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icteam

Evaluating the (ir)relevance of IoT solutions with respect to environmental limits based on LCA and backcasting studies

The case study of smart public lighting in Wallonia, Belgium (2020-2050)

LIMITS 2023 - Ninth Workshop on Computing within Limits

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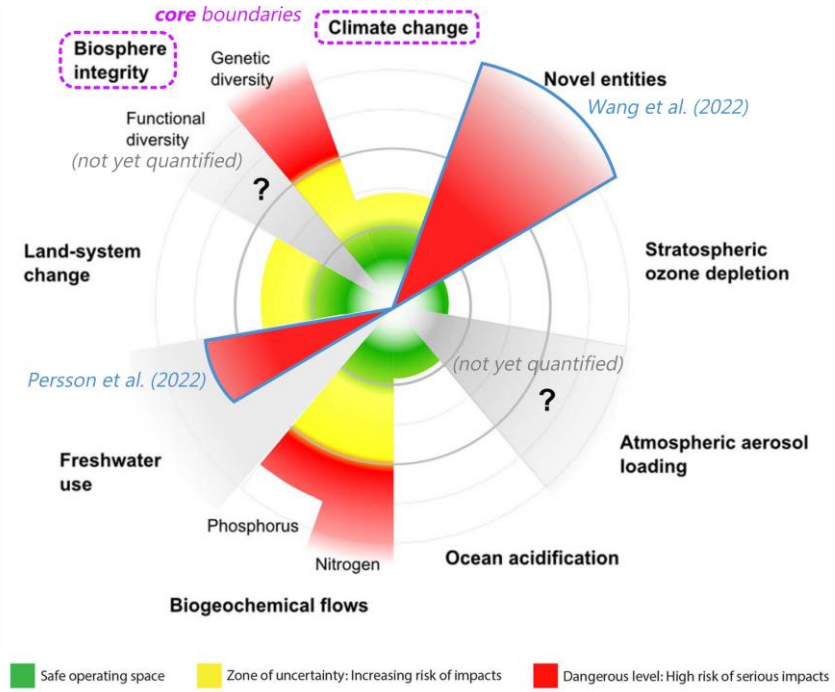
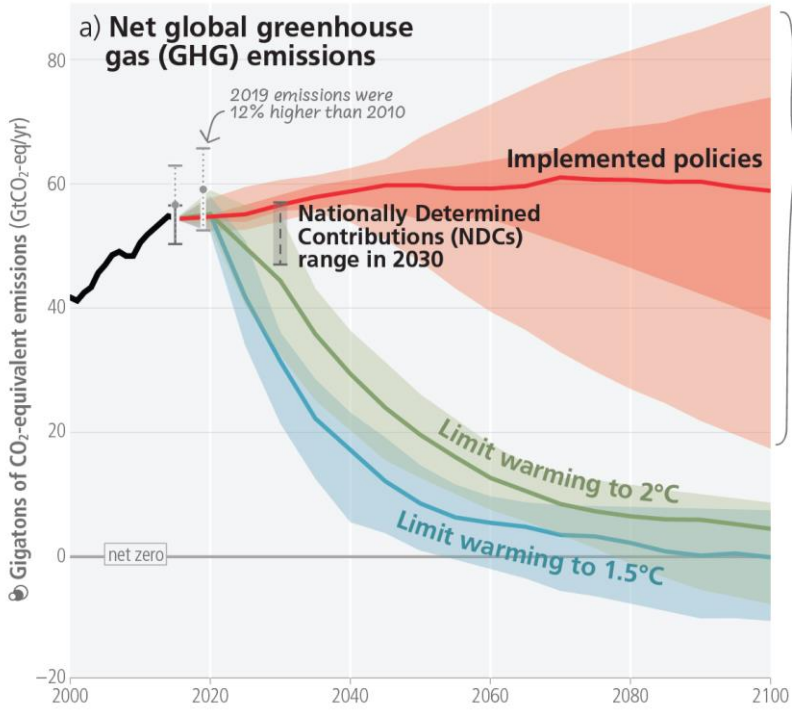
June, 14th 2023

General context





Six (out of nine) planetary boundaries exceeded, including the two core boundaries (climate change and biosphere integrity)

