

# Sustainability and IT (how) are they related?

SummerSoc 2023

Harald Schöning, VP Research. 28.6.2023



# What is Sustainability?



Source: un.org

# Two dimensions considered (but not fully covered!)

- Sustainability enabled by IT
  - .... and inhibited by IT
- Sustainability of IT itself
  - AI, programming in general, deployment

# Example: the SENATOR project

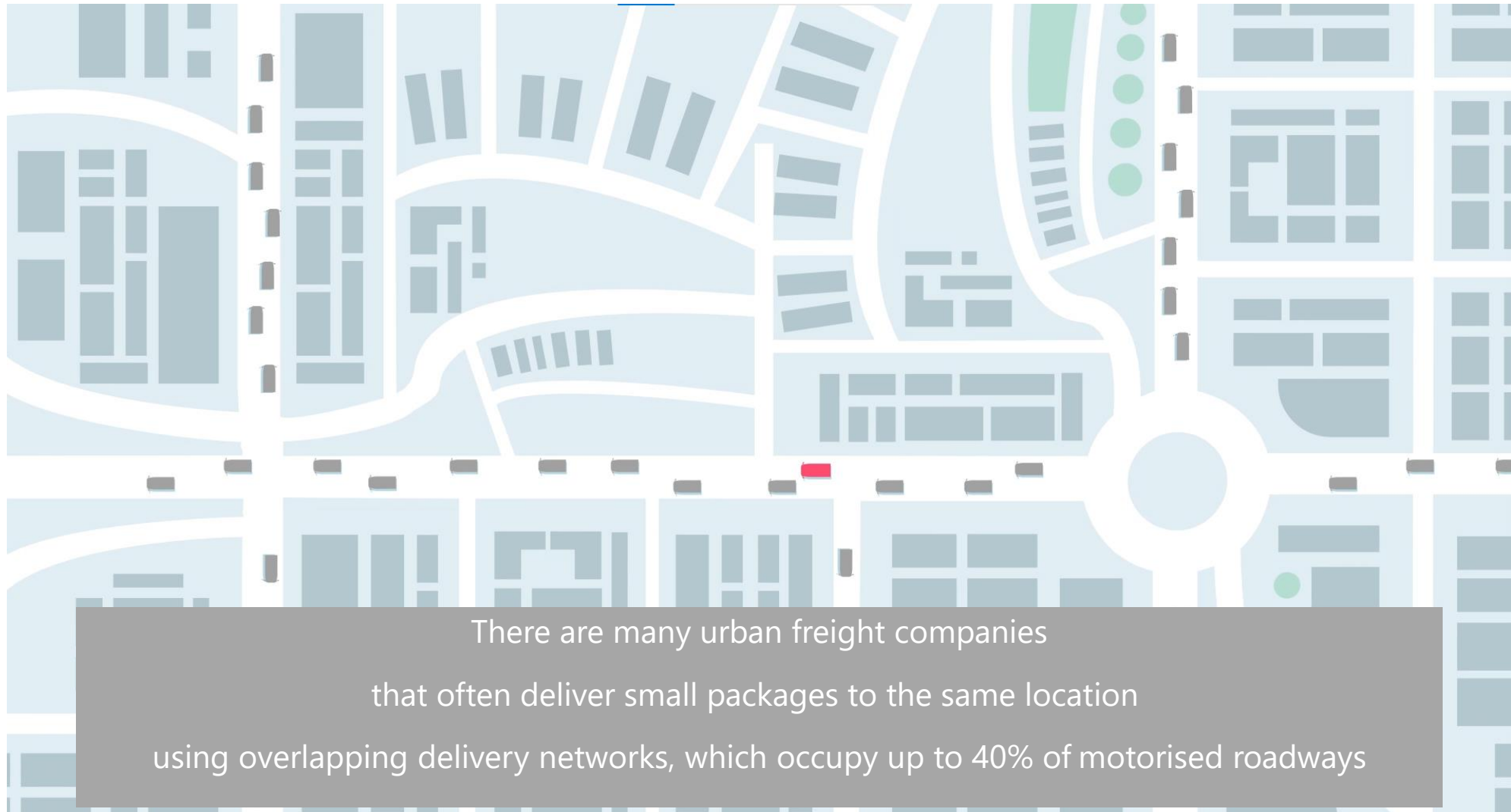
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**Senator**

