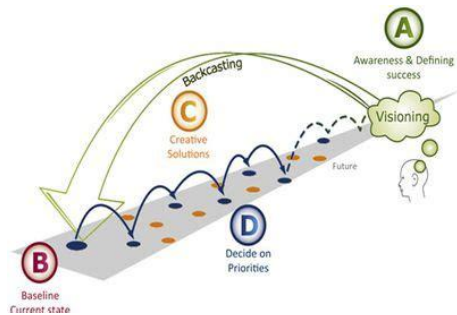
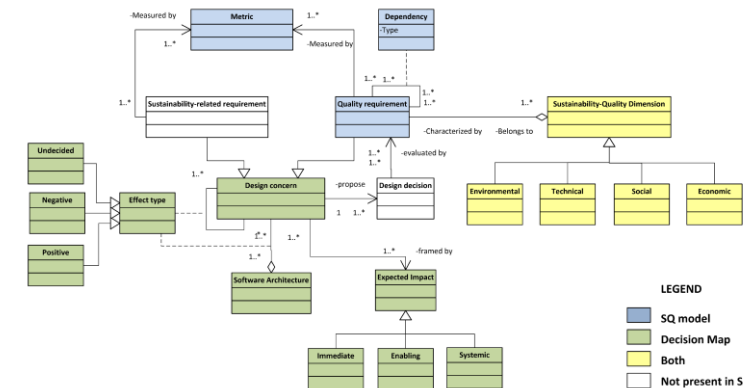
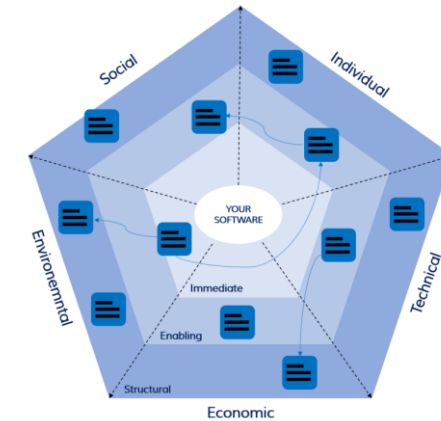
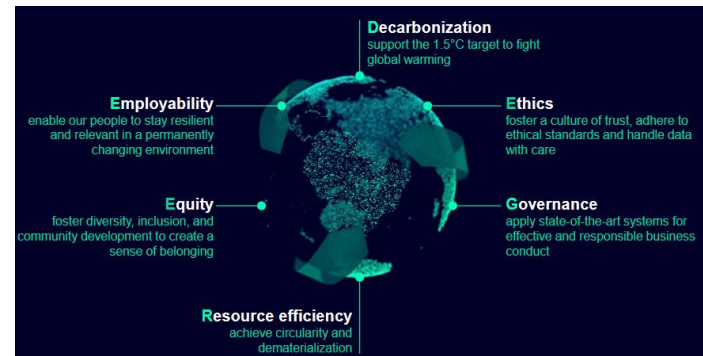


Frameworks for  
sustainable software  
engineering

Birgit Penzenstadler



	ASPIRING	AWARE	ACTING	AWESOME	INSPIRING
commitments	None	Carbon Neutral	Carbon Zero with offsets	10% (offset)	1% (offset)
footprint	Unknown	know scope 1&2	reducing per unit	reducing absolutely	~zero
metrics	None	report scope 1&2	daily scope 1&2&3	realtime	predicted
carbon ops	None	manual	Lightswitch Ops	auto- rightsizing	carbon SRE
energy	None	green hosting	dynamic mgmt	demand shaping	24/7 CFE
devices	None	some targets	10y/90%	10y/100%	Theseus' Ship
utilization	None	some multi-tenant	all multi-tenant	max orchestration	edge integration
products	None	carbon awareness	demand shaping	feature tracking	feature carbon error budgets
training	Adhoc	basic/champions	advanced	you are the trainer	you are the leader



# Mission

Compare existing sustainability frameworks for software-intensive systems with regards to their use cases, benefits and drawbacks.

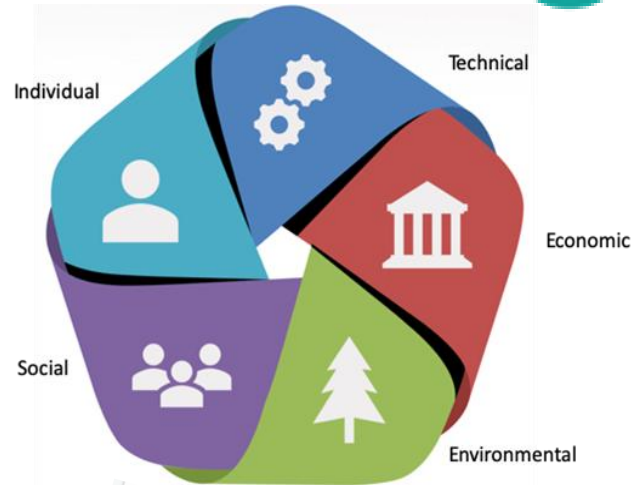


# Comparison of Sustainability Frameworks

1. Sustainability Awareness Framework (SusAF)
2. Sustainability Assessment Framework (SAF)
3. Siemens DEGREE
4. Maturity Model Integrated Green IT (mmigit)
5. Framework for strategic sustainable development (FSSD)
6. Four Cornerstone Framework
7. Green Software Maturity Matrix (GSMM)
8. Sustainable Organisational Framework for Technology (SOFT)

