Ethics & Sustainability Without the Hot Air?

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EDT Scientific Workshop

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EDT Opportunity - Commitments

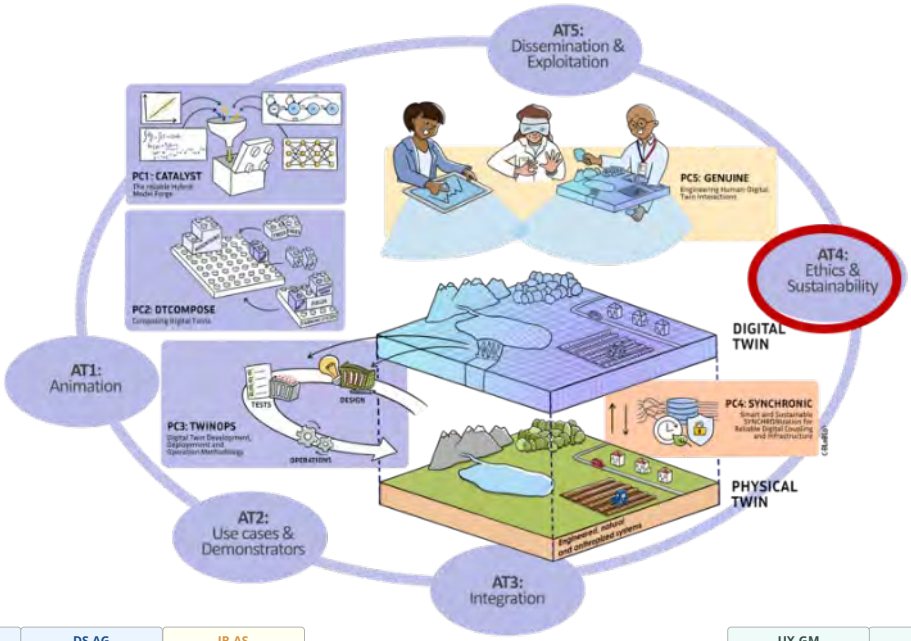
AT4: Ethics and Sustainability

A named transverse action, its own committee, liaison with key stakeholders

(from Annexe - Description of Programme)

Trustworthiness*

- one of the core capability pillars



DS.AR AI Model Repository	DS.AG Data Aggregation	IR.AS API Srvices				UX.GM Gamification	UX.DB Dashboards
DS.SR Simulation Model Repository	DS.AS Asynchronous Integration	IR.CL Collaboration Platform Integration	IC.CS Composition	IC.SM Simulation	IC.RP Reporting	UX.3R 3D Rendering	UX.XR Extended Reality (XR)
DS.SA Data Storage and Archive Services	DS.RT Real-time Processing	IR.DT Digital Twin Integration	IC.DL Distributed Ledger and Smart Contracts	IC.FL Federated Learning	IC.AL Alerts and Notifications	UX.GE Gaming Engine Visualization	UX.ER Entity Relationship Visualization
DS.DS Domain Specific Data Management	DS.BP Batch Processing	IR.IO OT/IoT System Integration	IC.BR Business Rules	IC.AI Artificial Intelligence	IC.OS Orchestration	UX.BP Business Process Mgmt & Workflow	UX.RM Real-time Monitoring
DS.IR Digital Twin Instance Repository	DS.CX Data Contextualization	IR.EG Engineering Systems Integration	IC.PS Prescriptive Recommendations	IC.PR Prediction	IC.IC Command and Control	UX.BI Business Intelligence	UX.AV Advanced Visualization
DS.RP Digital Twin Model Repository	DS.TR Data Transformation and Wrangling	IR.ET Enterprise System Integration	IC.MA Mathematical Analytics	IC.AA Data Analysis	IC.SR	UX.CI Continuous	UX.BV
DS.ON Ontology Management	DS.ST Data Streaming	MG.DG Data Governance	MG.SM System Monitoring	TW.RP Responsibility	TW.RL Reliability	TW.PR Privacy	TW.DS Device Security
DS.SG Synthetic Data Generation	DS.AI Data Acquisition and Ingestion	MG.EL Event Logging	MG.DM Device Management	TW.RS Resilience	TW.SF Safety	TW.SC Security	TW.EX Data Encryption

Data Services Integration Intelligence UX Management Trustworthiness

*Combemale, B., et al. 2025, Engineering Digital Twins: A Research Roadmap. In *2025 ACM/IEEE 28th (MODELS-C)*.

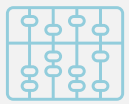
EDT Opportunity – Building Blocks

AT4: Ethics and Sustainability

to Do / Done

1. Named Lead
2. Methodology
3. Baseline data
4. Interface with PC1–PC5

Three Things AT4/EDT Could Do in Year One



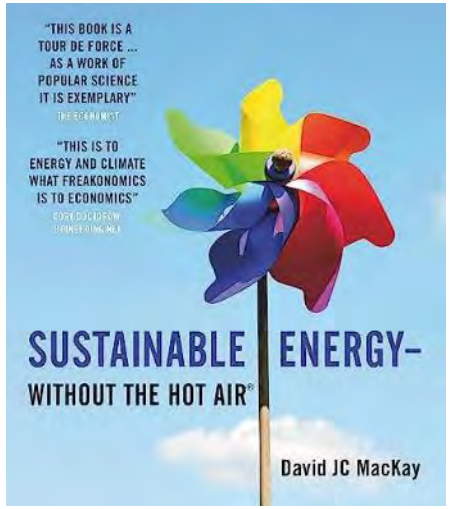
#01 Method - A published, re-usable **method for estimating a 'fair' share of compute resources** e.g., starting with one of EDT selected use case

#02 Values - A drafted **Charter of Intent;** EDT's own values, related and prioritised