**Watch the video: <https://www.youtube.com/watch?v=OiazparfFEs>**

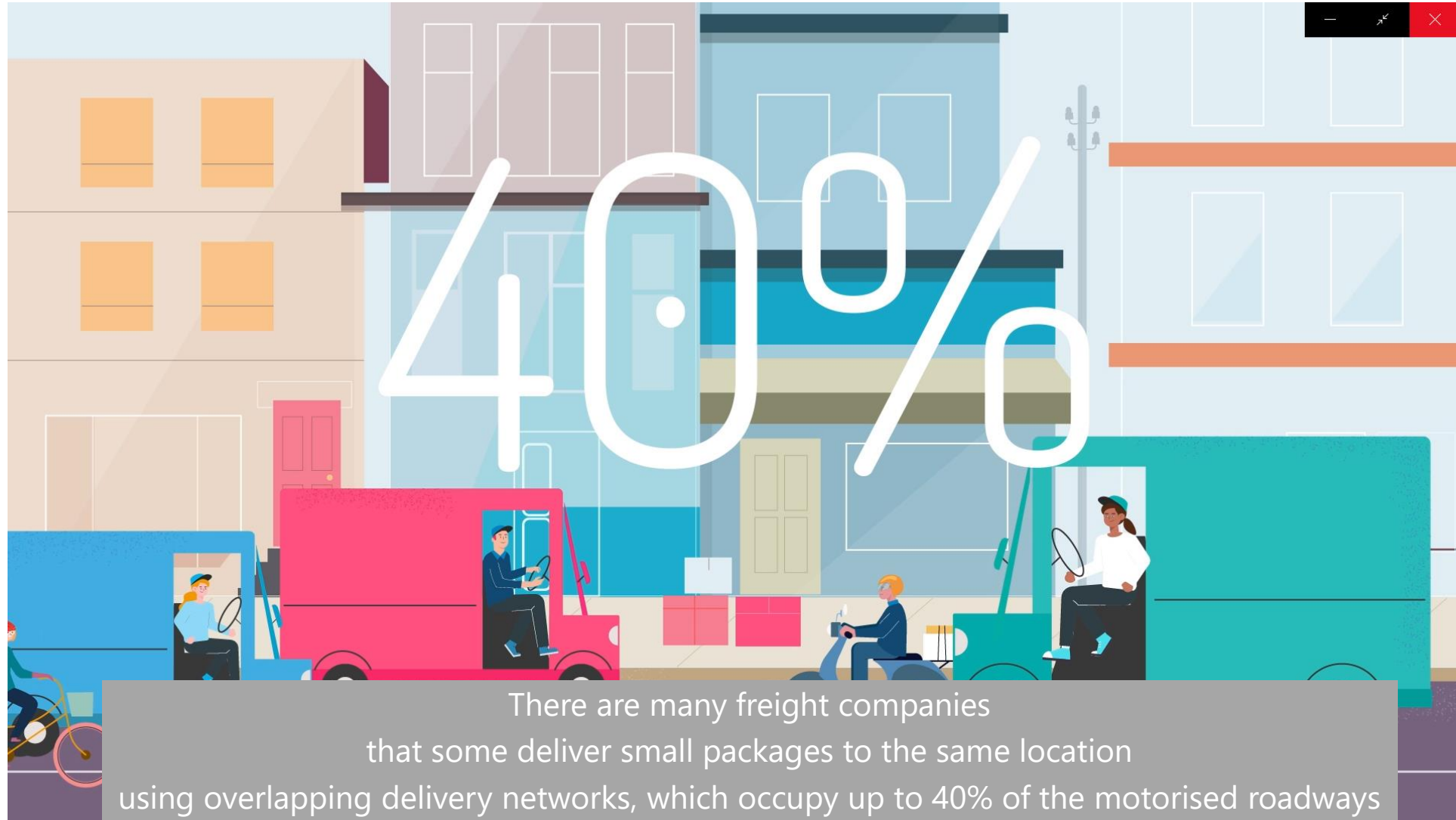
# Example: the SENATOR project



There are many urban freight companies  
that often deliver small packages to the same location  
using overlapping delivery networks, which occupy up to 40% of motorised roadways

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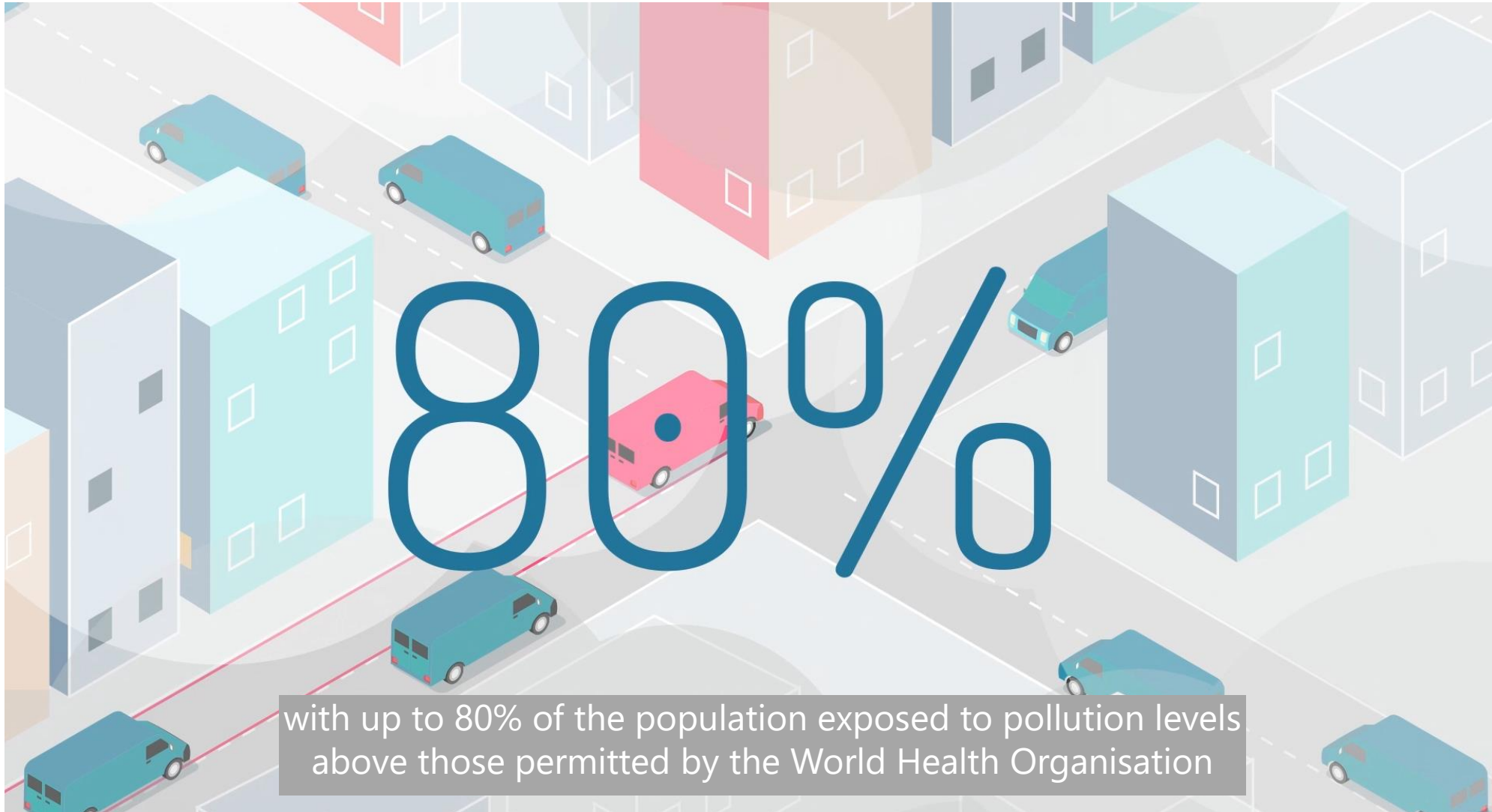
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# Example: the SENATOR project