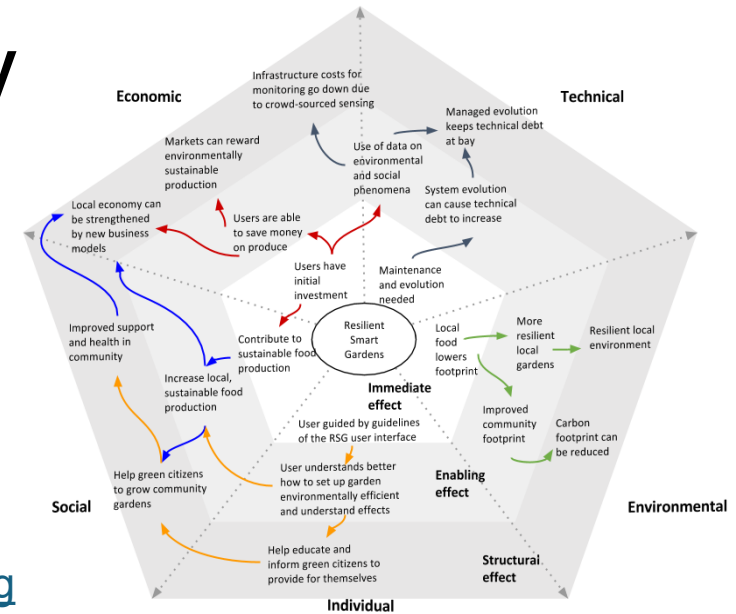


# KARLSKRONA MANIFESTO FOR SUSTAINABILITY DESIGN



## Sustainability Awareness Framework (SusAF)

<http://www.sustainabilitydesign.org>

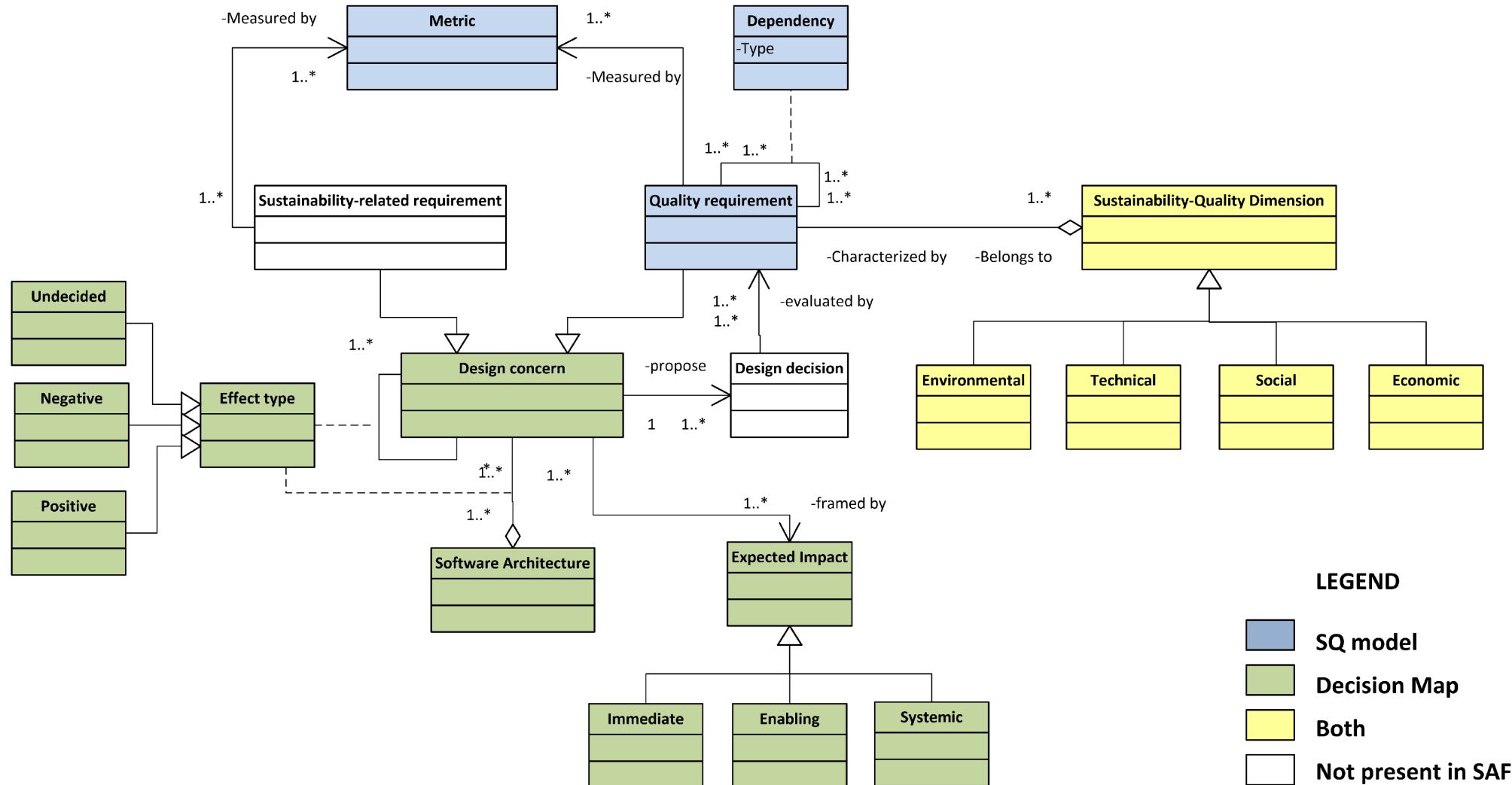


Leticia Duboc, Stefanie Betz, Christoph Becker, Steve Easterbrook, Sedef Akinli Kocak, Ruzanna Chitchyan, Ola Leifler, Jari Porras, Norbert Seyff, Ian Brooks, Shola Oyedeki, Colin C. Venters