Humanity has to strongly and quickly reduce its global GHG emissions

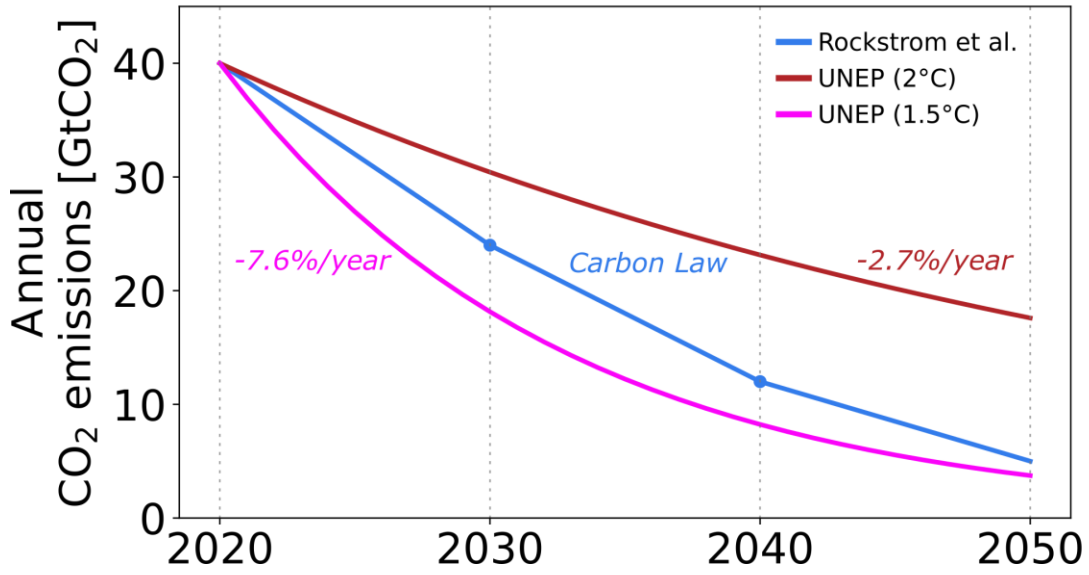
→ today's actions are critical

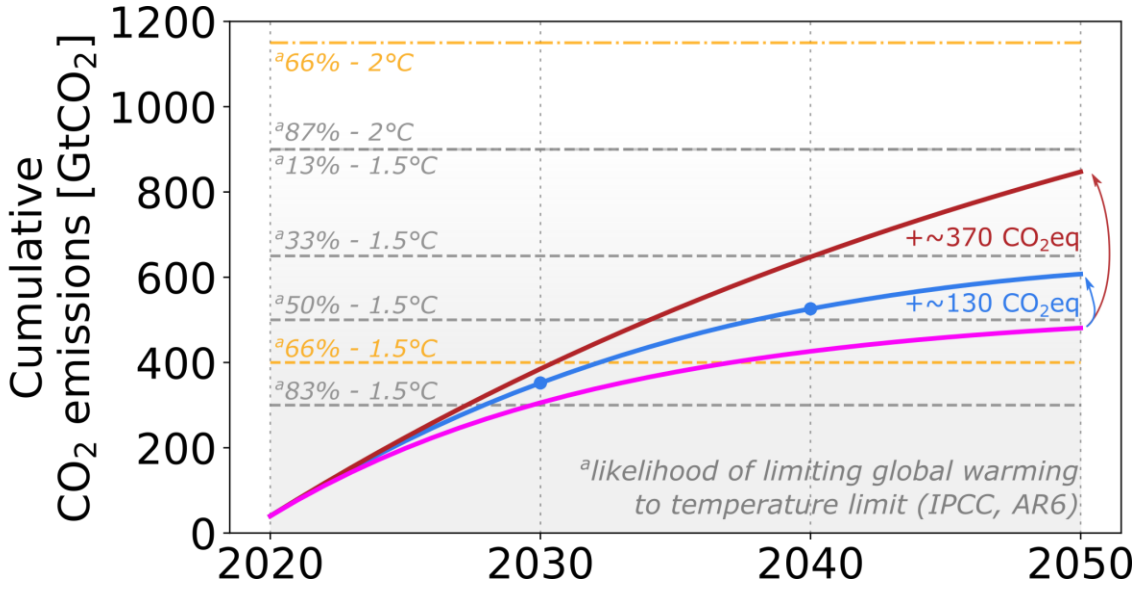
Source : Figures adapted from [1,2]

Pirson et al.

General motivation #1

Global strategies aligned with **GHG reduction pathways** should be considered, although it is almost never the case [7]