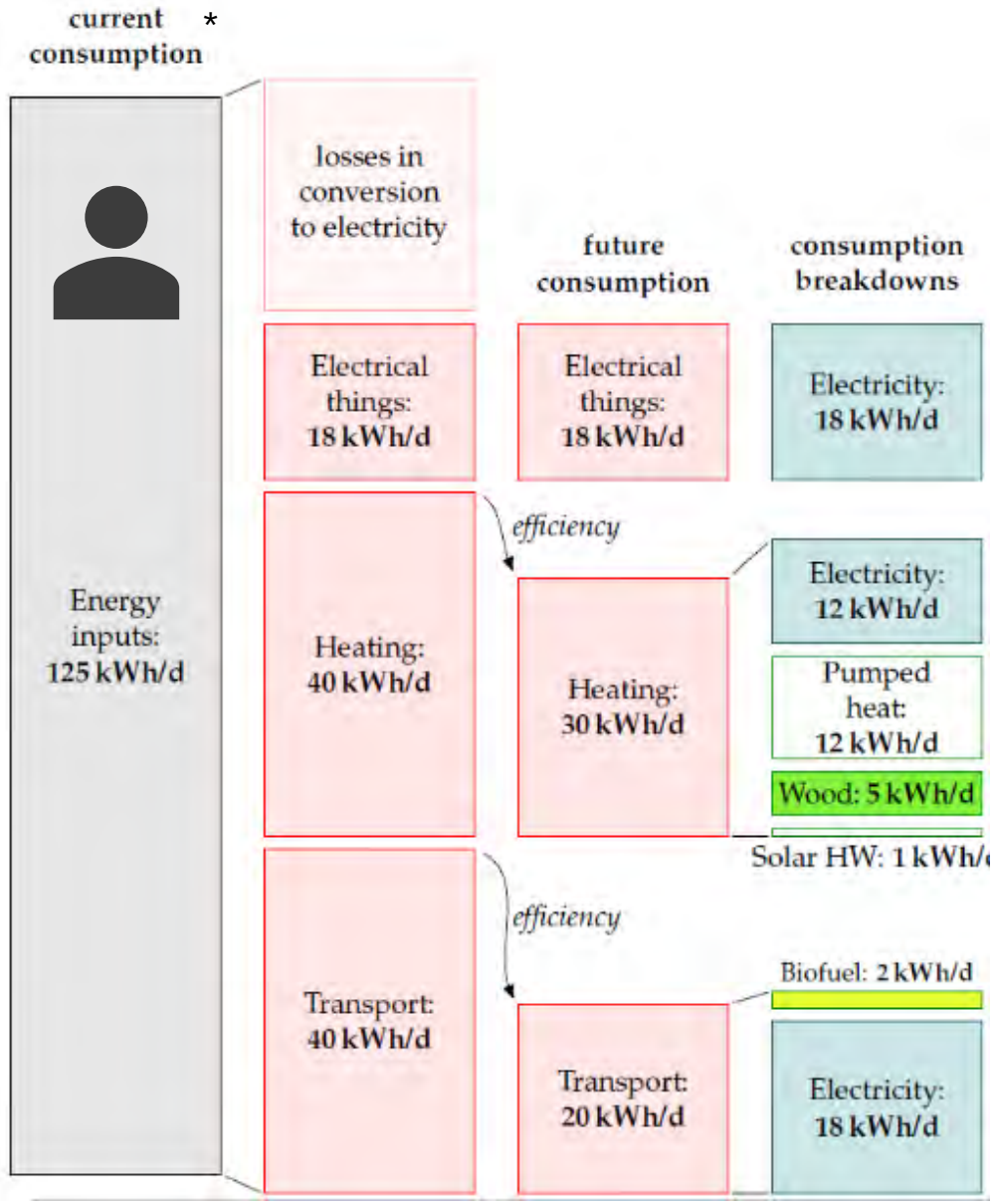
#03 People - A **stakeholder *gap* map** with the gaps named and a plan to fill them

#01 Method - MacKay's Lesson

Sustainable Energy Without the Hot Air (2008)

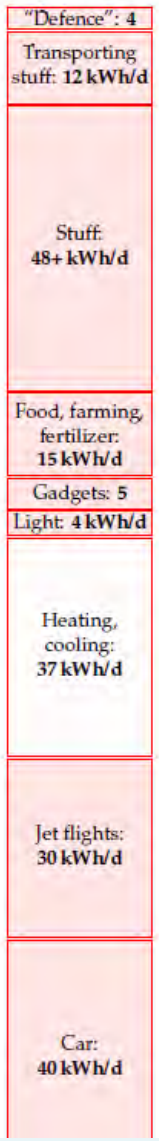


Convert energy supply and demand to the same relatable units: *kWh/day per person*



** Image from Sustainable Energy Without the Hot Air (2008) – 10pg synopsis - https://withouthotair.com/synopsis10.pdf*

#01 MacKay's rounding error (ICT)



- 2008: a "houseful of gadgets" ≈ a few kWh/day genuinely negligible next to heating, transport, food
- 2026: compute is not a gadget. It's core infrastructure

That assumption it doesn't seem to survive today's context where Data Centres and AI Fleet alone are the fasted growing sector (15% energy consumption growth) and expected to consume more that steel and chemical industry combined by 2030/35 (IEA 2025*)

* International Energy Agency (IEA) (2025) Energy and AI. Paris: IEA. Available at: https://www.iea.org/reports/energy-and-ai

#01 MacKay's Lesson, an Opportunity?

Why it can travel well

- A similar approach should apply anywhere a resource is scarce and/or contested or both
- Digital technology / AI compute seems an obvious candidate

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Data People

#01 MacKay's Lesson, Challenges

Why it may not travel so well 😳

- Embodied energy counts
- (AI) Training vs inference split
- Water
- Rare minerals
- Land
- Noise
- …

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Server Pool

#01 What About Using….

Tokens (as unit)?*

- The attempt: convert AI compute use into MacKay-style units
- E.g., tokens (questions) per day per person

> *We argue that […] the token budget does not resolve a deeper constraint: under structural uncertainty, **the decisive variable is** not how many questions can be answered but **which questions are worth asking - a problem of agency and direction** that computation alone cannot solve.*

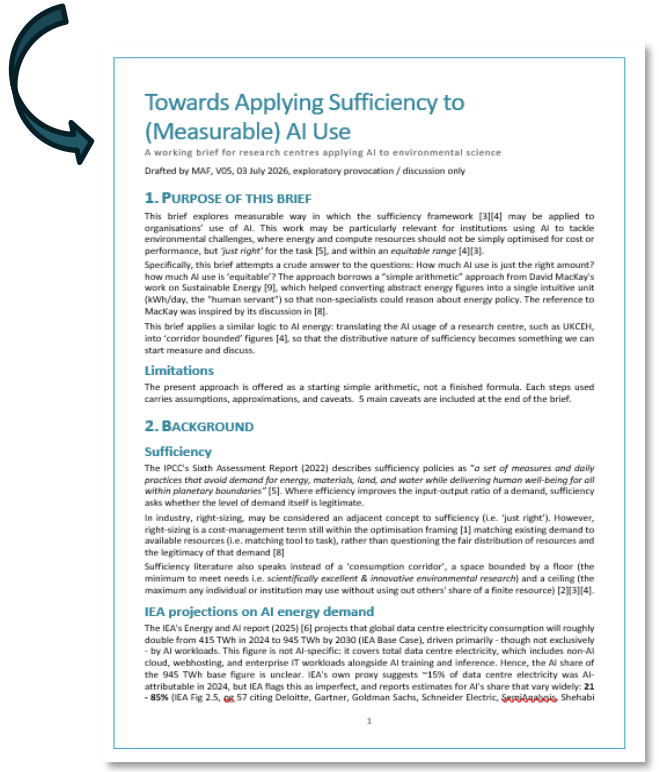
Litowitz, A., Polson, N. and Sokolov, V. (2026) 'Photons = tokens: The physics of AI and the economics of knowledge', arXiv preprint, arXiv:2603.06630

#01 How much AI compute is…?