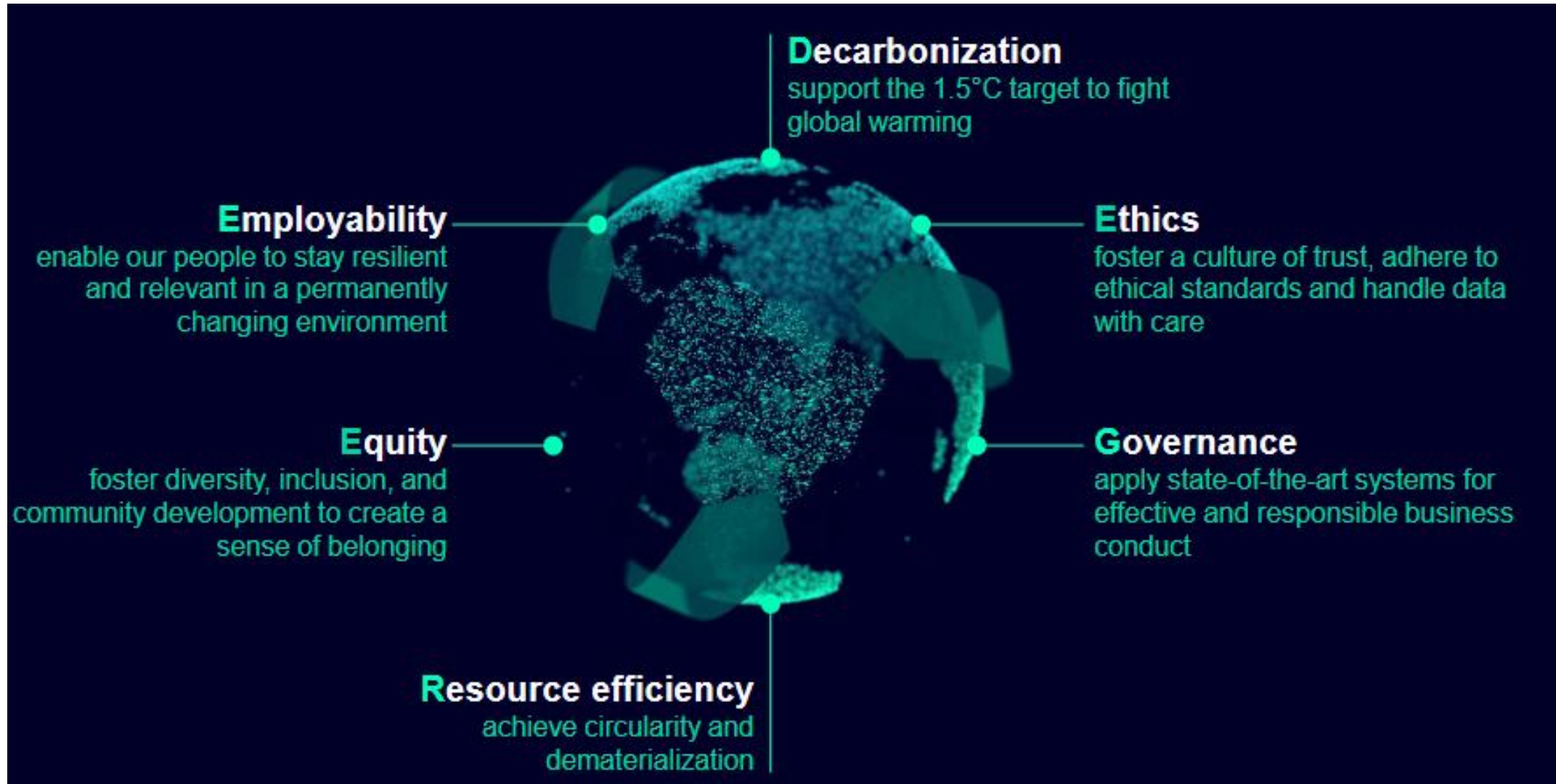
Betz, Stefanie, Birgit Penzenstadler, Leticia Duboc, Ruzanna Chitchyan, Sedef Akinli Kocak, Ian Brooks, Shola Oyedeki, Jari Porras, Norbert Seyff, and Colin C. Venters. "Lessons learned from developing a sustainability awareness framework for software engineering using design science." *ACM Transactions on Software Engineering and Methodology* 33, no. 5 (2024): 1-39.