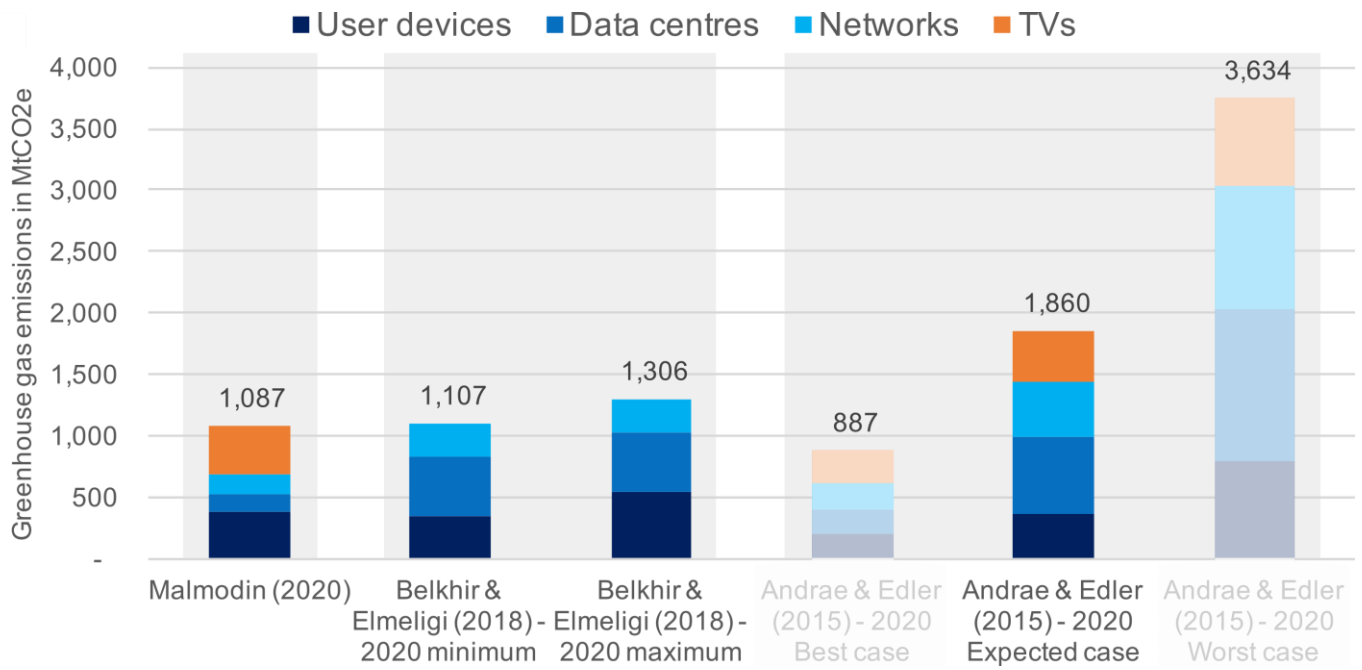




Pirson et al.

Original figures based on [10,11]

General motivation #2



About 2.1-3.9% of global GHG emissions [3]

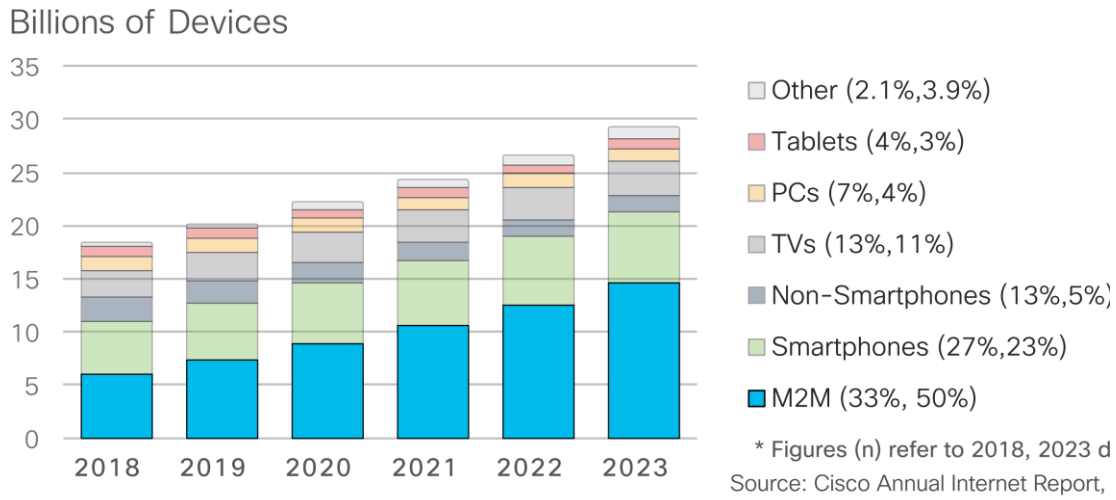
ICT has also a carbon footprint, which is also called to decrease according to GHG reduction targets.

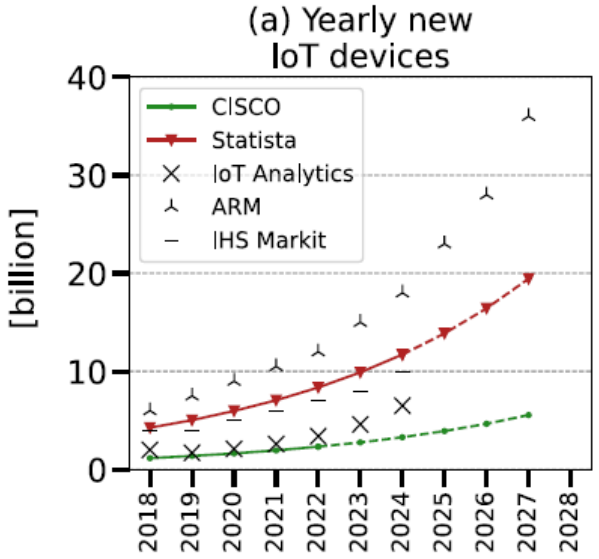
These studies **do not account** for the direct environmental effects of IoT devices.

