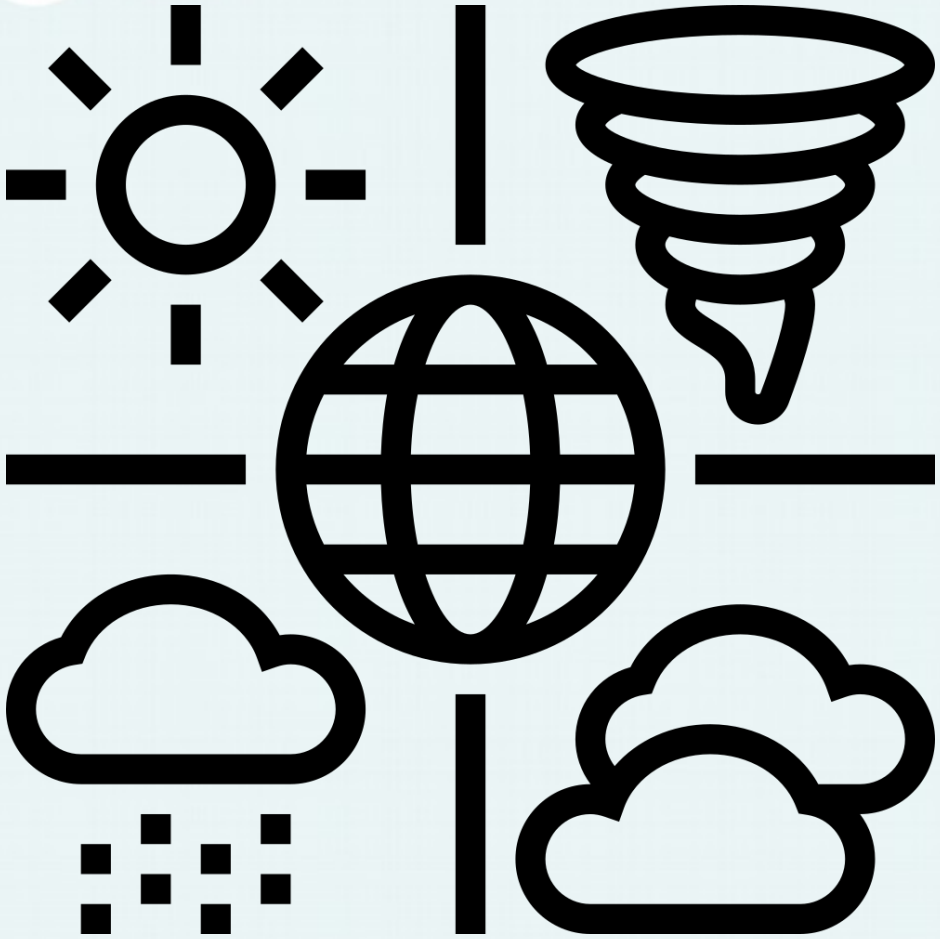
5 %



4 %

%

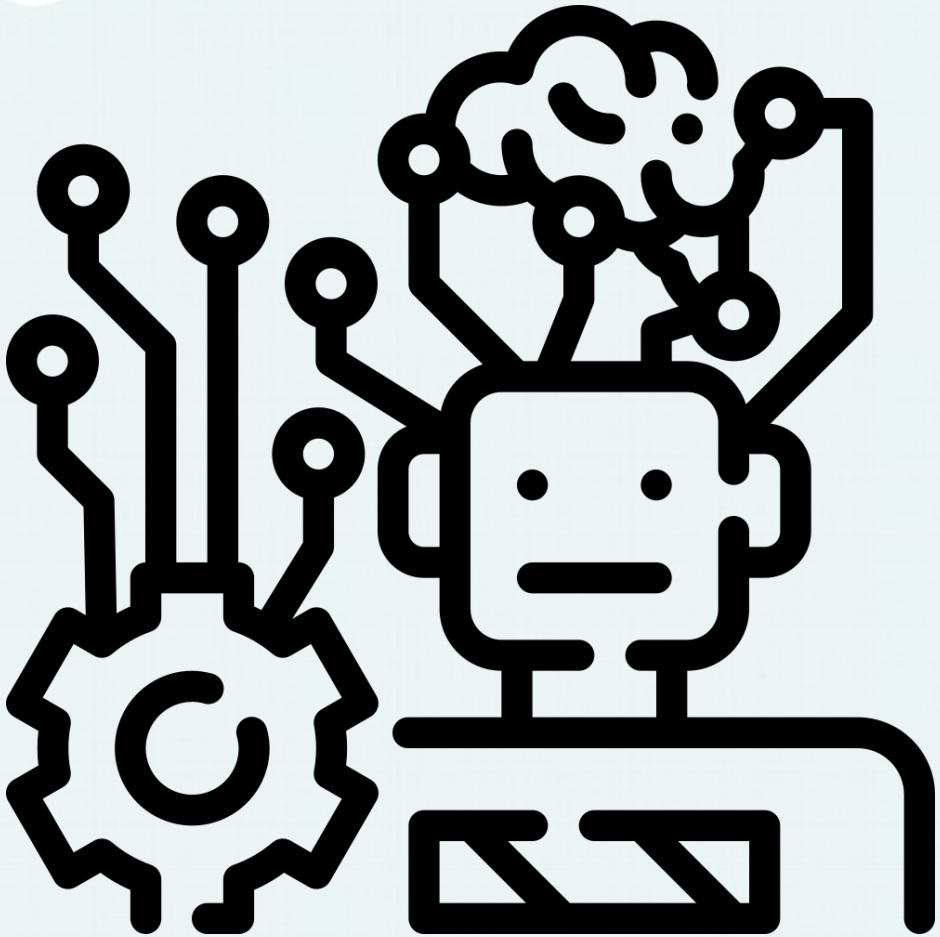
Software's Carbon Footprint



- Weather Forecast:
  - ICOsahedral Non-hydrostatic (ICON)
  - 2.5 tonnes of CO_2 / day
  - eq. to 13 215 km driving
  - eq. to 4 x NY ↔ SF flights
  - eq. to 227 new iPhone 12 / day
  - eq. to 210 years of 1 tree

[1] Lannelongue et al., 2021, Green Algorithms: Quantifying the Carbon Footprint of Computation