# SAF Toolkit





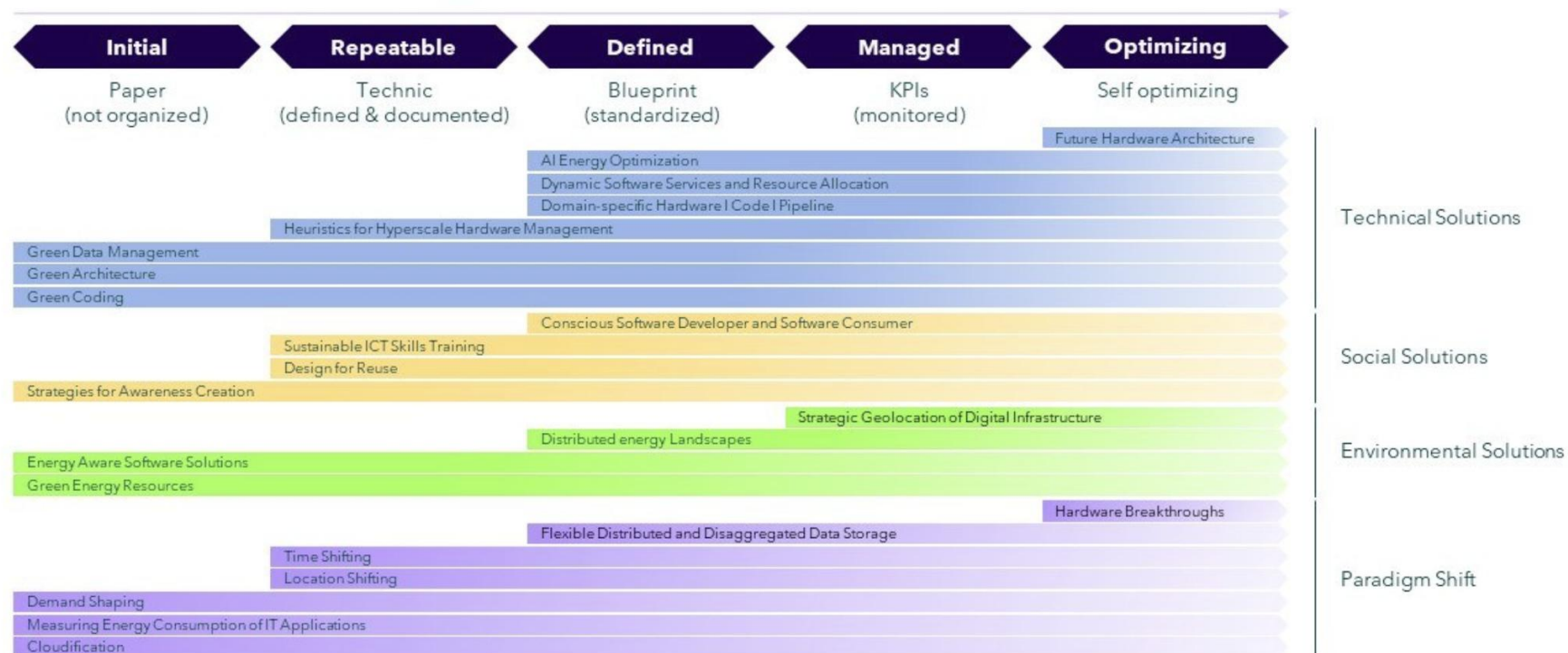
# Siemens DEGREE