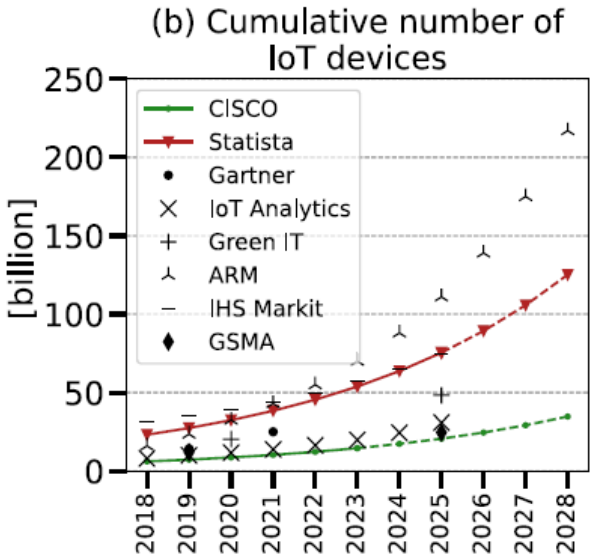
Source : Figure adapted from [3]

Pirson et al.

General motivation #2







However, IoT is identified as the **fastest-growing trend** of ICT devices… [3,4] and literature is scarce regarding the direct impacts of IoT [3,5,6]

→ The massive deployment of IoT devices should also be subject to **environmental analyses**

Source : Figures adapted from [4,5]

Pirson et al.

Purpose of this study

General goal: Plan for actionable future(s) of *limits and/or scarcity* that are *fundamentally different from the extrapolation of current trends* [8,9]

→ …but *HOW* to achieve this in practice?

What approach could be used to help keeping the IoT deployment within environmental limits?

Take-home messages

What approach could be used to help keeping the IoT deployment within environmental limits?

1. Improving the environmental performance of a product through LCA and eco-design **is not sufficient** to ensure environmental sustainability… which we illustrate with a full-scope multi-indicators LCA of a real-life deployed IoT solution for smart public lighting.

2. We show the potential of **using LCA with backcasting scenarios** to **discriminate** between the IoT solutions that should be deployed, and the ones that should be discouraged with respect to environmental limits.

Structure of the paper

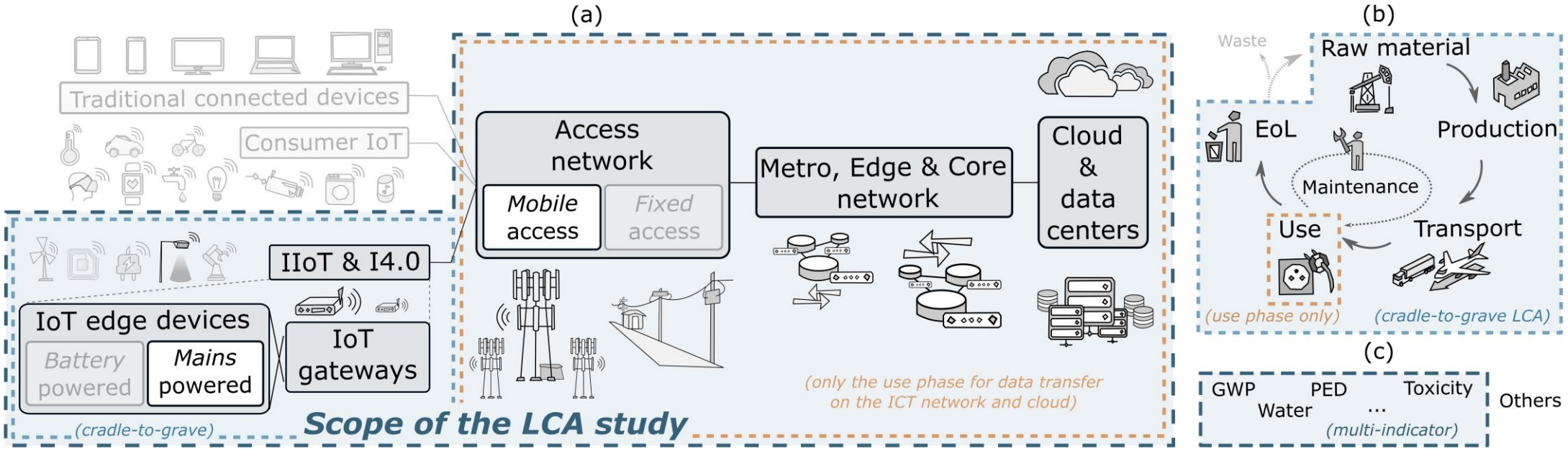
1. Introduction
2. General background and terminology
3. General limits of LCA as a tool for environmental sustainability
4. Using LCA to assess the direct impacts of a real-life distributed IoT network for smart lighting
   i. Methodology
   ii. Modeling assumptions
   iii. Results and interpretation
   iv. Discussion
5. Towards backcasting studies for the massive IoT deployment
   i. Backcasting as a well-suited approach
   ii. Streamlined backcasting on the use case of smart public lighting
   iii. Discussion
6. Conclusions and future works