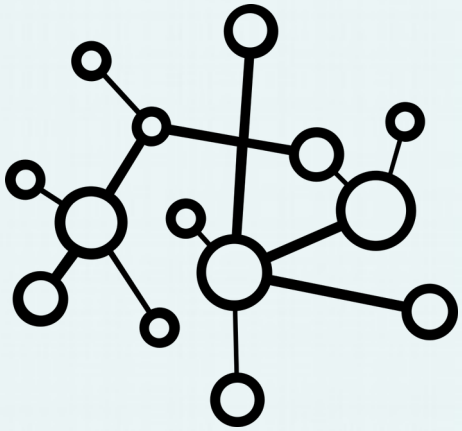
Software's Carbon Footprint

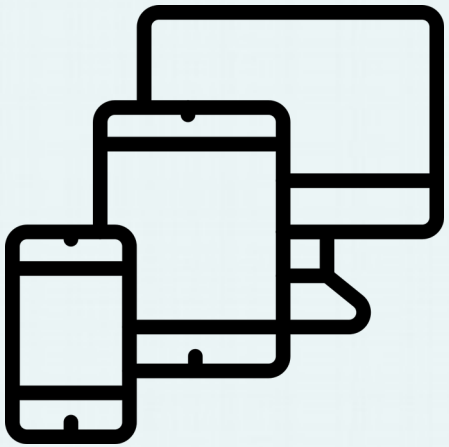


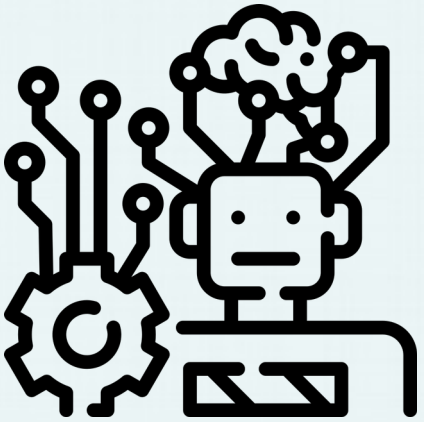
- Natural Language Processing:
  - Google's chatbot Meena
  - 164 tonnes of CO_2
  - eq. to 71 x NY ↔ Melbourne flights
  - eq. to 500 new iPhone 12 / day
  - eq. to 1500 years of 1 tree

[1] Lannelongue et al., 2021, Green Algorithms: Quantifying the Carbon Footprint of Computation

To Recap - Again







J’accuse!

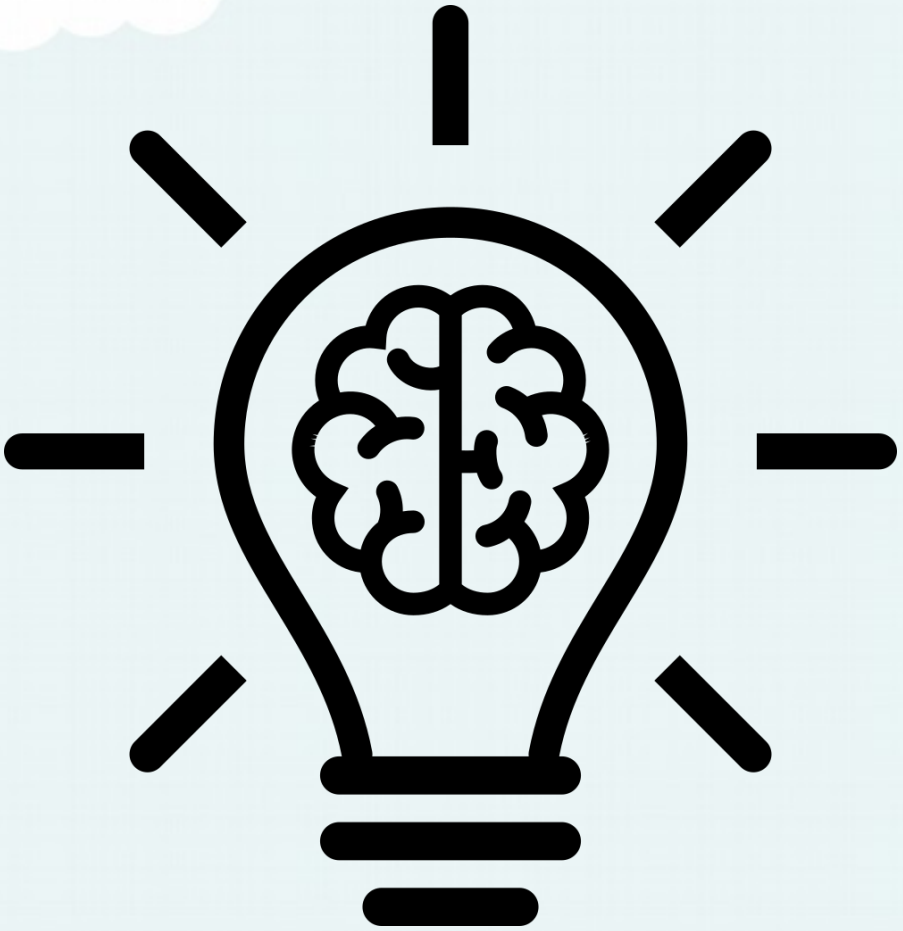
It’s all Evil Corp’s doing!

Optimise Everything!

- Algorithms
- Hardware
- Education
- Policies
- Understanding the link of research and impact on environmental and social justice