9 INDUSTRY, INNOVATION  
AND INFRASTRUCTURE



8 DECENT WORK AND  
ECONOMIC GROWTH



11 SUSTAINABLE CITIES  
AND COMMUNITIES



10 REDUCED  
INEQUALITIES



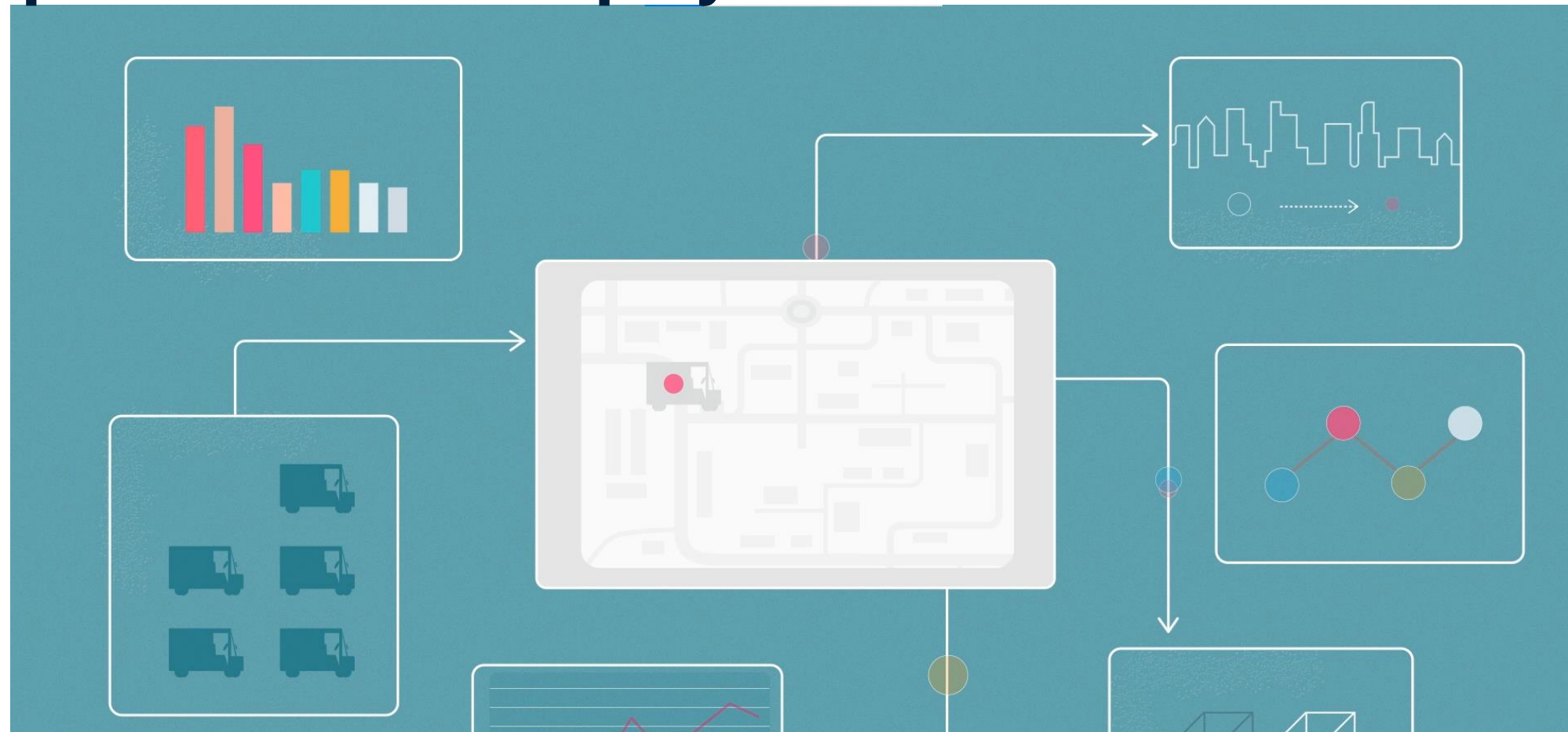
The logistics sector is committed to the Sustainable Development Goals of the 2030 agenda and the SENATOR projects reflects this.

In this environment, SENATOR offers a new model for urban planning.

**Watch the video: <https://www.youtube.com/watch?v=OiazpartFEs>**



# Example: the SENATOR project



Senator will help cities to better integrate freight delivery with urban planning. The use of real-time information and Artificial Intelligence will optimize delivery routes and determine which vehicle is the most suitable for each scenario

**Watch the video: <https://www.youtube.com/watch?v=OiazparfFEs>**

# Example: the SENATOR project



Led by Correos, the Spanish public postal system, 11 partners participate in the project

Watch the video: <https://www.youtube.com/watch?v=OiazparfFEs>

# Sustainability fostered by IT

## Other examples

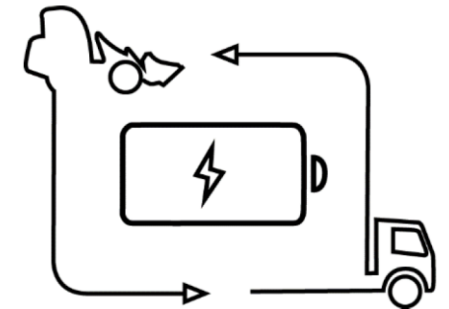
Adaption of production to react to volatility in energy availability

→ adapt production physics



Enabling higher value circular economy (reuse, refurbishing)