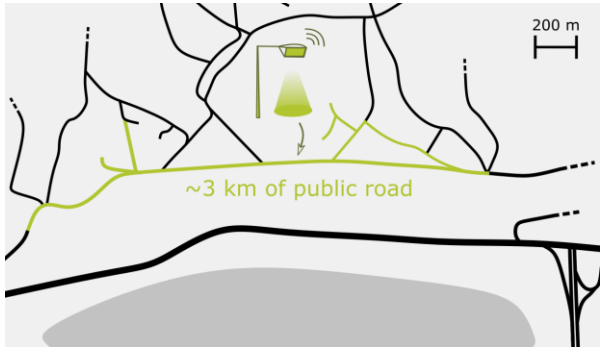
Focus of this talk

(only a small part of the paper content)

Using LCA to assess the direct impacts of a real-life distributed IoT network for smart lighting

Methodology





(FU:) 108 IoT nodes, 1 gateway

24/7 during 10 years

- → **Full-scope cradle-to-grave** analysis (including maintenance, deployment, …) of a **real-life deployed** IoT solution
- → **12 impact categories** under study, mainly from ReCiPe 2016 (H)
- → Sphera LCA software & databases and **very detailed modeling** of the IoT hardware (teardowns, desencapsulation of integrated circuits, …)
- → Modeling assumptions and details in the paper

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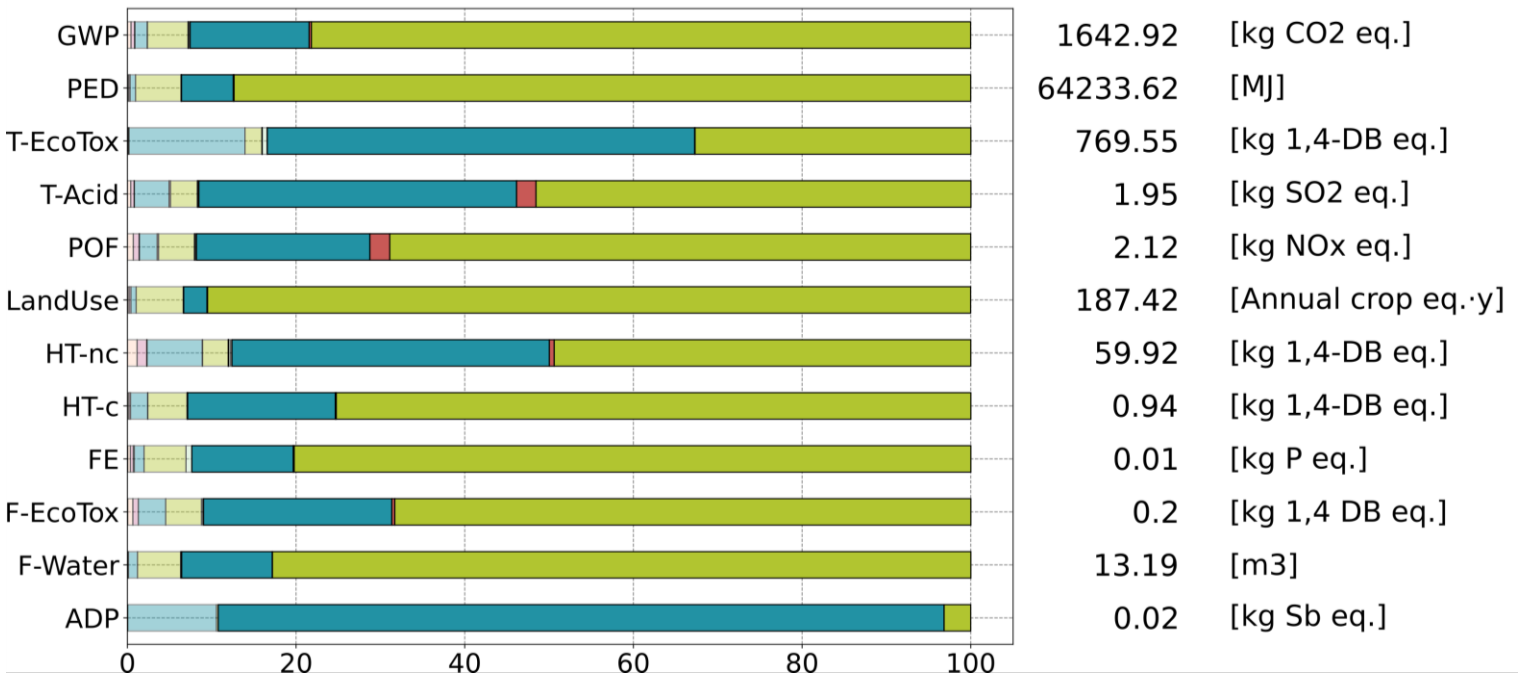
Results and interpretation