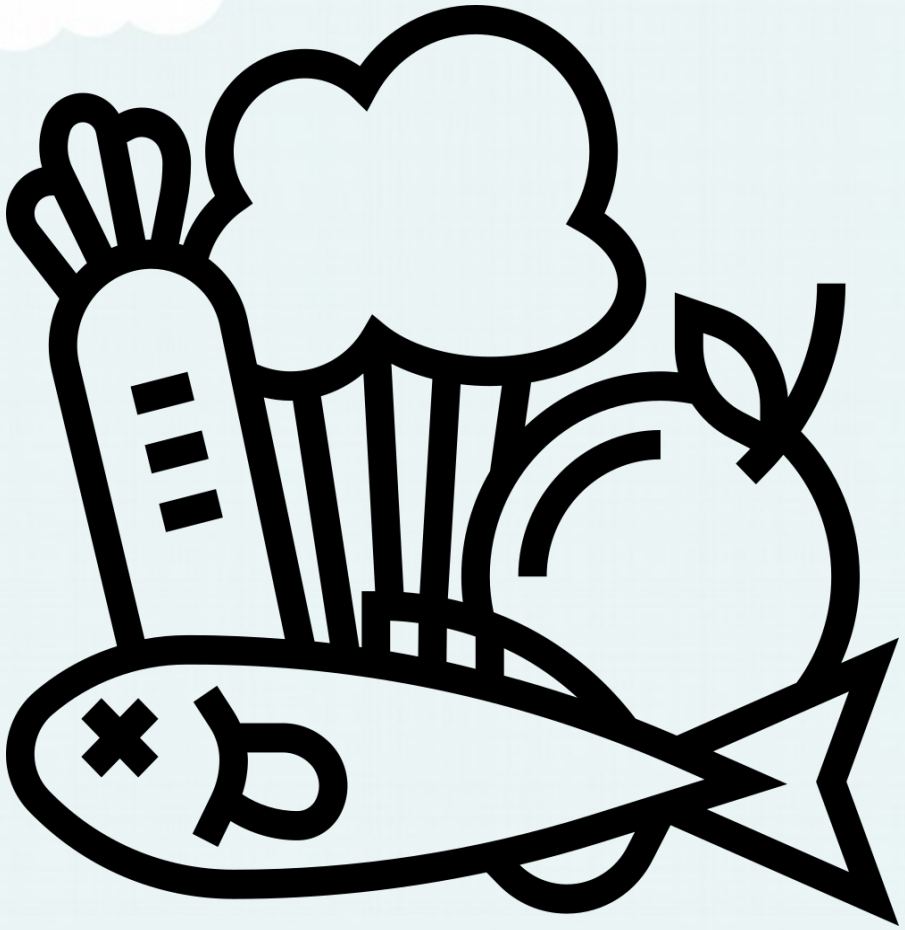
[1] Gupta et al., 2021, Chasing Carbon: The Elusive Environmental Footprint of Computing; [2] Lannelonge et al., 2021, Green Algorithms: Quantifying the Carbon Footprint of Computation; [3] Gomes et al., 2019, Computational sustainability: computing for a better world and a sustainable future; [4] Freitag et al., 2021, The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations; [5] Gormally et al., 2019, 'Doing good science': The impact of invisible energy policies on laboratory energy demand in higher education; [6] Bates et al., 2018, Championing Environmental and Social Justice;

Reimagine Everything!



- Food System (30% GHG)
- Fast Fashion (10% GHG)
- Renewable Energy
- Transportation System
- Digitalisation
- Education
- City planning
- Waste (e.g. food waste 8% GHG)
- Agriculture
- Etc

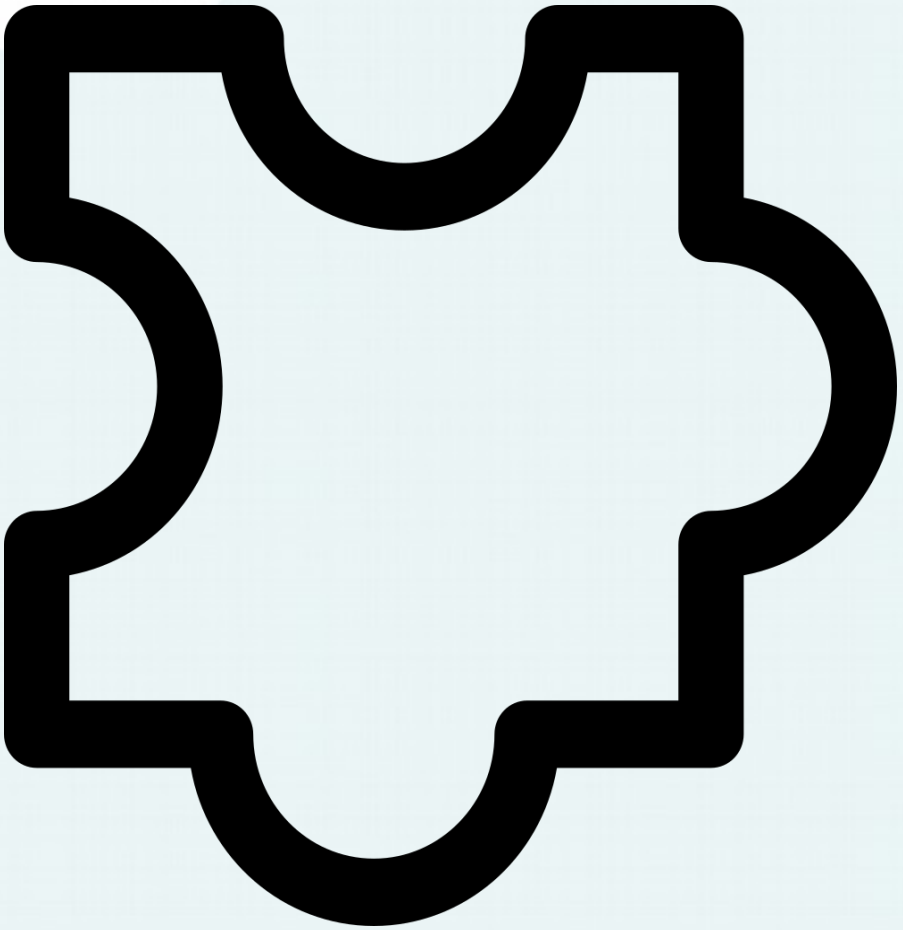
My Research



- Food System (30% GHG)
- Dietary change can reduced by 50%
- 15% of Europe shops food online
- → 2.5% global GHG emissions reduction

[1] Shakeri et al., 2021, Envirofy your Shop: Development of a Real-time Tool to Support Eco-friendly Food Purchases Online

My Research



Envirofy: the first eco-friendly e-commerce grocery tool which supports real shoppers in making sustainable choices.

Initial results: Behaviour Change Techniques can reduce a shop's total carbon footprint by 15%!

Website: https://envirofy.eu

[1] Shakeri et al., 2021, Envirofy your Shop: Development of a Real-time Tool to Support Eco-friendly Food Purchases Online

Sustainability Research

HCI	Out There
• Behaviour-intention gap when food shopping [7] • Digital streaming services e.g. Youtube [3] • Being “uncomfortable” for the environment [4] • Eco-feedback [10] • Etc.	• Low power-consuming processors, that generate less heat, hence require less cooling [1] • Agrivoltaic [2] • Optimising parcel deliveries [5] • NVIDIA’s Maxine [6] • Reduction of Bing query search space [8] • Compiler Optimisation [9] • Energy-Aware Software [11] • Etc.