→ dismantling



REVAMP

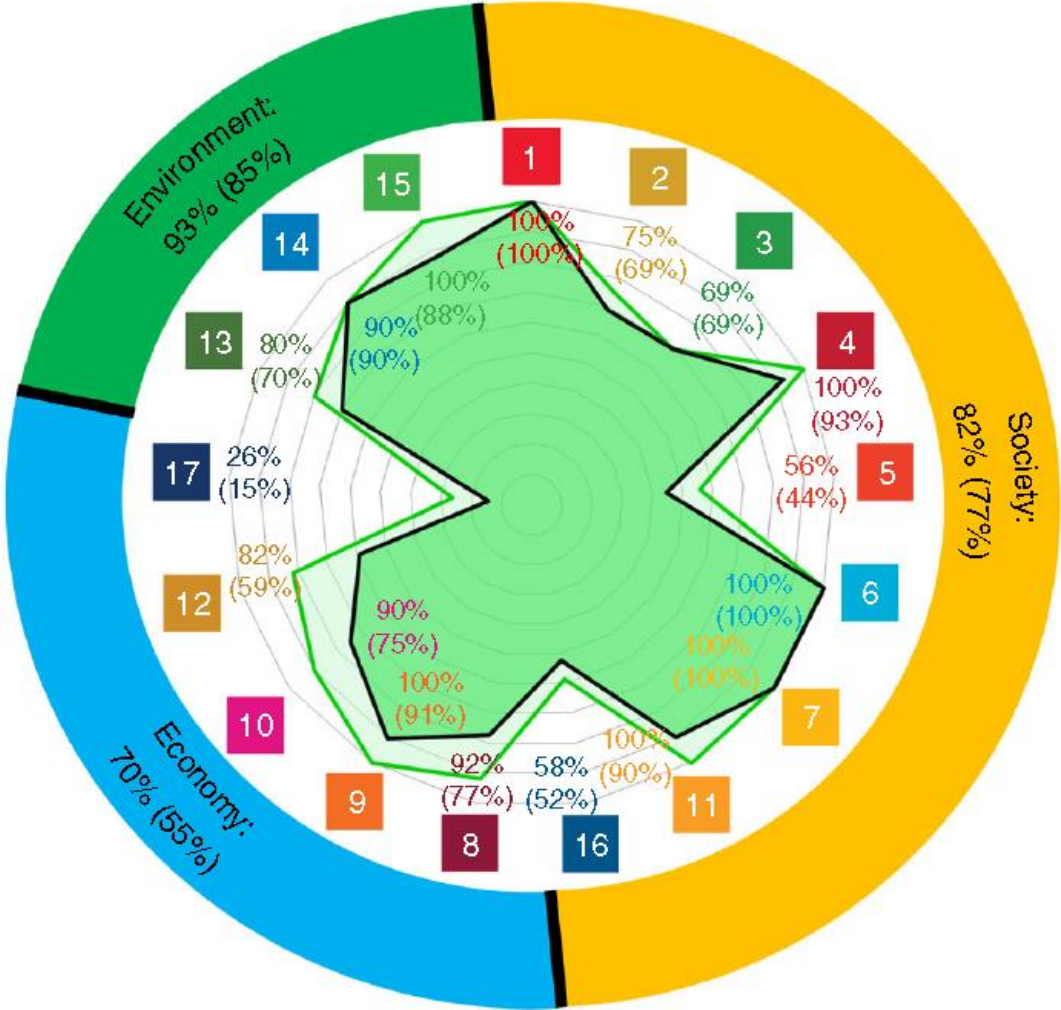
Predict heat islands in cities

→ city planning