1. Worth?
2. Enough?
3. *'Just right'*?
4. 'Just' and 'Right'?
5. Equitable?

Questions inspired by **Sufficiency*** literature

and a BoE attempt followed…



Towards Applying Sufficiency to (Measurable) AI Use

A working brief for research centres applying AI to environmental science

Drafted by MAF, V05, 03 July 2026, exploratory provocation / discussion only

1. PURPOSE OF THIS BRIEF

This brief explores measurable way in which the sufficiency framework [3][4] may be applied to organisations' use of AI. This work may be particularly relevant for institutions using AI to tackle environmental challenges, where energy and compute resources should not be simply optimised for cost or performance, but *'just right'* for the task [5], and within an *equitable range* [4][3].

Specifically, this brief attempts a crude answer to the questions: How much AI use is just the right amount? how much AI use is 'equitable'? The approach borrows a "simple arithmetic" approach from David MacKay's work on Sustainable Energy [9], which helped converting abstract energy figures into a single intuitive unit (kWh/day, the "human servant") so that non-specialists could reason about energy policy. The reference to MacKay was inspired by its discussion in [8].

This brief applies a similar logic to AI energy: translating the AI usage of a research centre, such as UKCEH, into 'corridor bounded' figures [4], so that the distributive nature of sufficiency becomes something we can start measure and discuss.

Limitations

The present approach is offered as a starting simple arithmetic, not a finished formula. Each steps used carries assumptions, approximations, and caveats. 5 main caveats are included at the end of the brief.

2. BACKGROUND

Sufficiency

The IPCC's Sixth Assessment Report (2022) describes sufficiency policies as *"a set of measures and daily practices that avoid demand for energy, materials, land, and water while delivering human well-being for all within planetary boundaries"* [5]. Where efficiency improves the input-output ratio of a demand, sufficiency asks whether the level of demand itself is legitimate.

In industry, right-sizing, may be considered an adjacent concept to sufficiency (i.e. 'just right'). However, right-sizing is a cost-management term still within the optimisation framing [1] matching existing demand to available resources (i.e. matching tool to task), rather than questioning the fair distribution of resources and the legitimacy of that demand [8]

Sufficiency literature also speaks instead of a 'consumption corridor', a space bounded by a floor (the minimum to meet needs i.e. *scientifically excellent & innovative environmental research*) and a ceiling (the maximum any individual or institution may use without using out others' share of a finite resource) [2][3][4].

IEA projections on AI energy demand

The IEA's Energy and AI report (2025) [6] projects that global data centre electricity consumption will roughly double from 415 TWh in 2024 to 945 TWh by 2030 (IEA Base Case), driven primarily - though not exclusively - by AI workloads. This figure is not AI-specific: it covers total data centre electricity, which includes non-AI cloud, webhosting, and enterprise IT workloads alongside AI training and inference. Hence, the AI share of the 945 TWh base figure is unclear. IEA's own proxy suggests ~15% of data centre electricity was AI-attributable in 2024, but IEA flags this as imperfect, and reports estimates for AI's share that vary widely: **21 - 85%** (IEA Fig 2.5, or 57 citing Deloitte, Gartner, Goldman Sachs, Schneider Electric, Semianalysis, Shehabi

1

*Intergovernmental Panel on Climate C; Change (IPCC) (2022) Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth

#01 Sufficiency, a Working Definition

“

Sufficiency** is an **amount** of something that is **enough** **for a particular** **purpose

(i.e. it is about measurement and scope….)

Fawcett, T. and Darby, S. (2019) 'Energy sufficiency in policy and practice: the question of needs and wants', in Proceedings of the eceee 2019 Summer Study on Energy Efficiency. Stockholm: European Council for an Energy Efficient Economy

#01 Energy Sufficiency, as a ‘state’

“

***Energy sufficiency** **is a state** in which people’s basic needs for energy services are met equitably (and within) ecological limits*

Fawcett, T. and Darby, S. (2019) 'Energy sufficiency in policy and practice: the question of needs and wants', in Proceedings of the eceee 2019 Summer Study on Energy Efficiency. Stockholm: European Council for an Energy Efficient Economy