[1] https://www.bamboosystems.io/architecture/; [2] Dinesh et al., 2021, The potential of agrivoltaic systems; [3] Preist et al., 2019, Evaluating Sustainable Interaction Design of Digital Services: The Case of Youtube; [4] Tyler et al., 2019, Are you sitting uncomfortably? A tale of comfort, energy and productivity; [5] Ngyuen et al., 2019, Optimising Parcel Deliveries in London using dual mode routing; [6] https://developer.nvidia.com/maxine#nvidia-maxine; [7] Shakeri et al., 2021, Envirofy your Shop: Development of a Real-time Tool to Support Eco-friendly Food Purchases Online; [8] Tonellotto et al., 2018, Efficient query processing for scalable web search; [9] Koehler et al., 2021, Sketch-Guided Equality Saturation: Scaling Equality Saturation to Complex Optimizations in Languages with Bindings; [10] Sanguinetti et al., 2018, Information, timing, and display: A design-behavior framework for improving the effectiveness of eco-feedback; [11] Fonseca et al., A Manifesto for Energy-Aware Software;

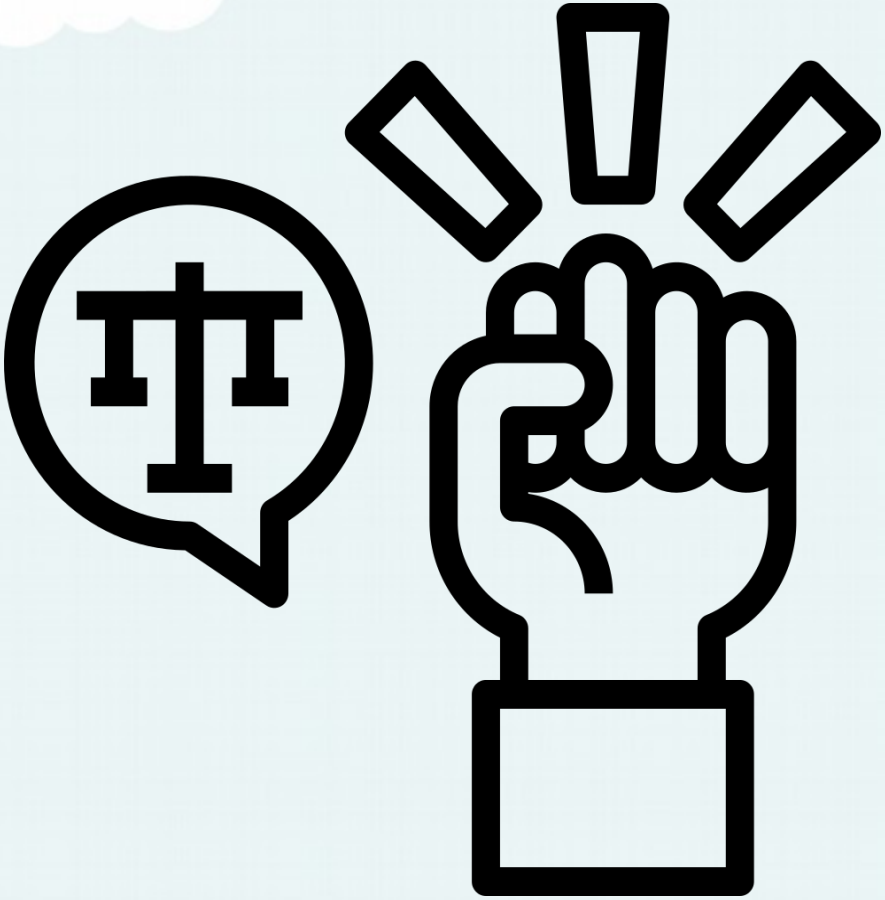
Sustainable CS for Social Justice

Changing Concepts of Sustainability:

- Ecological
- Economic
- Social

[1] Osburg, 2017, Sustainability in a Digital World Needs Trust; [2] Solomonian et al., 2021, The critical intersection of environmental and social justice: a commentary; [3] https://www.cfr.org/blog/why-cobalt-mining-drc-needs-urgent-attention, accessed 27/10/2021