# All fine? SDGs and AI

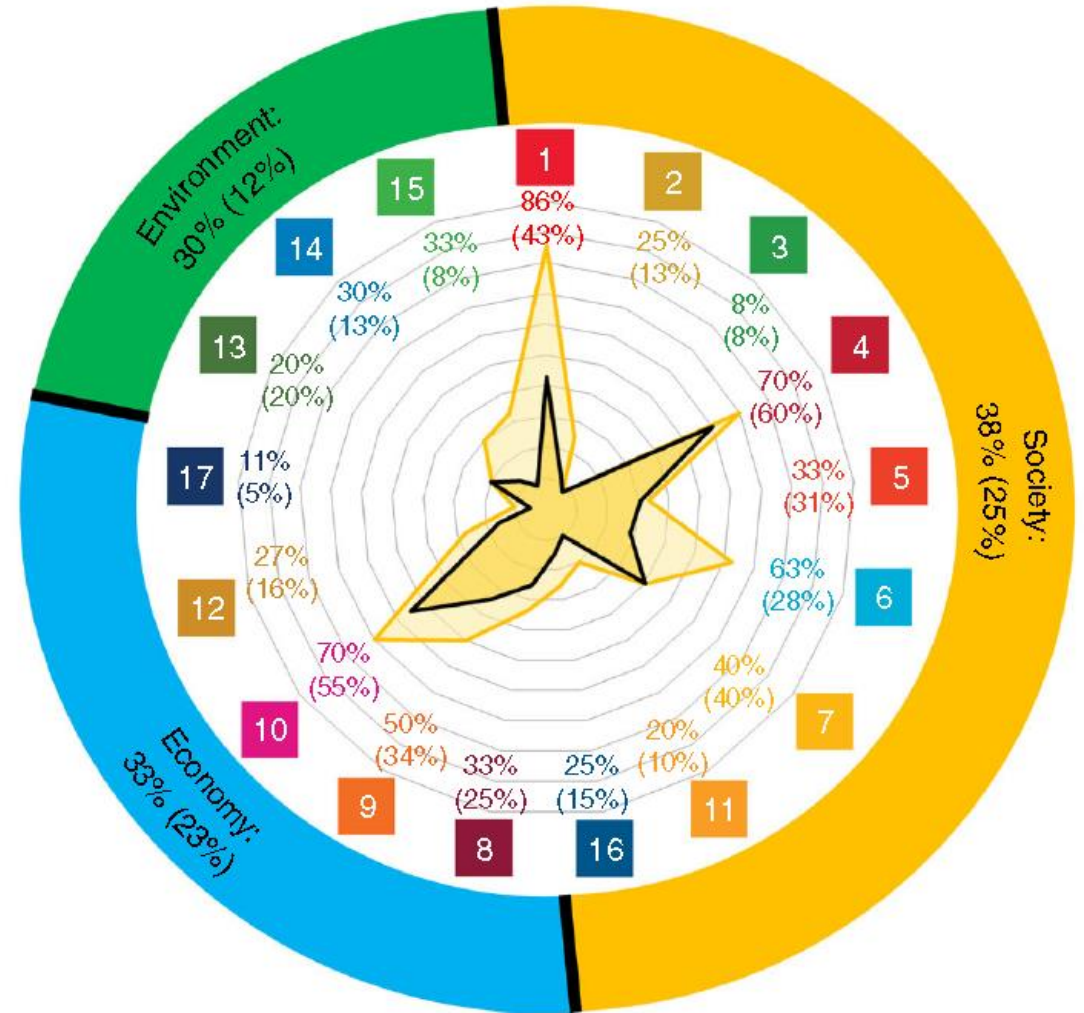
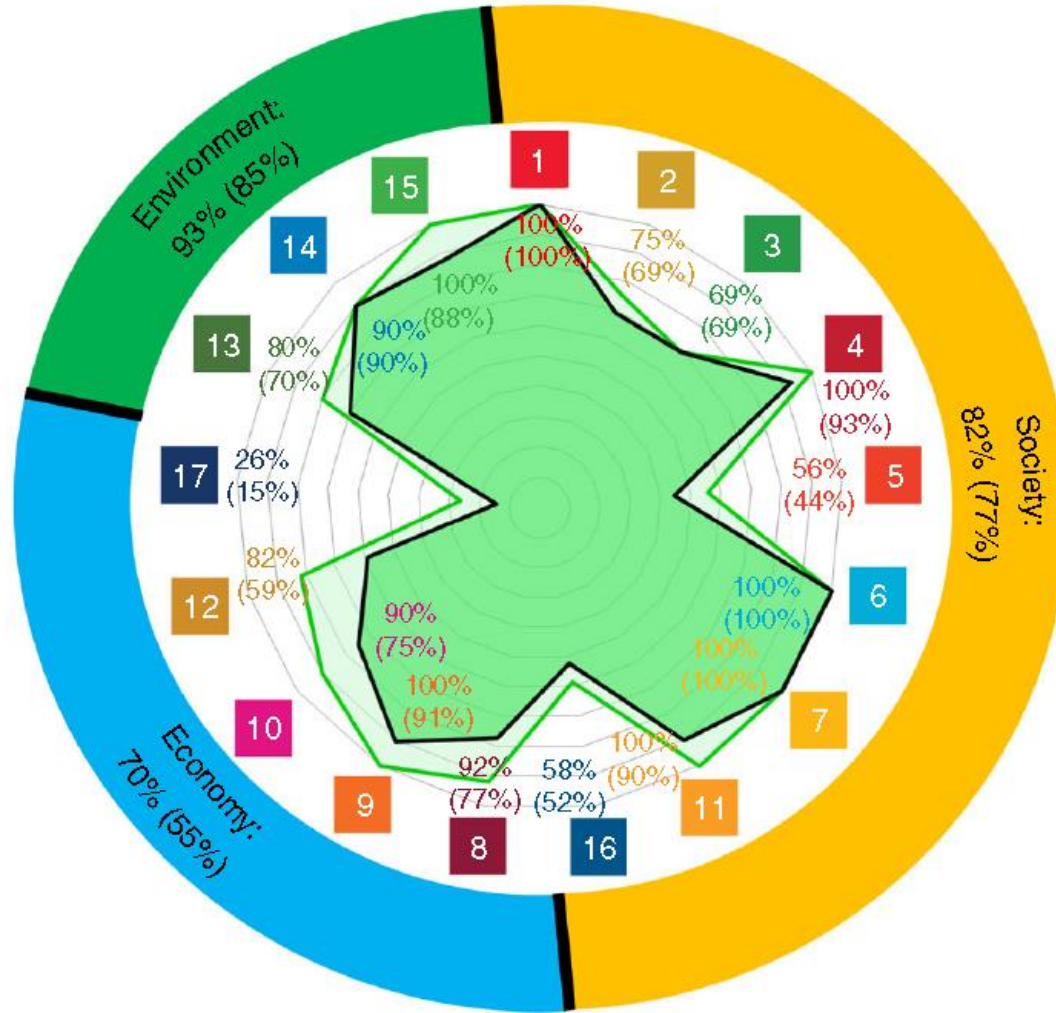
**a** Positive impacts of AI: 79% (71%)