- The use phase dominates for the majority of indicators, whereas the production is clearly dominating for ecotoxicity and abiotic depletion potential.
- The IoT nodes dominate the footprint due to their higher number (108:1)
- Impacts of data transfer are very small in this case (<<1%)

More results in the paper!

LCA can help to do better… but is it good enough?

- → A predictable and conventional approach would be to use LCA results for eco-design but…
- → Based on existing literature, we illustrate the fact that although LCA can help do to better (e.g., eco-design), it falls short from answering the question "is it good *enough*?" to reach environmental targets for the sector using that IoT solution.

- → Need for a broader framework (at the application level) to discriminate between IoT solutions that should be fostered, and the ones that should be discouraged with respect to environmental limits.

More details and analyses in the paper!

Towards backcasting studies for the massive IoT deployment

Main methodological “shifts”

Traditional approach	This study
Focus on the IoT (or ICT) as a stand-alone solution and define the **environmental balance**	Integrate the IoT solution into the relevant application sector (e.g., in this study the public lighting) and **focus on environmental targets**
Use of **forecasting** studies - Partial or no integration of higher order effects - Need to define a “most likely scenario” - …	Use of **backcasting** study - Integration of higher order effects (even with significant uncertainty) - Calls for trans- and interdisciplinary interactions - Goal-oriented - …

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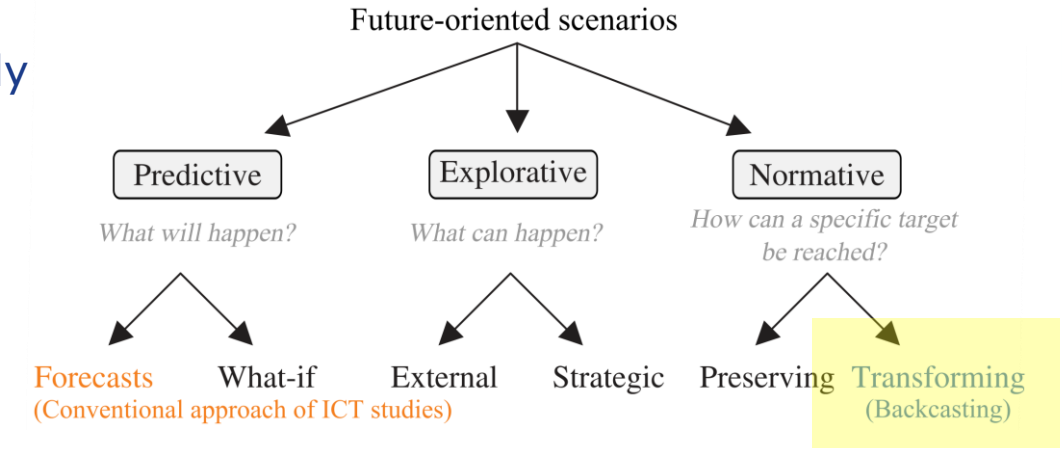
An approach based on future studies

We define key features to chose an appropriate future study



- To be **goal-oriented**
- To integrate **quantitative** inputs
- To allow for the integration of **higher order effects**
- To consider a **period of time** spanning at least 10 years from now
- To capture **spatio-temporal features** specific to a territory
- To be at least suited to **environmental analysis** (if possible complemented by socio-economic considerations)
- To be able to cope with **important uncertainties** without compromising the relevance of the analysis

Source : Figure adpated from [13,14]

Backcasting as a well-suited approach

- Backcasting consists it defining a vision of a **desirable** future and then working backwards from the end-point vision to the present [12]. This approach has been proposed in the 1990's and is particularly well-suited in the context of environmental limits.
- The **key** characteristic of backcasting compared to predictive forecasting techniques is to focus on *how desirable futures can be attained*, rather than *predicting what futures are likely to happen* [12] → **fundamental difference!**

  (calls for new imaginaries, break away from default modes of thinking, lock-ins, path dependencies, …)
- However, quantitative examples are scarce and exploratory work is needed.