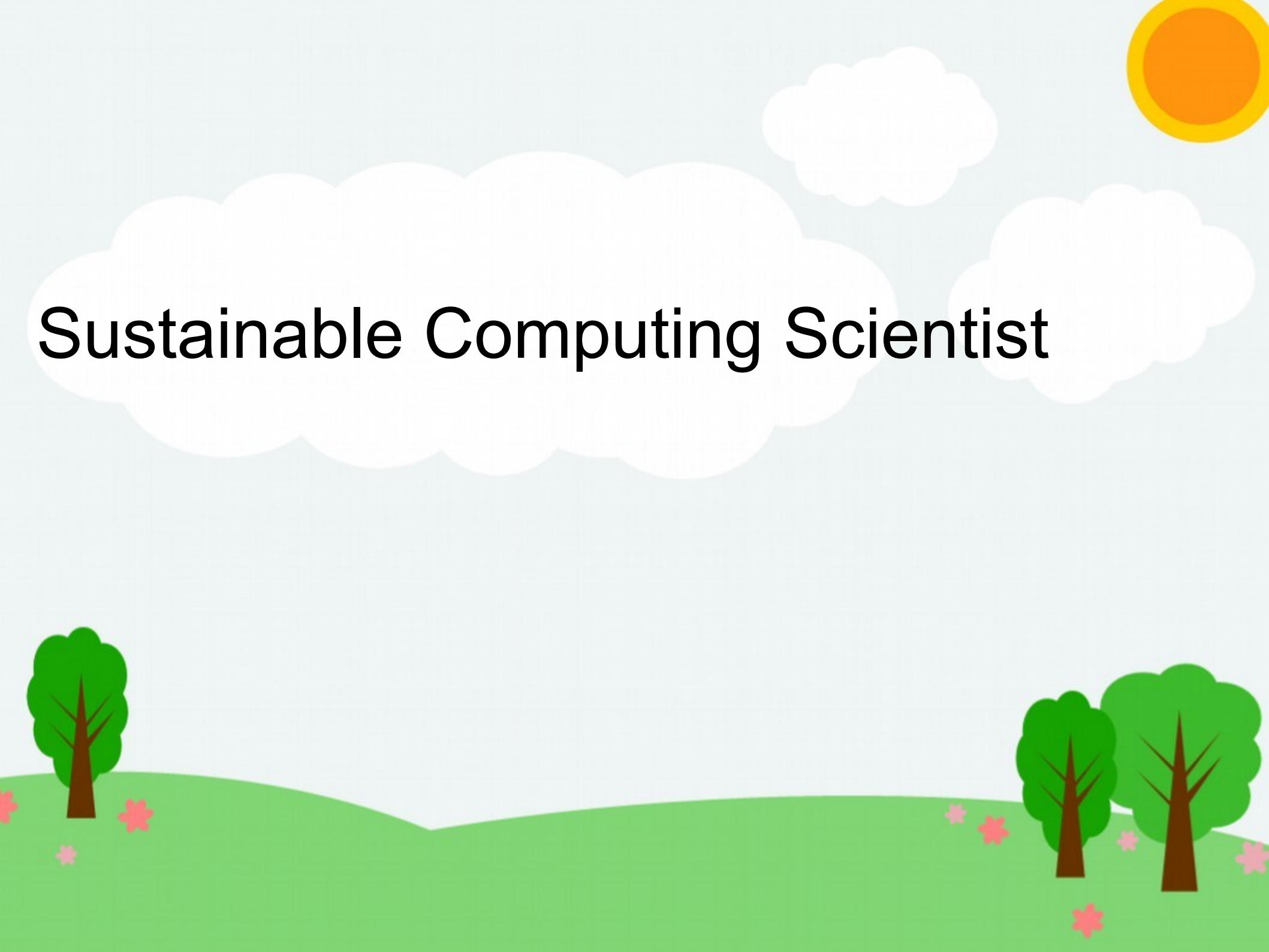
Call to Action



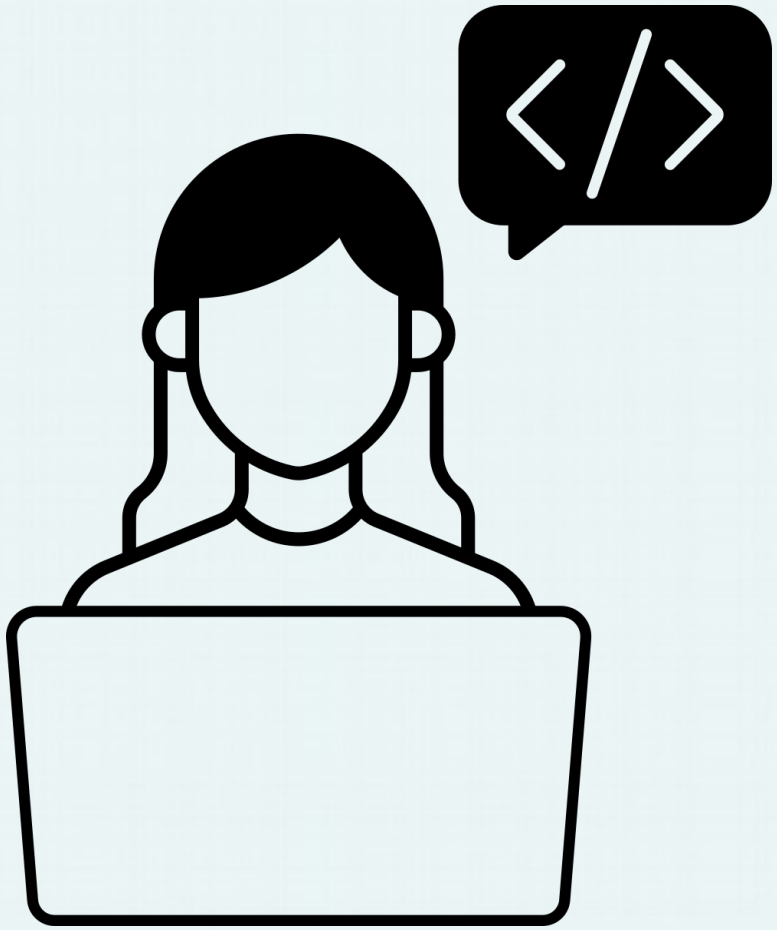
“Should every paper contain a paragraph commenting on how the outcomes of the research might affect environmental and social justice?” [1]

[1] Bates et al., 2018, Championing Environmental and Social Justice: Embracing, Embedding, and Promoting Broader Notions of Sustainability in HCI; [2] Solomonian et al., 2021, The critical intersection of environmental and social justice: a commentary; [3] https://www.cfr.org/blog/why-cobalt-mining-drc-needs-urgent-attention, accessed 27/10/2021

Sustainable Computing Scientist



Dr Gözel’s Footprint?