# All fine? SDGs and AI

**a** Positive impacts of AI: 79% (71%)

**b** Negative impacts of AI: 35% (23%)

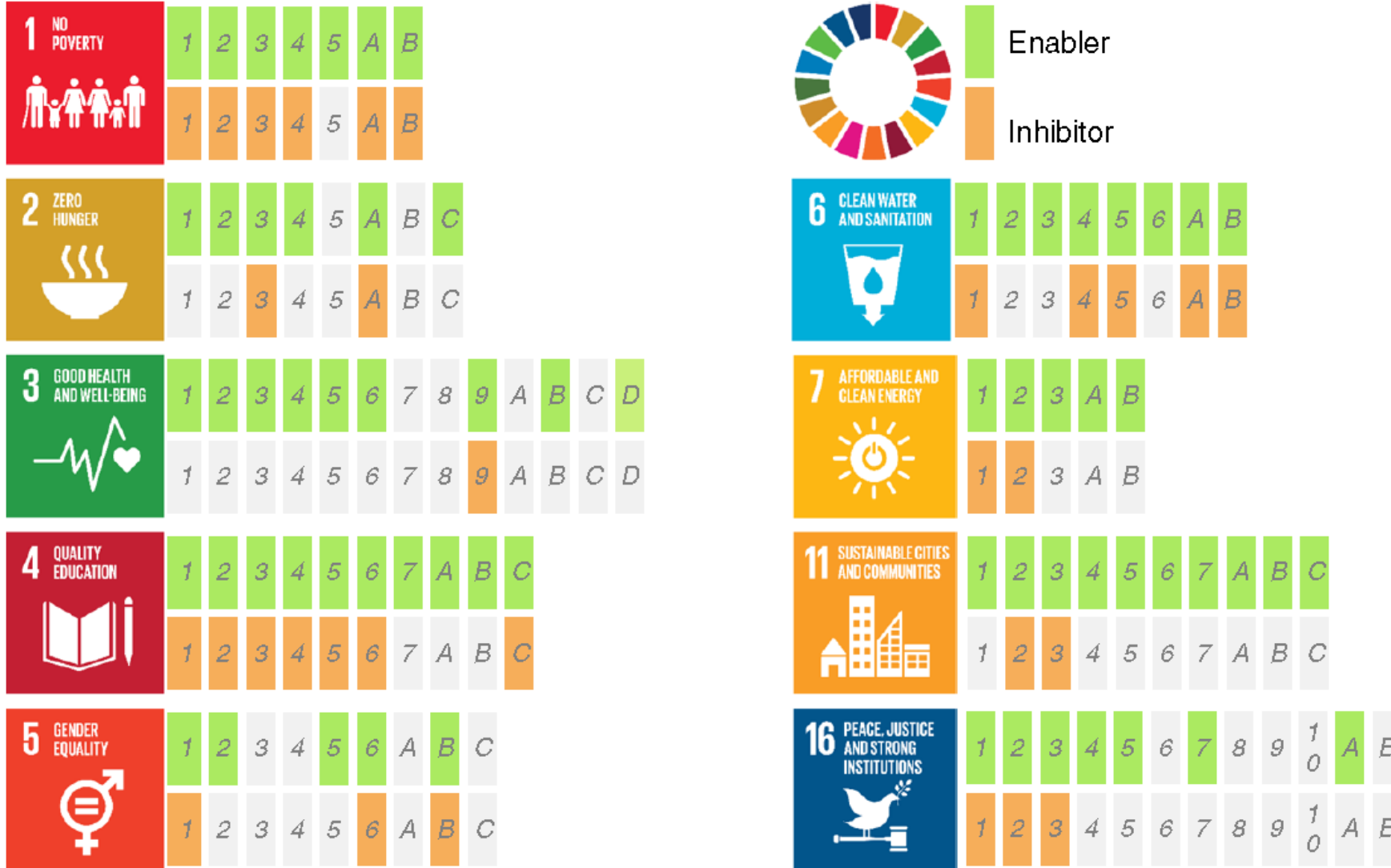


Summary of positive and negative impact of AI on the various SDGs.

Vinuesa, R. et al.: The role of artificial intelligence in achieving the Sustainable Development Goals, NATURE Communications 2020, <https://doi.org/10.1038/s41467-019-14108-y>

# A closer look

## Society



Detailed assessment of the impact of AI on the SDGs within the Society group

# Funny enough: not mentioned as inhibitor



Target

**7.3**

By 2030, double the global rate of improvement in energy efficiency

But:

Bitcoin is on position 55 of the energy consumption of the world's nations – before Denmark and Hungary

- And by the way accounts for CO2 emissions equal to that of Greece
- A single Bitcoin transaction equals the passenger footprint of a flight from Amsterdam to New York

Ok, that's not AI → is AI doing much better?

# Let's ask ChatGPT



how much energy does ChatGpt consume per prompt?



As an AI language model, I don't have direct information about the exact energy consumption of ChatGPT per prompt. The energy consumption of running AI models can vary depending on various factors, such as the hardware infrastructure used, optimization techniques, and the specific implementation of the model.



However, it's worth noting that large language models like GPT-3 consume a significant amount of computational resources and energy. Training these models requires substantial computational power and energy consumption. Inference, which is the process of generating responses based on user prompts, is generally less resource-intensive than training, but it still requires considerable computational resources.

To mitigate the environmental impact of AI models, researchers and developers are actively exploring energy-efficient architectures and methods to reduce the carbon footprint associated with AI technologies. Efforts are being made to optimize the models, improve hardware efficiency, and explore renewable energy sources for powering data centers.

Ultimately, the energy consumption of AI models like ChatGPT depends on a range of factors, and without specific details about the infrastructure and implementation, it is challenging to provide an accurate estimate.



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# Can LLM do better?

ChatGPT is reported to need 3 Wh / several cents of energy cost per prompt or \$3 Mio a day. Training GPT-3 consumed 1.287 GWh

But even LLM can do better:

Although GPT-3 and BLOOM have the same number of parameters (175,000,000,000), the energy and climate impacts differ:

**GPT-3: 1.287 MWh energy consumption, 502 tons CO<sub>2</sub> emissions**

**BLOOM: 433 MWh energy consumption, 25 tons CO<sub>2</sub> emissions**

Energy-efficient HW

Greenwashing?????

# Just that – or is there more than using better hardware?

Model training is more expensive than model usage

- *Learned* models are not panacea
- When is re-training *really* required?
- Consider model reuse
  - Binhang Qi et al: Reusing Deep Neural Network Models through Model Re-engineering, <https://arxiv.org/abs/2304.00245>
  - Bajcsy, P. et al. (2023). Characterization of AI Model Configurations for Model Reuse. In: Karlinsky, L., Michaeli, T., Nishino, K. (eds) Computer Vision – ECCV 2022 Workshops. ECCV 2022. Lecture Notes in Computer Science, vol 13804. Springer, Cham. [https://doi.org/10.1007/978-3-031-25069-9\\_30](https://doi.org/10.1007/978-3-031-25069-9_30)