#01 Energy Sufficiency - ceilings, floors, corridors…

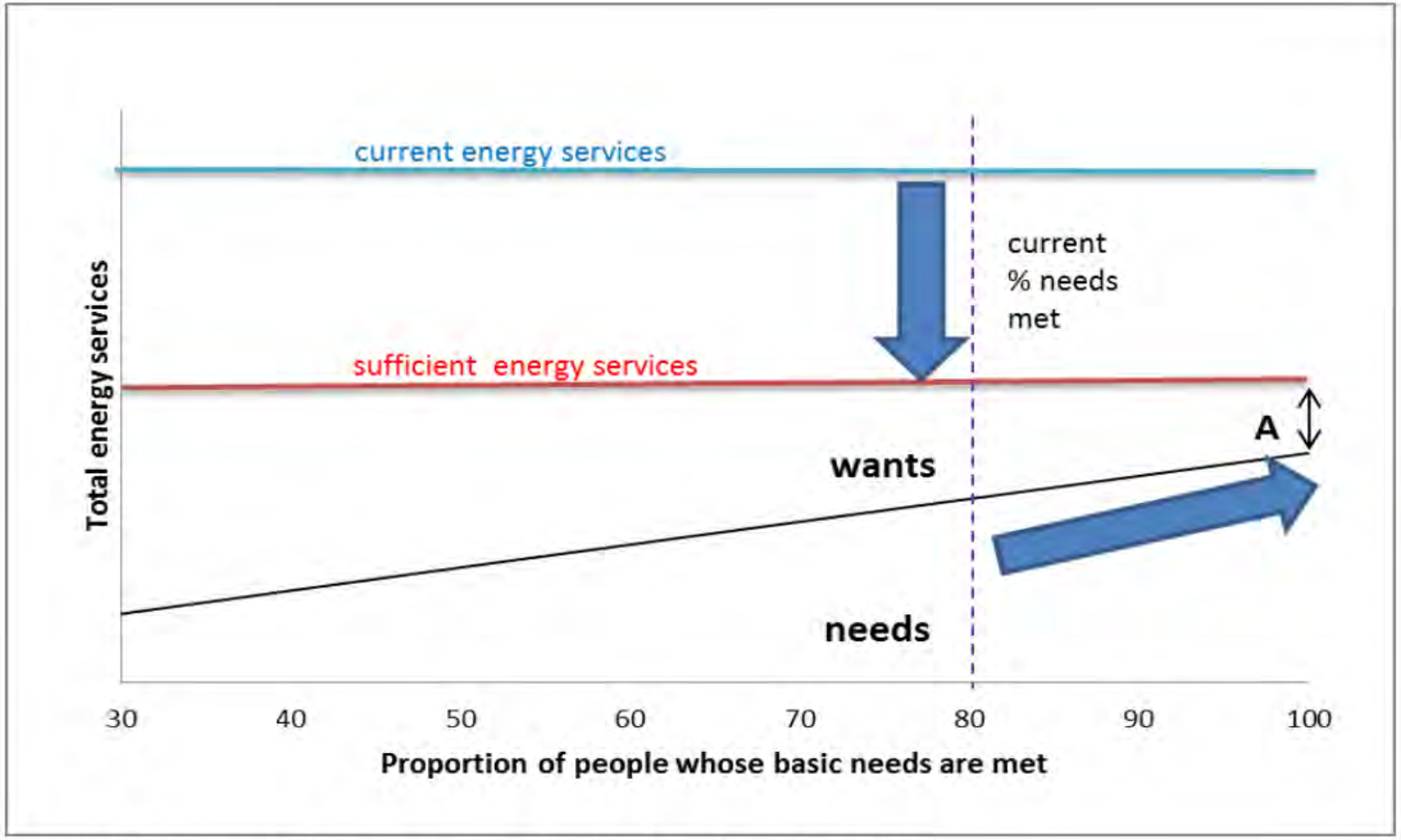


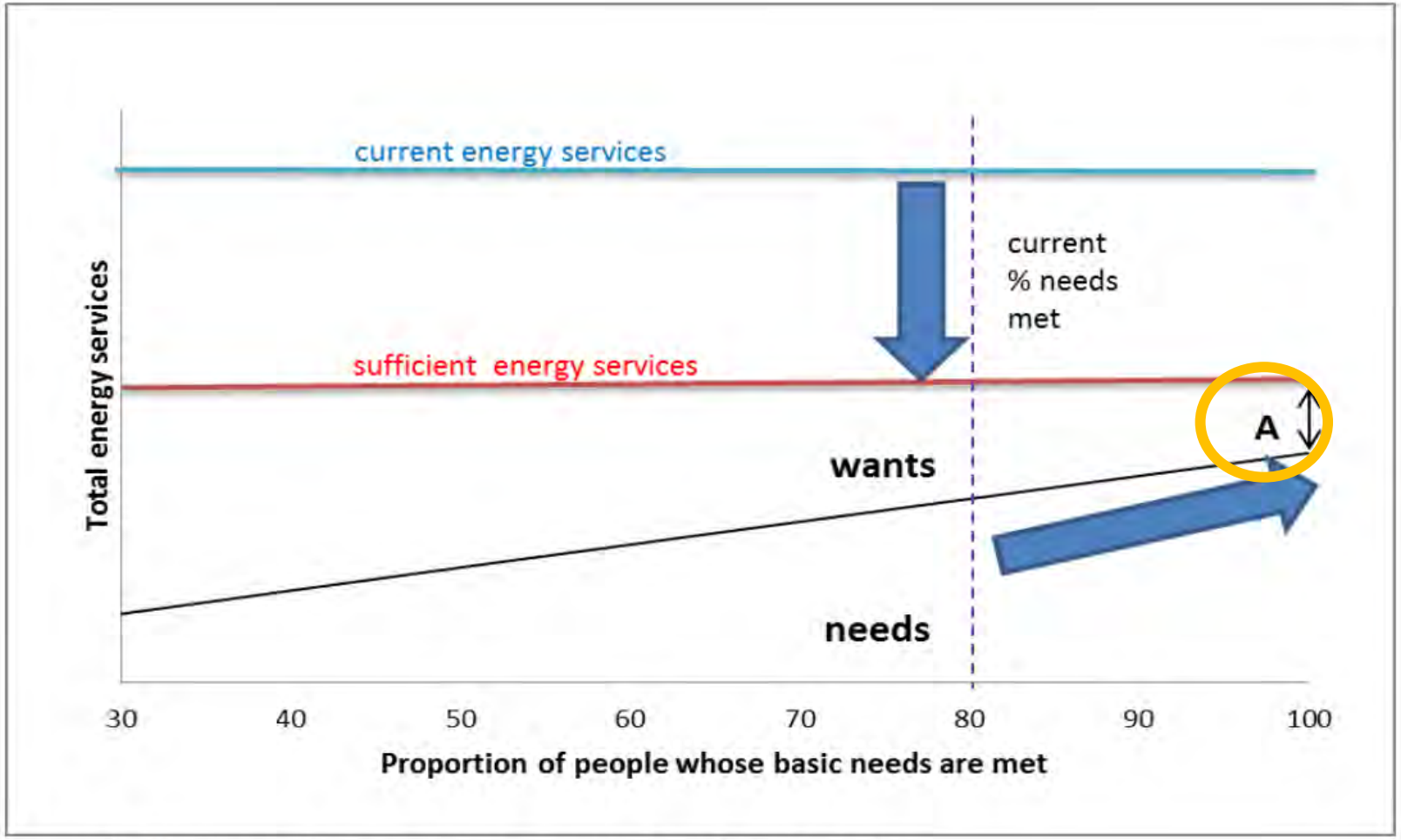
Figure 2: Illustration of energy services, want and needs (not to scale!)

Fawcett, T. and Darby, S. (2019) 'Energy sufficiency in policy and practice: the question of needs and wants', in Proceedings of the eceee 2019 Summer Study on Energy Efficiency. Stockholm: European Council for an Energy Efficient Economy

#01 Energy Sufficiency - Space

“

what space (if any) is left for wants, and how should this space be shared.