CO_2 in Context

1 kg of CO_2 ~ 1 tree month

1 kg of CO_2 ~ 8.3 km car

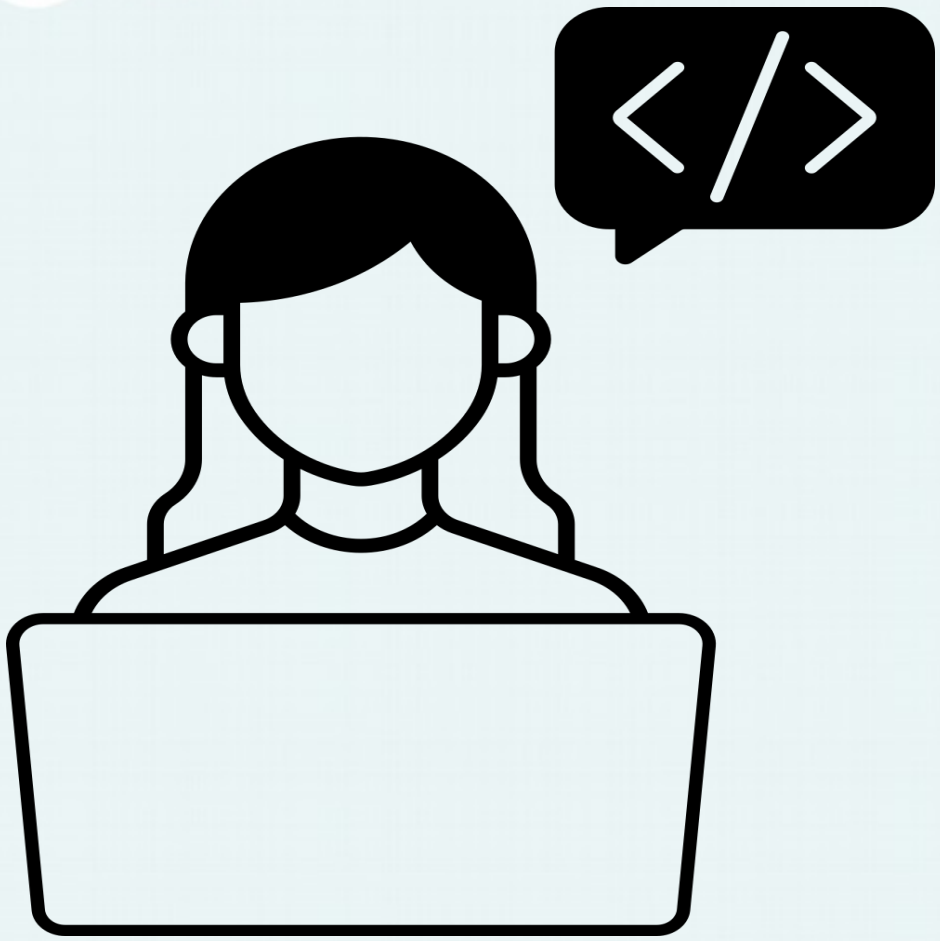
1 kg of CO_2 ~ 6 miles car

100 kg of CO_2 ~ 9 tree years (109 months)

100 kg of CO_2 ~ 833 km car

100 kg of CO_2 ~ 520 miles car

Working

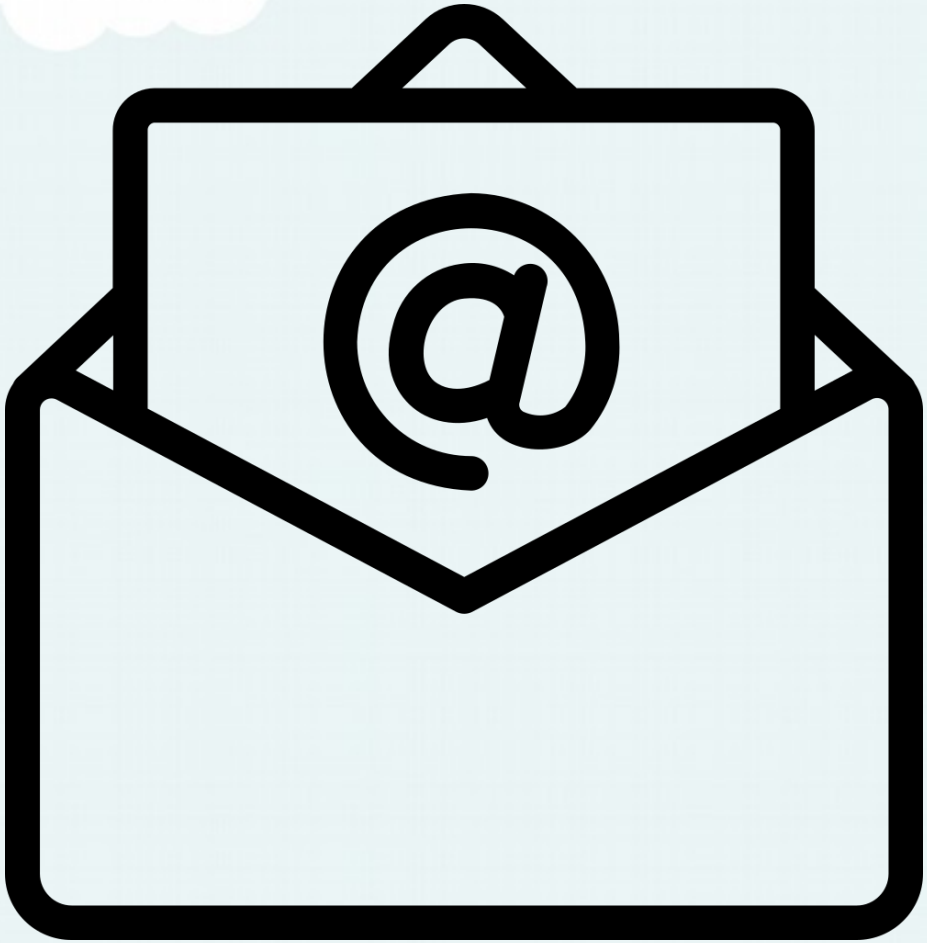


- Dr Gözel:
  - 1 year: 47 kg of CO_2e [2]
  - eq. to 268 km driving
  - eq. to 1 flight London → Paris

- Not including:
  - Monitor
  - Browsing / querying the internet
  - Communication (email, slack, teams)
  - Video conferencing
  - Cloud storage
  - etc

[1] Lannelongue et al., 2021, Green Algorithms: Quantifying the Carbon Footprint of Computation; [2] www.green-algorithms.org

Emails



- 1 email: 4 gr CO_2e [1]
- 1 email + attachment: 50 gr CO_2e
- 50% of email traffic is spam

- 1 week:
  - Received: 21 / day + 1.2 attachment / day
  - Sent: 3.6 / day + 0.8 attachment / day
- → **103.6 kg CO_2e** / year
  - eq. to 115 tree months (9.5 years)
  - eq. to 850 km car
- → 1.5 kg CO_2e “thank you” / year
  - eq. to 1.5 tree months
  - eq. to 12.5 km car
  - → ~ 4 billion active email users

[1] Mike Berners-Lee, 2020, How Bad are Bananas? The Carbon Footprint of Everything, ISBN: 9781788163811