# Generalized view - Green data science

**Table 2** Overview of design principles for green data science

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## *Reduce*

Design Principle #1 – Reduce data

Design Principle #1.1 – Reduce number of data items

Design Principle #1.2 – Reduce number of attributes

Design Principle #1.3 – Reduce size of attributes

Design Principle #2 – Reduce operations

Design Principle #2.1 – Reduce trial and error

Design Principle #2.2 – Reduce model

## *Reuse*

Design Principle #3 – Reuse own operations, data, and models

Design Principle #4 – Reuse from others

## *Support*

Design Principle #5 – Share data, models, and skills

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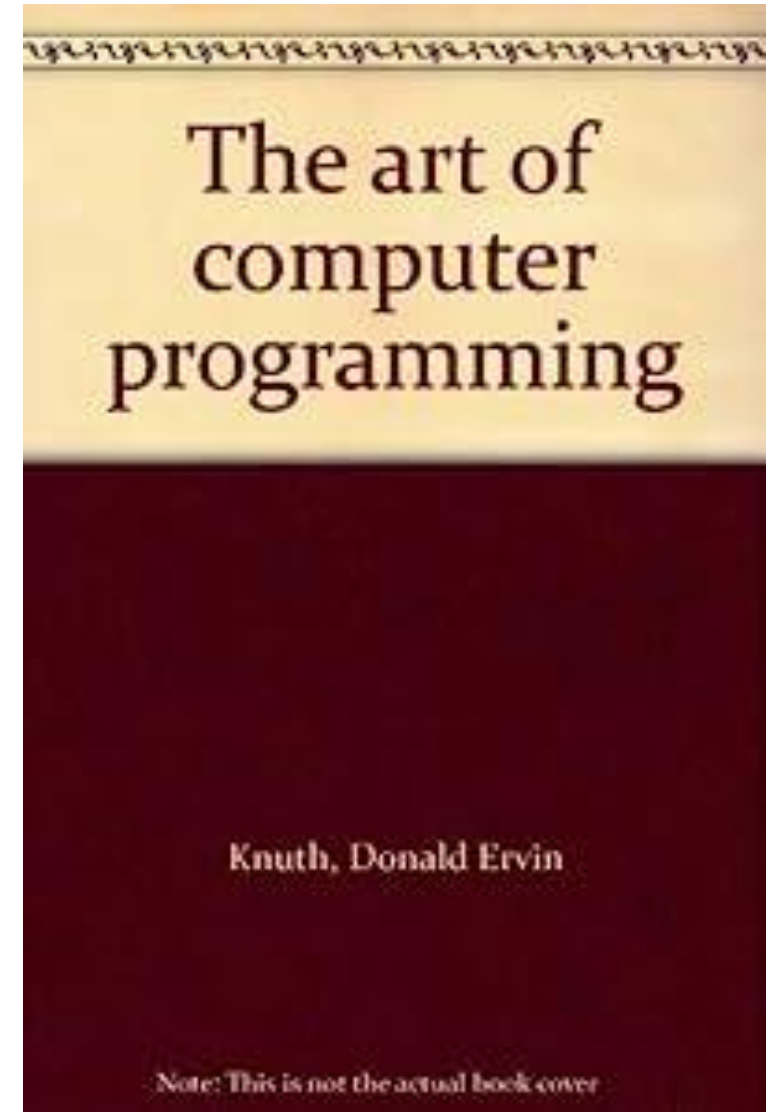
Schneider, J. et al: Reuse, Reduce, Support: Design Principles for Green Data Mining, Business Information Systems Engineering 65(1): 65-83 (2023)

# Complexity still matters

Choosing the right (efficient) Algorithms can reduce computing time  
*and increase energy efficiency*

User Interfaces (fancy vs. efficient)

Distributed ledger vs. central data storage  
Consensus protocol also matters



# Do not compute more than you need!

Apply the well-known techniques

## Often, improved response time also improves energy efficiency

- Use Caching where appropriate
- Queries should not retrieve more than needed
  - `SELECT * ....`

## But not always, e.g.

- Reduce read-out rates of sensors to what is needed

# How about programming languages?

fannkuch-redux				
	Energy	Time	Ratio	Mb
(c) C ↓ <sub>2</sub>	215.92	6076	0.036	2
(c) C++ ↑ <sub>1</sub>	219.89	6123	0.036	1
(c) Rust ↓ <sub>11</sub>	238.30	6628	0.036	16
(c) Swift ↓ <sub>5</sub>	243.81	6712	0.036	7
(c) Ada ↓ <sub>2</sub>	264.98	7351	0.036	4
(c) Ocaml ↓ <sub>1</sub>	277.27	7895	0.035	3
(c) Chapel ↑ <sub>1</sub> ↓ <sub>18</sub>	285.39	7853	0.036	53
(v) Lisp ↓ <sub>3</sub> ↓ <sub>15</sub>	309.02	9154	0.034	43
(v) Java ↑ <sub>1</sub> ↓ <sub>13</sub>	311.38	8241	0.038	35
(c) Fortran ↓ <sub>1</sub>	316.50	8665	0.037	12
(c) Go ↑ <sub>2</sub> ↑ <sub>7</sub>	318.51	8487	0.038	2
(c) Pascal ↑ <sub>10</sub>	343.55	9807	0.035	2
(v) F# ↓ <sub>1</sub> ↓ <sub>7</sub>	395.03	10950	0.036	34
(v) C# ↑ <sub>1</sub> ↓ <sub>5</sub>	399.33	10840	0.037	29
(i) JavaScript ↓ <sub>1</sub> ↓ <sub>2</sub>	413.90	33663	0.012	26
(c) Haskell ↑ <sub>1</sub> ↑ <sub>8</sub>	433.68	14666	0.030	7
(i) Dart ↓ <sub>7</sub>	487.29	38678	0.013	46
(v) Racket ↑ <sub>3</sub>	1,941.53	43680	0.044	18
(v) Erlang ↑ <sub>3</sub>	4,148.38	101839	0.041	18
(i) Hack ↓ <sub>6</sub>	5,286.77	115490	0.046	119
(i) PHP	5,731.88	125975	0.046	34
(i) TypeScript ↓ <sub>4</sub> ↑ <sub>4</sub>	6,898.48	516541	0.013	26
(i) Jruby ↑ <sub>1</sub> ↓ <sub>4</sub>	7,819.03	219148	0.036	669
(i) Lua ↓ <sub>3</sub> ↑ <sub>19</sub>	8,277.87	635023	0.013	2
(i) Perl ↑ <sub>2</sub> ↑ <sub>12</sub>	11,133.49	249418	0.045	12
(i) Python ↑ <sub>2</sub> ↑ <sub>14</sub>	12,784.09	279544	0.046	12
(i) Ruby ↑ <sub>2</sub> ↑ <sub>17</sub>	14,064.98	315583	0.045	8