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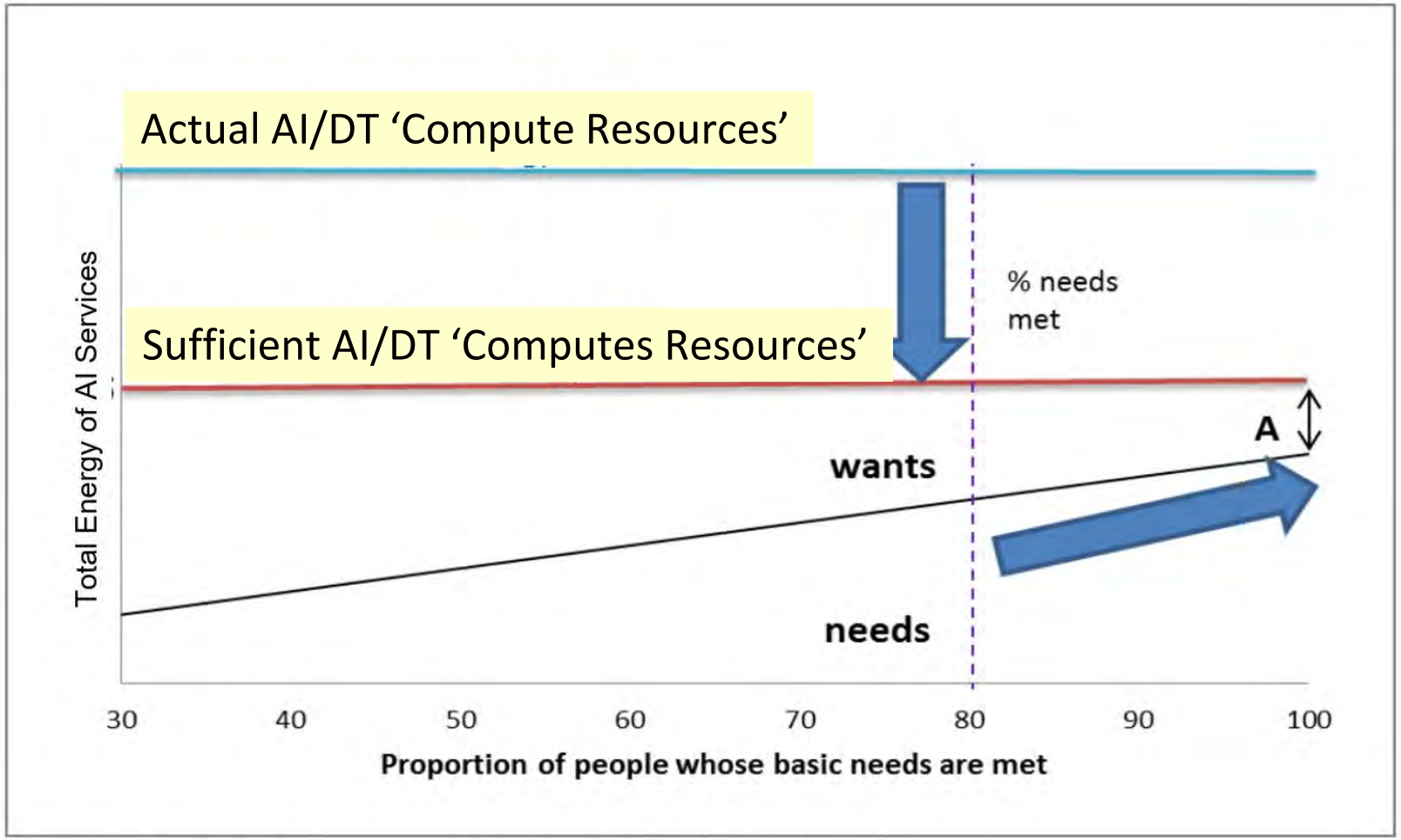
#01 AI/DT Sufficiency?

…what would be an equitable allocation of AI/DT compute resources?

What could be a single relatable unit?