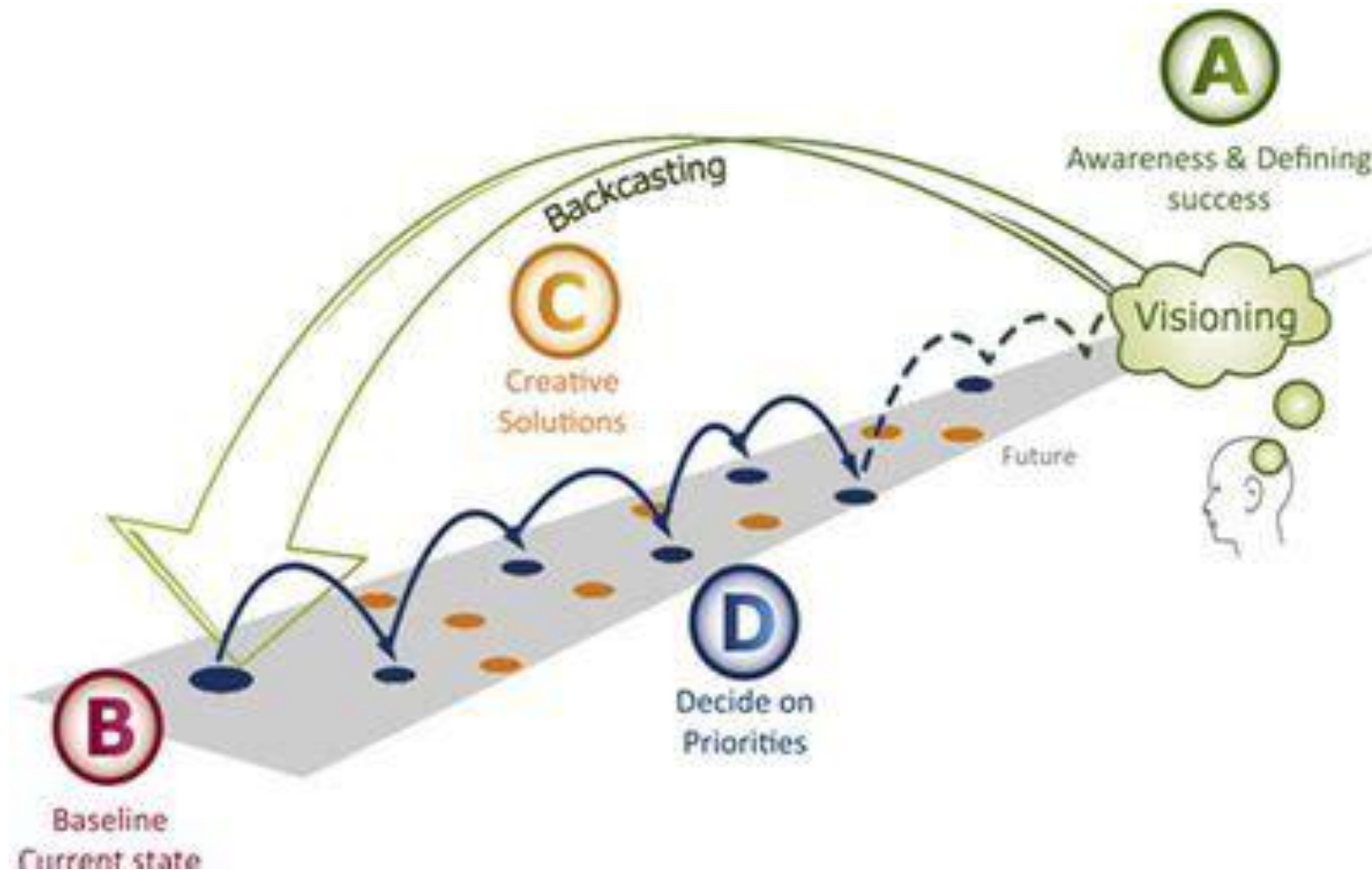
# Maturity Model Integrated Green IT (mmigit)