Streamlined backcasting on smart public lighting

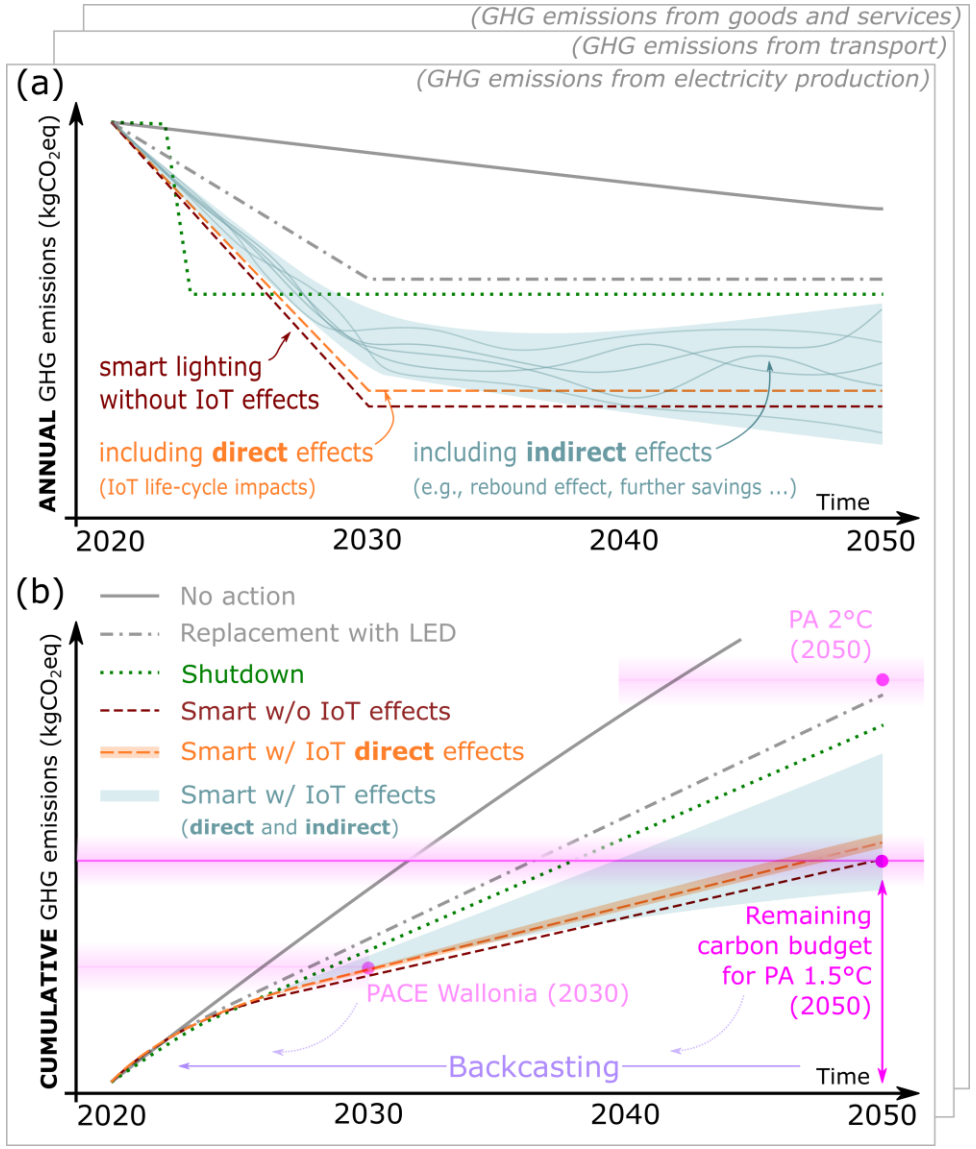
Conceptual results

Case study: smart public lighting in Wallonia (Belgium) from 2020 to 2050

We aim at understanding *if* and *how* the deployment of an IoT solution for smart public lighting could help to meet the Paris Agreement (PA) target of 1.5° C for the public lighting in Wallonia.

Scenario	Description	Comment
Baseline		
No action	Current infrastructure with an electricity mix decarbonization of 0.8%/year† [67]	No action
Replacement with LED	Linear replacement of all streetlights with energy-efficient LED lamps by 2030	Already planned
Non-technological		
Shutdown	Current infrastructure with shutdown during 40% of the night time from 2022 to 2050	Inspired by recent shutdown
Smart		
Smart w/o IoT effects	Dynamic remote dimming and predictive maintenance (smart lighting without IoT effects)	Technological (IoT)
Smart w/ IoT direct effects	Dynamic remote dimming and predictive maintenance (life-cycle impacts of IoT included)	Technological (IoT)
Smart w/ IoT effects	(Conceptual) Integration of indirect effects together with Smart w/ IoT direct effects	Socio-technological (IoT)

† : the effect of electricity mix decarbonation (*exogenous variable*) is not taken into account in the other scenarios



More details in the paper!