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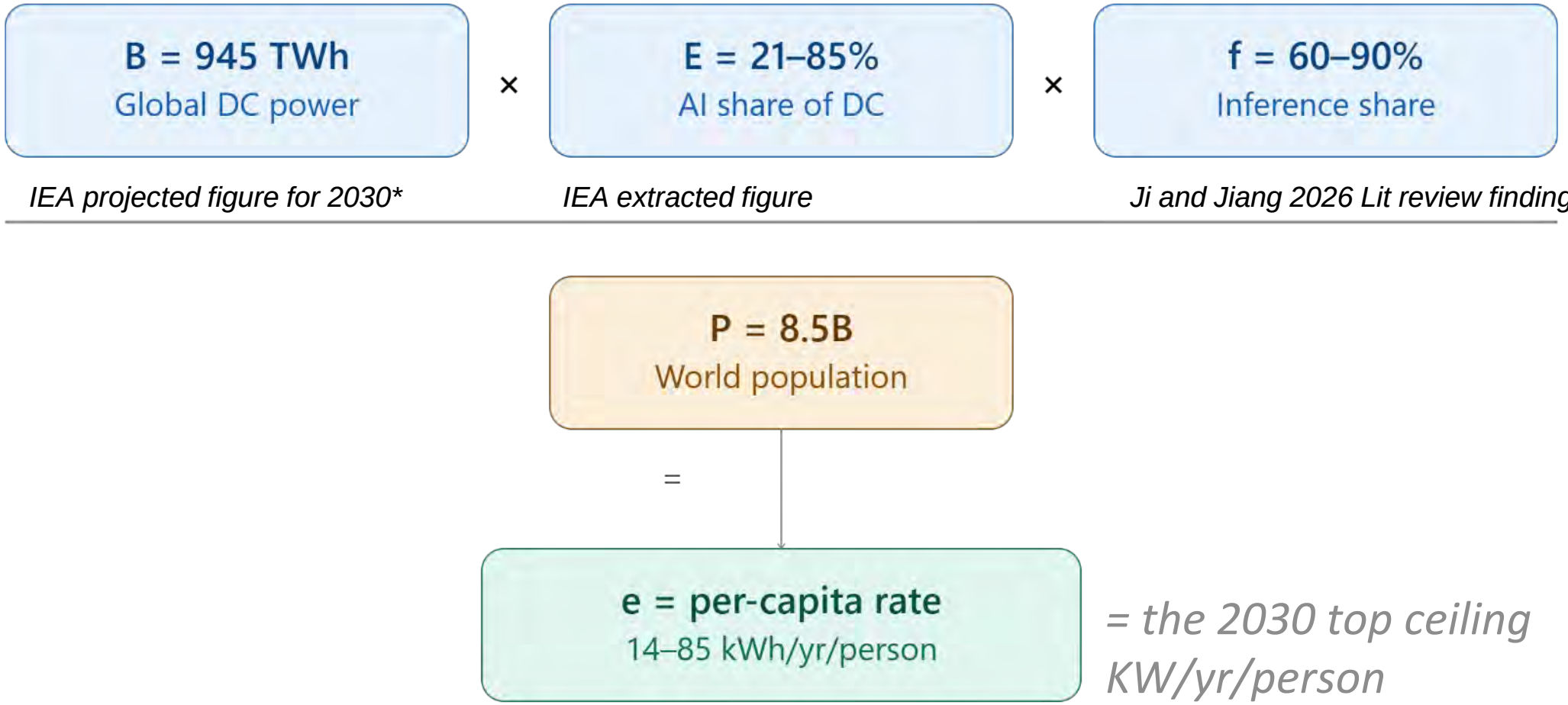
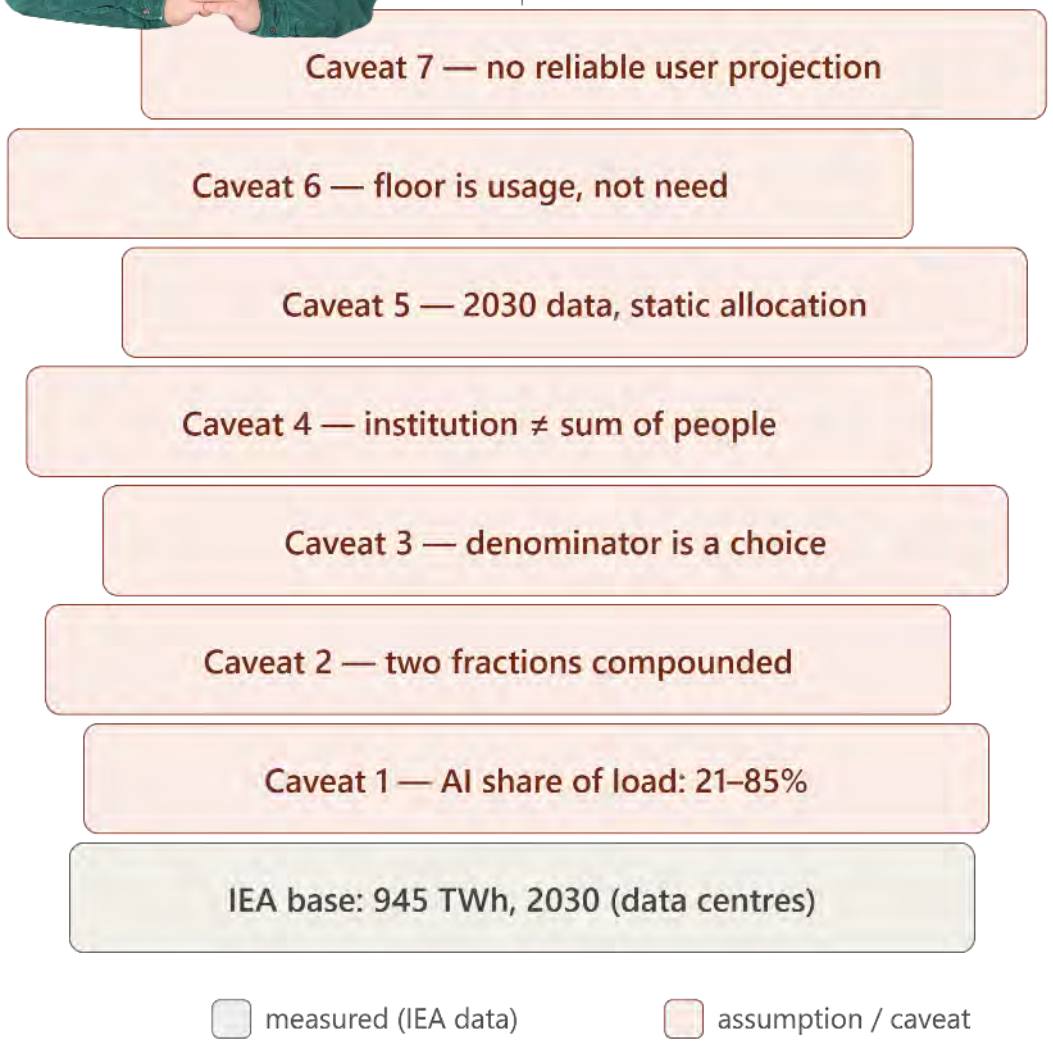
#01 AI use – a Back of Envelope Try - in KWh/yr/person…



- International Energy Agency (IEA) (2025) Energy and AI. Paris: IEA. Available at: https://www.iea.org/reports/energy-and-ai (Accessed: 1 July 2026).
- Ji, Z. and Jiang, M. (2026) 'A systematic review of electricity demand for large language models: evaluations, challenges, and solutions', Renewable and Sustainable Energy Reviews, 225, 116159.

#01 …the Caveats Stacked!

1. **AI share of data-centre load:** unresolved, 21-85% depending on source
2. **Inference/training split:** 60–90% range in the literature
3. **Population denominator** an equity choice
4. Institutional entitlement ≠ N × individual entitlement
5. 2030 IEA and Population data static allocation
6. No floor proxy - a current-usage anchor
7. **No de-duplicated AI-user count** across providers



#01 Key Takeway

The value of this exercise isn't the numbers, it’s …

1. whether sufficiency (e.g., as *ceiling* and *floor)* for AI or any tech compute is even **a legitimate way to frame the conversation**
2. and **what data** we'd need to move the approach forward

…

- **Who has the data** to answer the questions?
  - compute providers…
- **Who should be asking**?
  - users, institutions, regulators

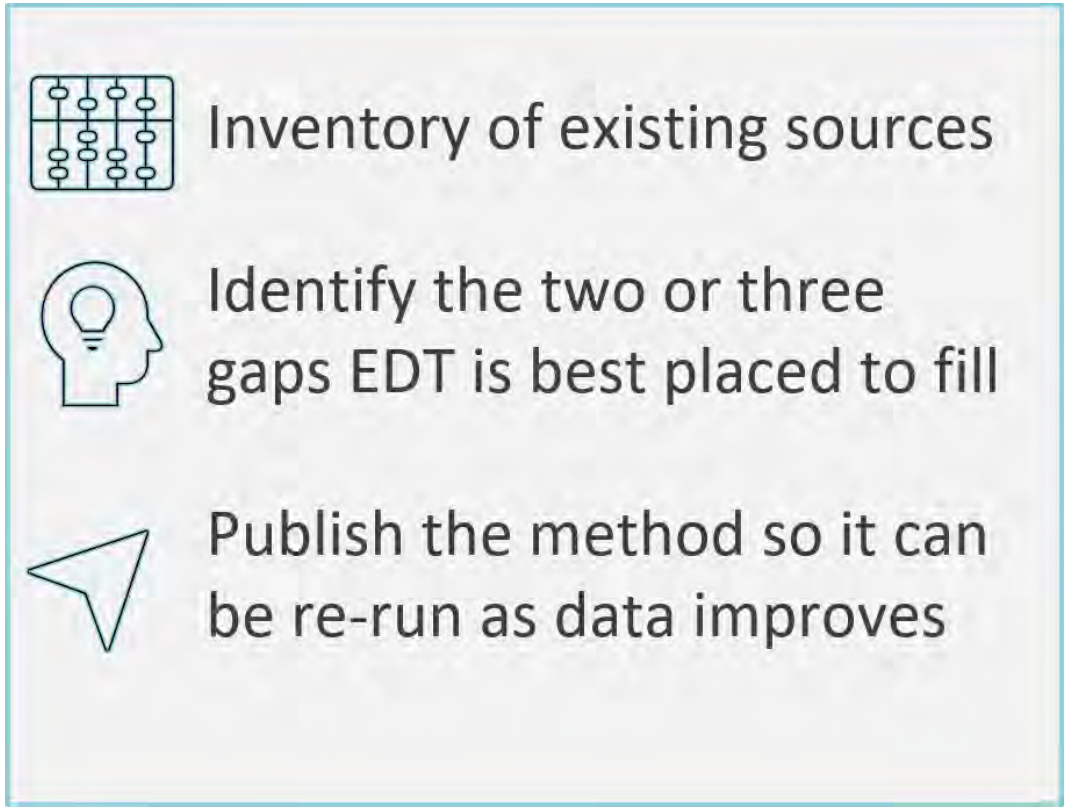
#01 What Does it Mean for EDT?