Energy

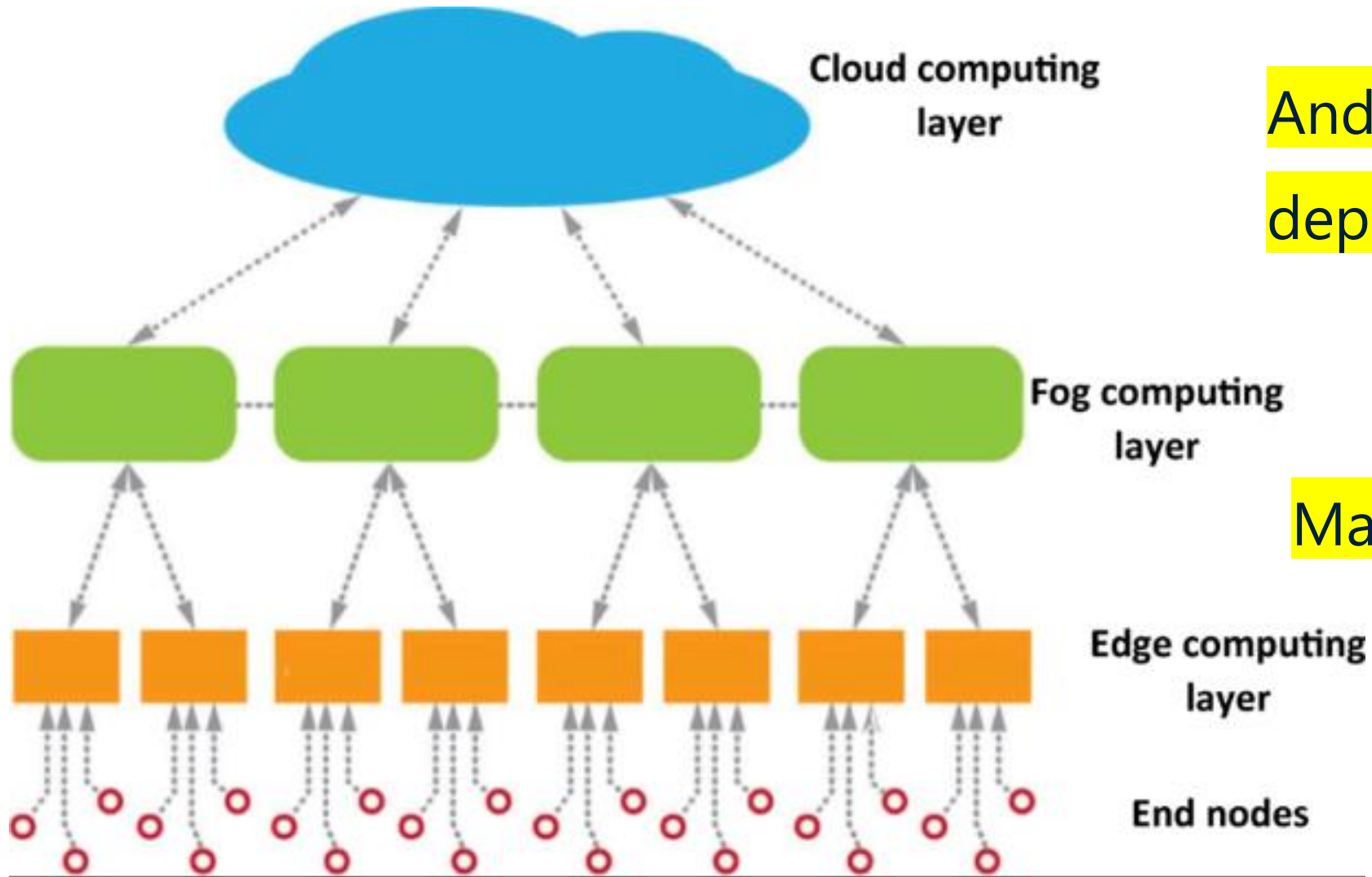
C: 215.92

Java: 311.38

Python: 12,784.09

Pereira, R. et al: Energy Efficiency across Programming Languages-  
How Do Energy, Time, and Memory Relate?  
SLE'17, October 23–24, 2017, Vancouver, Canada

# How about cloud computing?



And choose the right deployment in the cloud

Make use of the hierarchy

Early filtering and compression

Source: winsystems.com



# Of course, there is more to consider

e.g. if you operate a data center

- **Mode of Operation (usage ratio, temperature etc.)**
    - Be careful: PUE (power usage efficiency) might be misleading!
  - **You do not always need full hardware performance**
  - **Even scheduling has an influence**
- **look at what has been done for mobile phones!**

# The whole system matters

Judging your **entire** solution with respect to sustainability

- Positive and negative impact of the *application*
  - Maybe hard for a data scientist....
- Impact of *running* the application

How to design a *system* for sustainability?

van der Aalst, W.M.P, Hinz, O., Weinhardt, C.: Sustainable Systems Engineering, Business Information Systems Engineering 65(1):1-6 (2023)

See also: **A guide to sustainable IT**

[https://www.softwareag.com/en\\_corporate/resources/it-portfolio-management/guide/guide-to-sustainability-in-it.html](https://www.softwareag.com/en_corporate/resources/it-portfolio-management/guide/guide-to-sustainability-in-it.html)