Green IT – New thinking and acting

## MMIGIT (Maturity Model Integrated Green IT) - Solutions Landscape Green IT



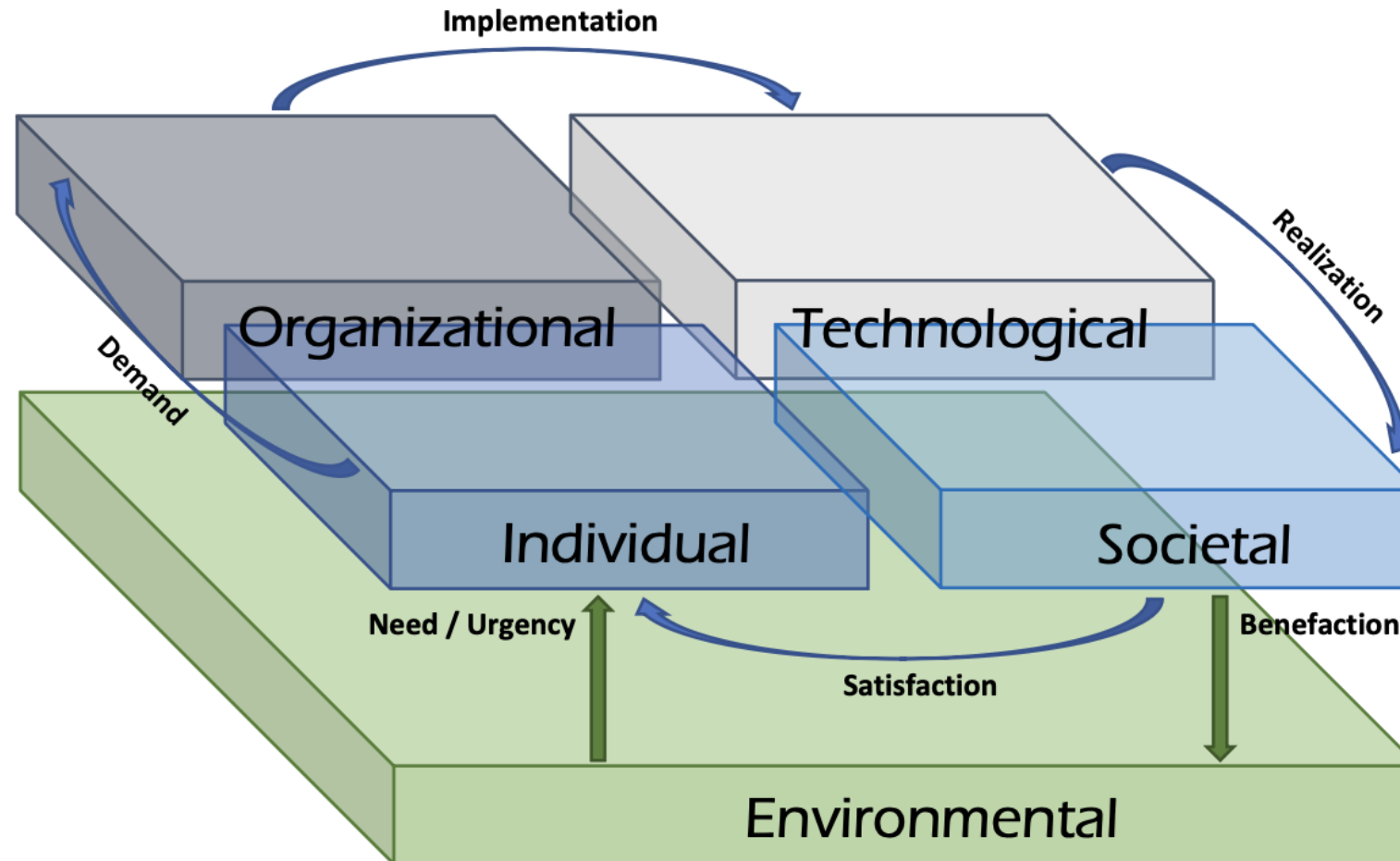
# Framework for strategic sustainable development (FSSD)



G. I. Broman and K.-H. Rob`ert, "A framework for strategic sustainable development," Journal of Cleaner Production, vol. 140, pp. 17–31, 2017, systematic Leadership towards Sustainability. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0959652615015930>



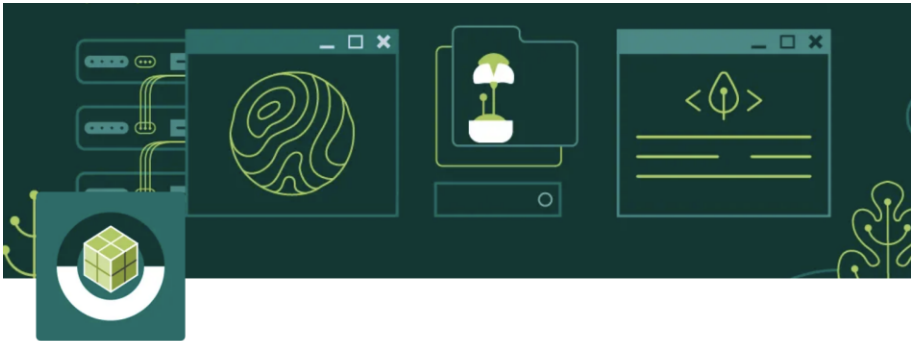
# Four Cornerstone Framework



# Green Software Maturity Matrix (GSMM)

	ASPIRING	AWARE	ACTING	AWESOME	INSPIRING
 commitments	None	Carbon Neutral	Carbon Zero with offsets	10% (offset)	1% (offset)
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 products	None	carbon awareness	demand shaping	feature tracking	feature carbon error budgets
 training	Adhoc	basic/champions	advanced	you are the trainer	you are the leader

# Sustainable Organisational Framework for Technology (SOFT)



## Sustainable Organisational Framework for Technology (SOFT)

Type	Status
Guide	Draft
Properties	
Description	A framework for decision-making during the development, implementation, and operation of technology applications by incorporating all available methodologies and instruments.
GitHub Repository	<a href="https://github.com/Green-Software-Foundation/soft">https://github.com/Green-Software-Foundation/soft</a>
Website	<a href="https://docs.google.com/document/d/12YtwEDH2DH2do97FBXY6uO3cHUUIDAD8/edit#heading=h.562vo7bcb2is">https://docs.google.com/document/d/12YtwEDH2DH2do97FBXY6uO3cHUUIDAD8/edit#heading=h.562vo7bcb2is</a>
Mailing List	<a href="mailto:toss@greensoftware.foundation">toss@greensoftware.foundation</a>
Launch date	October 16, 2023