What data exists:

INSEE (population)? RTE (grid)?, GDS, EcoInfo?

What doesn't exist (?)

- DT/AI-specific usage data at population scale
- de-duplicated user counts, task-level wants/needs floors



A possible task?

#02 Values – From Compute To Choice

Sufficiency

a demand/supply corridor bounded by

- a floor (needs) and
- a ceiling (a *fair* share of wants)

EDT

Case-study selection for EDT may be itself be a sufficiency question:

which use cases sit near the floor (necessary) vs stretch toward or past the ceiling (want) ?

#02 Values - Spelling Them out

Values* = belief and principles guiding actions, behaviour, and evaluation of behaviour

They are not self-evident; they, and their associated behaviour, need to be spelled out unambiguously

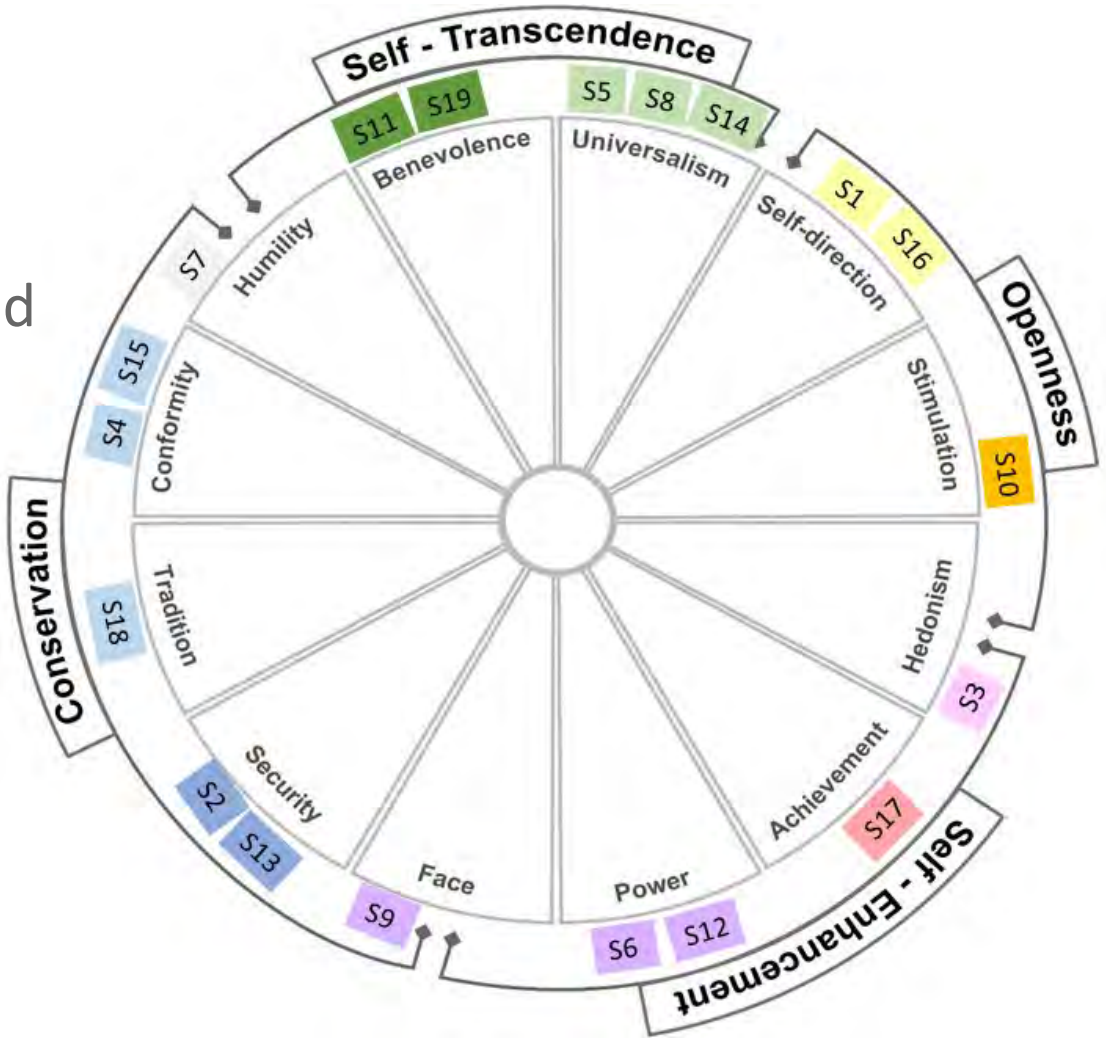
Where to start:

Honest mapping e.g., of EDT (project) values

- Do not dismiss values relational nature
  - e.g. "working code *before* documentation"

Then Review them against…

- Code of Ethics (e.g. ACM/IEEE)
- Human Rights (e.g. EU check-list - ALTAI)
- Laws (e.g. EU AI ACT, GDPR…)



Universal Values Model*

* Ferrario, M.A. and Winter, E., 2022. Applying human values theory to software engineering practice: Lessons and implications. IEEE Transactions on Software Engineering, 49(3), pp.973-990.

#02 A Charter of Intent for EDT?