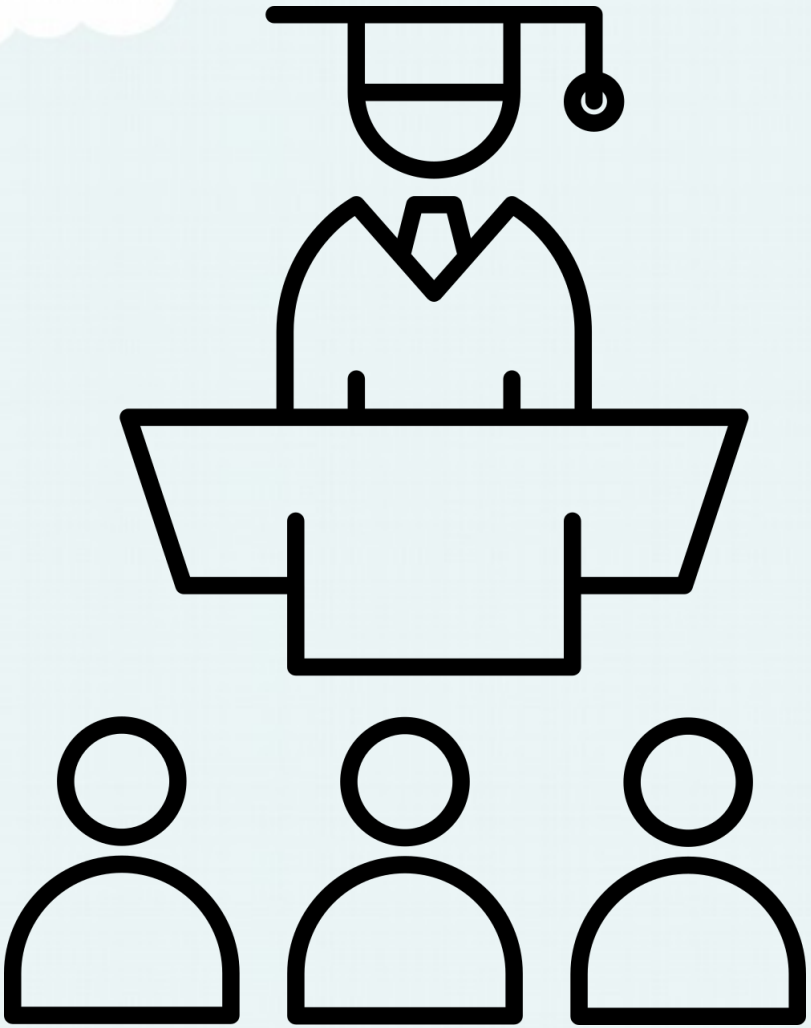
Browsing / Querying

- Search web address: 0.8 gr CO_2
- Search web: 10 gr CO2

- 1 week:
  - 990 web queries →10 kg per
  - 440 kg / year
    - eq. to 440 tree months (36 years)
    - eq. to 3665 km car
- Not including:
  - Phone
  - Tablet

[1] https://www.energuide.be/en/questions-answers/do-i-emit-co2-when-i-surf-the-internet/69/, accessed 30/10/2021

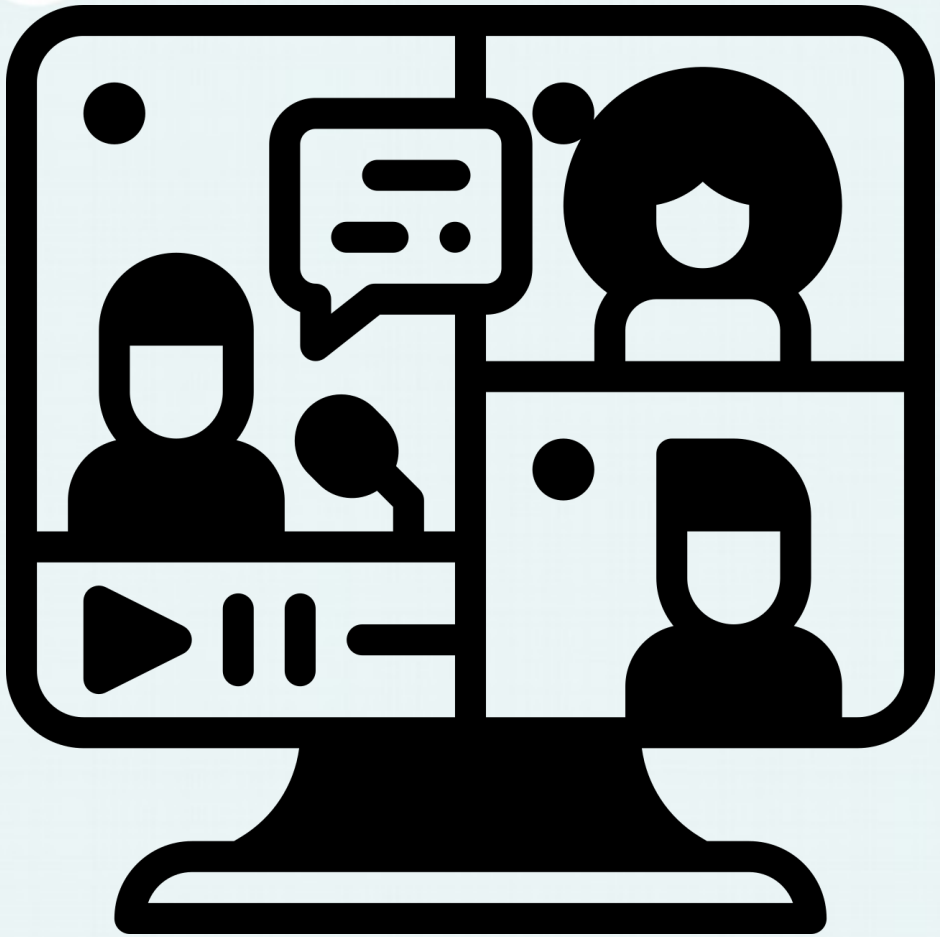
Academic Conferences



- There and back [1]:
  - ~3 tonnes of CO_2e / attendee
    - eq. to 3000 tree months (250 years)
    - eq. to 24990 km car
- ¼ of attendees opt virtual [1]:
  - 67 - 71% less CO_2e

[1] Jäckle, 2020, Reducing the Carbon Footprint of Academic Conferences by Online Participation: The Case of the 2020 Virtual European Consortium for Political Research General Conference