# Sustainability Playbook for Framework Usage

1. Set the Direction
  1. Align goals
  2. Define North Stars
  3. Assign ownership
2. Build Awareness (SusAF)
3. Assess Capabilities (GSMM, MMIGIT)
4. Sustainable Architecture (SAF)
5. Operationalise (SOFT, DevOps integration)
6. Measure, Report, Improve

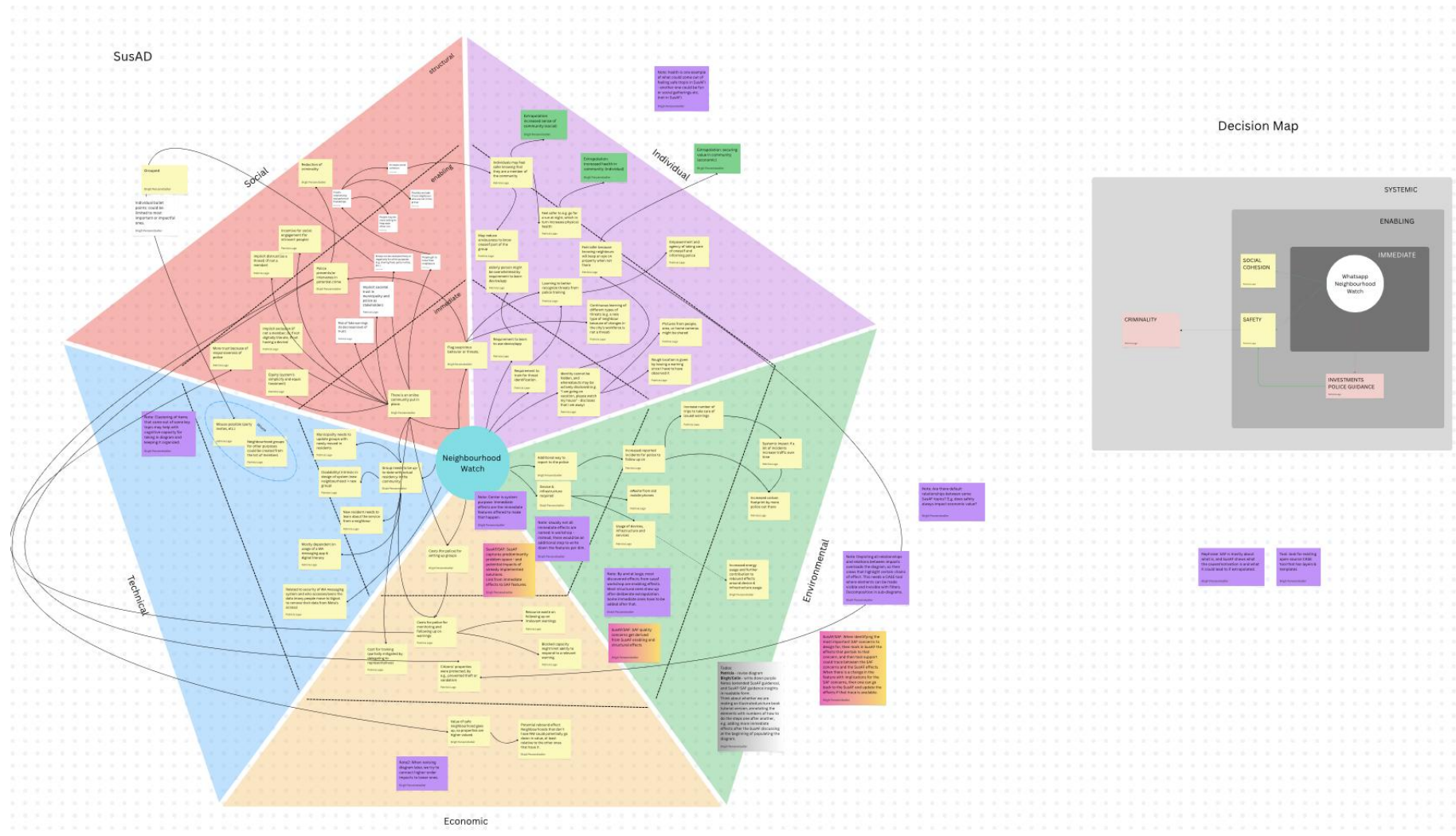
# Recommended Starting Bundle

If you need the simplest possible starting point:

- **SusAF workshop (2 hours)**
- **GSMM maturity check (1 hour)**
- **SAF Toolkit assessment (2 hours)**
- **SOFT-inspired adoption steps (ongoing)**
- This delivers awareness → assessment → measurable decision  
→ organisational embedding with minimal overhead.