A Charter as a possible outcome

examples…

Karlskrona Manifesto (ICSE2015) - Sustainability Design & Software

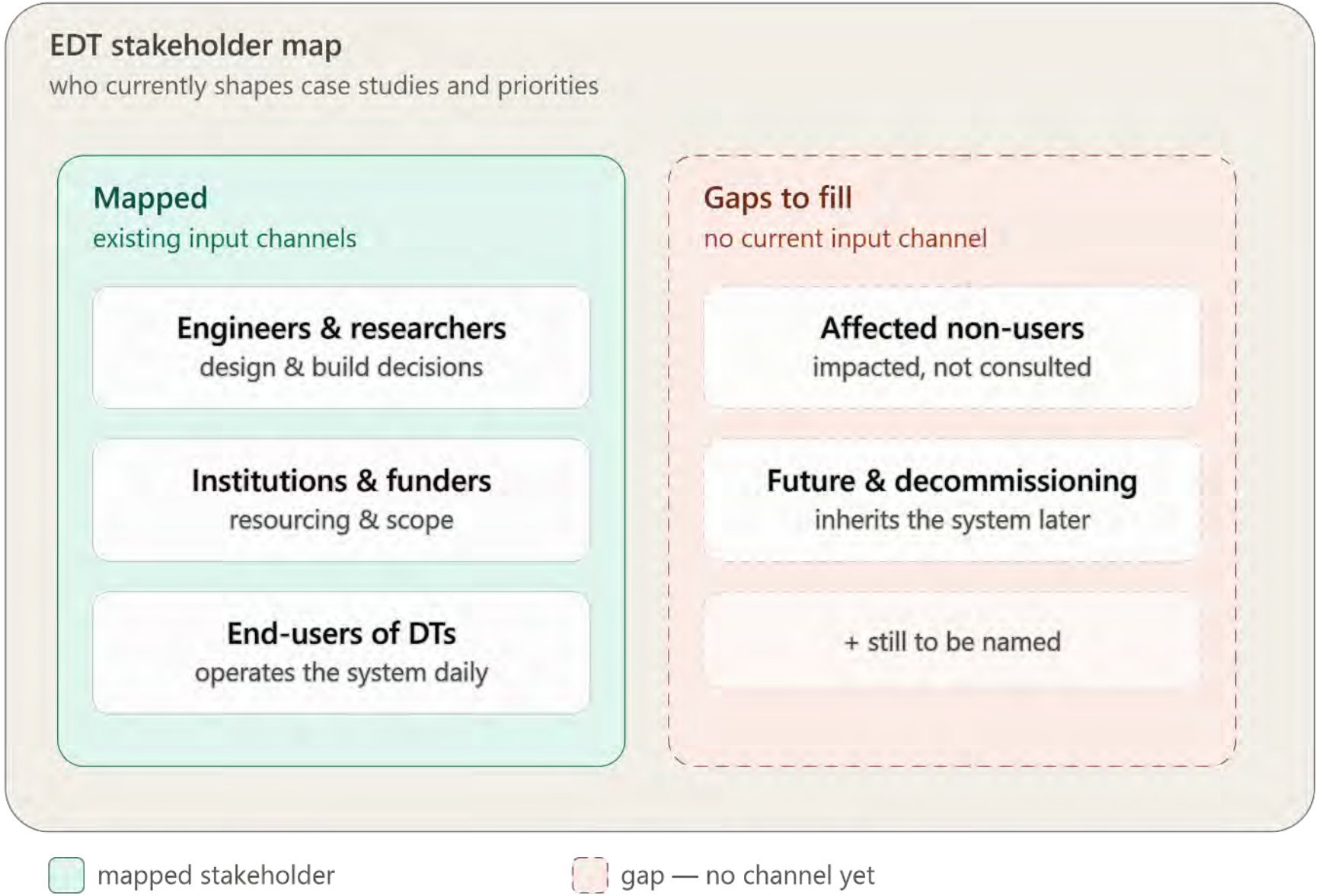
The sustainability-specific charter for SE

The Denver Manifesto (CHI2017) - values and Academia

A charter naming values and how they relate, drafted by a community - bottom up

- Becker, C., et al. 2015, May. Sustainability design and software: The karlskrona manifesto. ICSE2025
- Ferrario et al. 2017, Values in computing. In Proceedings of the 2017. CHI2017 (link to text)

#03 People Whose Values? Stakeholders ‘Gap’ Mapping



#03 A Cautionary Example: EU AI HLEG 2019

EU's 2019 "Ethics Guidelines for Trustworthy AI" drew criticism

On two main counts:

- **Process -** *who was at the table*
- **Content** - *what got prioritised.*

Hardly any ethicists involved

The composition of the HLEG AI group is part of the problem: it consisted of only four ethicists alongside 48 non-ethicists – representatives from politics, universities, civil society, and above all industry. That's like trying to build a state-of-the-art, future-proof AI mainframe for political consulting with 48 philosophers, one hacker and three computer scientists (two of whom are always on vacation).

** Thomas Metzinger is Professor of Theoretical Philosophy at the University of Mainz – April 2019*

https://www.tagesspiegel.de/politik/ethics-washing-made-in-europe-5937028.html

#03 Trustworthy AI Systems?

> *The result* is a compromise of which I am not proud, but which is nevertheless the best in the world on the subject ***

* The EY Ethics Guidelines for Trustworthy AI

> *Machines are not trustworthy; only humans can be trustworthy (or untrustworthy) **.*

*** Thomas Metzinger in* www.tagesspiegel.de/politik/ethics-washing-made-in-europe-5937028.html

Figure: "Interrelationship of the seven requirements for Trustworthy systems: all are of equal importance, support each other, and should be implemented and evaluated throughout the AI system's lifecycle" https://ec.europa.eu/futurium/en/ai-alliance-consultation/guidelines/1.html

#03 EDT, Opportunity: Science Informing Policy

Where other regulatory known gaps sit:

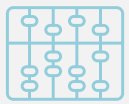
E.g., EU AI Act

- Non-discrimination: comparatively codified
- Environmental protection: comparatively thin* Art 37 **Charter of Fundamental Rights of the European Union**

EDT - through AT4 - is well placed to generate the evidence that gap needs, treat compliance to existing regulations as 'floor', the minimum…

* Ibrahim, I.A., Zaidan, E., Truby, J. and Hoppe, T., 2026. The AI Act and its green blind spots: Hidden environmental risks in the AI lifecycle. *Technology in Society*, p.103284.

Three Things AT4/EDT Could Do in Year One



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Values - A drafted **Charter of Intent;** EDT's own values, related and prioritised

People - A **stakeholder *gap* map** with the gaps named and a plan to fill them

Questions

- What framing, what method?
- What (e.g. data) do we actually need, and for whom?
- What does responsible design, maintenance, and decommissioning cost (e.g. compute and wider resources) ?
- What costs (broadly considered) and who decides, who pays them?
- What values, whose values (and what associated behaviour), and in what order?