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Conclusions

What approach could be used to help keeping the IoT deployment within environmental limits?

Conventional LCA are *not sufficient* → need for a broader framework

We show the potential of using LCA with backcasting scenarios to help understanding *if*, and most importantly, *how* IoT could help to meet GHG reduction pathways, contrary to traditional forecasting studies in the field of ICT.

Check out the **full paper** here:

Our previous work on …

… the environmental footprint of IC production


56 IEEE TRANSACTIONS ON SEMICONDUCTOR MANUFACTURING, VOL. 36, NO. 1, FEBRUARY 2023

The Environmental Footprint of IC Production: Review, Analysis, and Lessons From Historical Trends

Thibault Pirson, *Graduate Student Member, IEEE*, Thibault P. Delhaye, Alex G. Pip, Grégoire Le Brun, Jean-Pierre Raskin, *Fellow, IEEE*, and David Bol, *Senior Member, IEEE*


The Environmental Footprint of IC Production: Meta-Analysis and Historical Trends

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Embedded Tutorial Paper

Moore's Law and ICT Innovation in the Anthropocene

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From Silicon Shield to Carbon Lock-in? The Environmental Footprint of Electronic Components Manufacturing in Taiwan (2015-2020)

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… the environmental footprint of IoT and 5G


Journal of Cleaner Production 322 (2021) 128966

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Assessing the embodied carbon footprint of IoT edge devices with a bottom-up life-cycle approach

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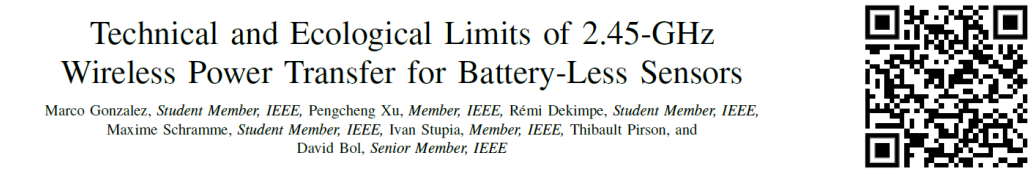
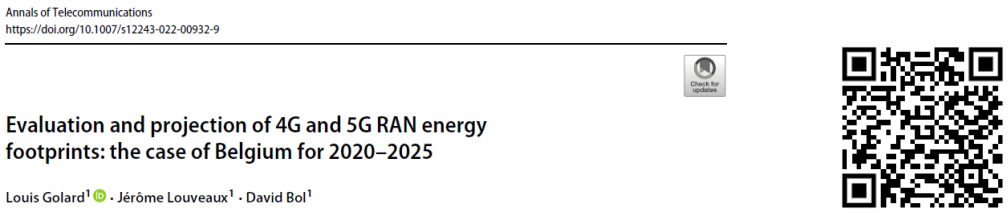

Technical and Ecological Limits of 2.45-GHz Wireless Power Transfer for Battery-Less Sensors

Marco Gonzalez, *Student Member, IEEE,* Pengcheng Xu, *Member, IEEE,* Rémi Dekimpe, *Student Member, IEEE,* Maxime Schramme, *Student Member, IEEE,* Ivan Stupia, *Member, IEEE,* Thibault Pirson, and David Bol, *Senior Member, IEEE*


Annals of Telecommunications
https://doi.org/10.1007/s12243-022-00932-9

Evaluation and projection of 4G and 5G RAN energy footprints: the case of Belgium for 2020–2025

Louis Golard[1] · Jérôme Louveaux[1] · David Bol[1]

Received: 17 June 2022 / Accepted: 28 October 2022
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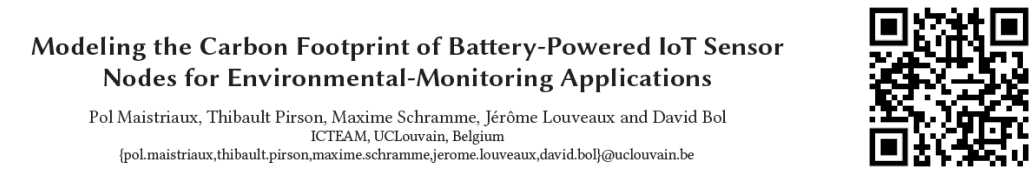
Modeling the Carbon Footprint of Battery-Powered IoT Sensor Nodes for Environmental-Monitoring Applications

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Thank you

This work was supported by the Walloon Region and EU region under FEDER project IDEES, the Brussels region under COPINE-IoT project, the F.R.S.-FNRS of Belgium.

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Open discussion & feedbacks

Reverse Panel Discussion: **Break-out rooms questions**

Question 1:

Why should we favor the use of backcasting instead of forecasting in the context of ICT and environmental limits?

Question 2:

What challenges do you see in translating global top-down environmental limits to national or sub-national scale?