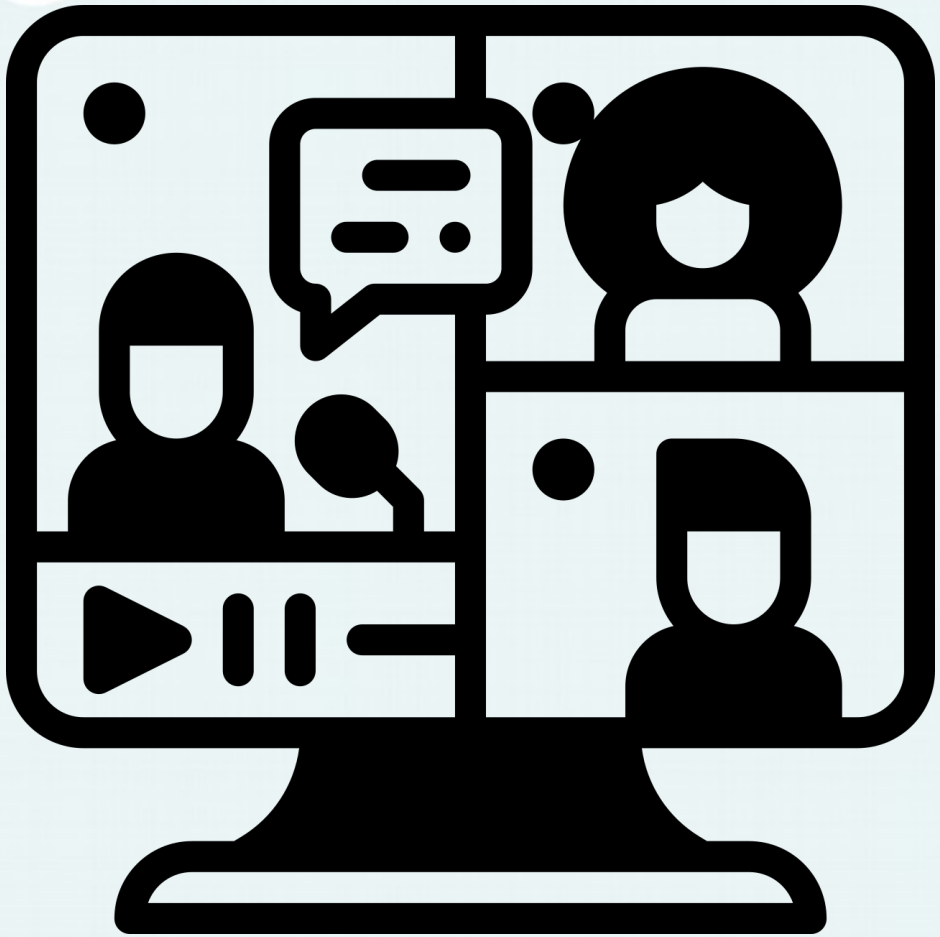
Online Conferences



- Allow for:
- Integration of academics from the Global South
- Integration of young academics without sufficient funds
- Increased gender diversity as people (mainly women) with (child) caring responsibilities
- Smaller Universities to host conferences

[1] Jäckle, 2020, Reducing the Carbon Footprint of Academic Conferences by Online Participation: The Case of the 2020 Virtual European Consortium for Political Research General Conference

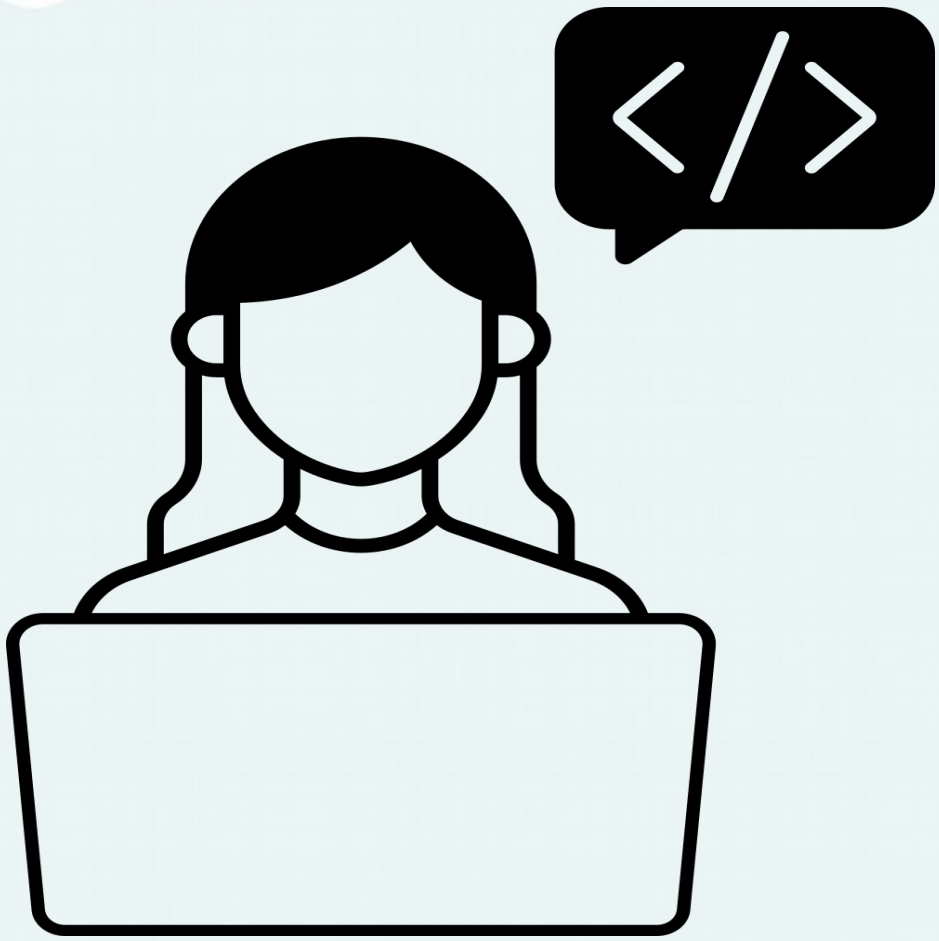
Video Conferencing Tools



- Weekly:
  - 3-persons: 3.4kg of CO_2e
    - eq. to 3.5 tree months
    - eq. to 29 km car
  - 10-persons: 11.3 kg of CO_2e
    - eq. to 12 tree months
    - eq. to 94 km car
- Annually:
  - ≥ 646.8 kg of CO_2e
    - eq. to 650 tree months (54 years)
    - eq. to 5368 km car

* https://www.utilitybidder.co.uk/business-electricity/zoom-emissions/

Dr Gözel's Footprint!



Laptop: 47 kg CO_2e

Emails: 103.6 kg CO_2e

Browsing: 440 kg CO_2e

Academic Conferences: 3000 kg CO_2e

Online Meetings: 650 kg CO_2e

Total: 4240.6 kg CO_2e

- 4622 tree months (385 years)
- 35,324 car km

Many Thanks

The carbon footprint of making this presentation*:

718 gr CO_2e

eq. to 4.11 km driving

eq. to 3 weeks for 1 tree

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My research:

https://envirofy.eu

* Carbon Footprint Calculator: http://green-algorithms.org

Icons: https://thenounproject.com