# In parallel: SusAF & SAF Toolkit integration



Betz, S., Penzenstadler, B., Duboc, L., Chitchyan, R., Kocak, S. A., Brooks, I., ... & Venters, C. C. (2024). Lessons learned from developing a sustainability awareness framework for software engineering using design science. *ACM Transactions on Software Engineering and Methodology*, 33(5), 1-39.

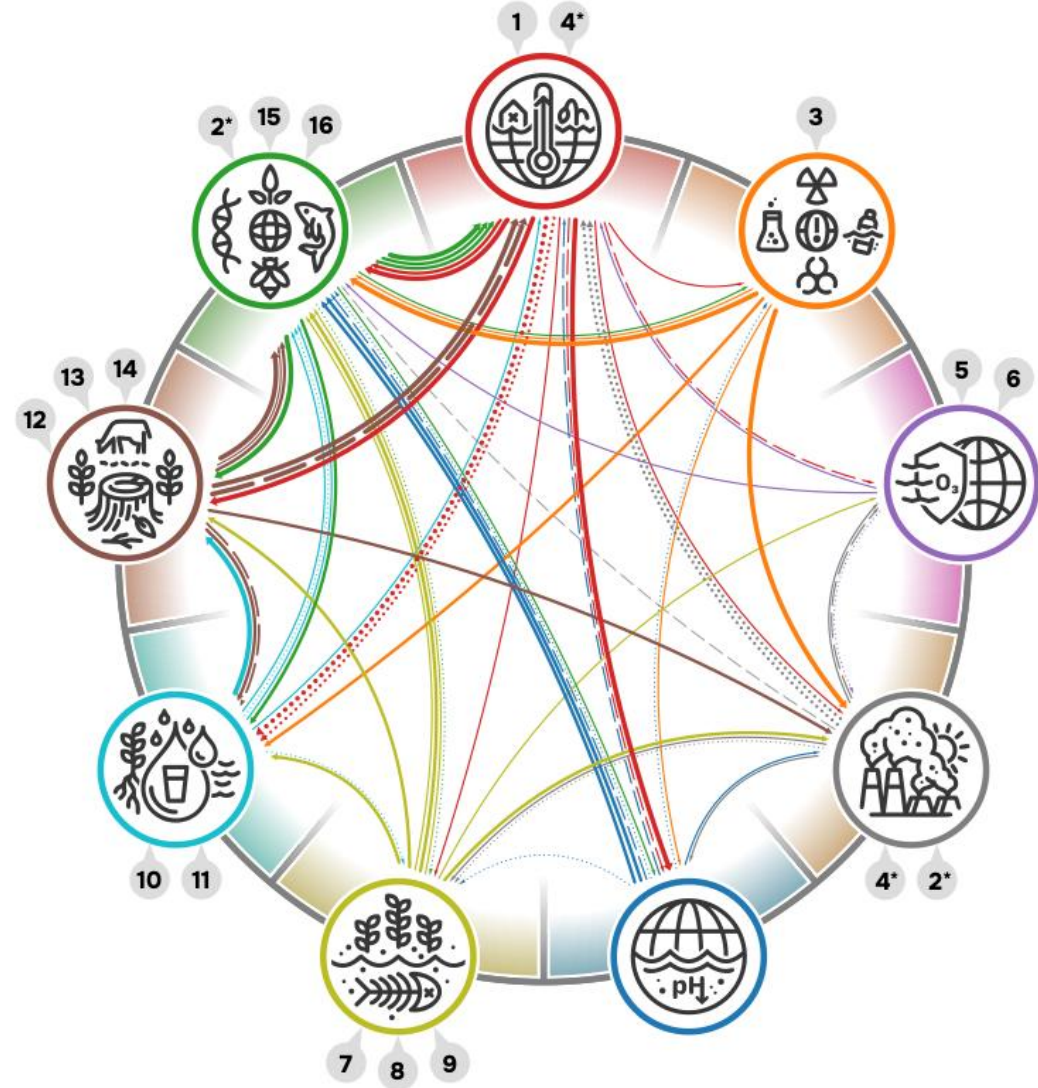
Lago, Patricia, Nelly Condori Fernandez, Iffat Fatima, Markus Funke, and Ivano Malavolta. "The sustainability assessment framework toolkit: a decade of modeling experience." *Software and Systems Modeling* 24, no. 2 (2025): 361-383.

# System dynamics

The interconnections between PBs are multidirectional and vary in strength.

Addressing one issue often implies the need to address several others at the same time, e.g. 1.5°C.

When this is done correctly, what initially seems like a challenging task can lead to significant benefits across different processes.



**PB INTERCONNECTIONS**

- COLOR**
  - Planetary Boundary
  - Boundaries
- WIDTH**
  - Interconnection
  - Relevance
- SOLID LINE**
  - Connection increasing transgression
- DASHED LINE**
  - Connection decreasing transgression
- DOTTED LINE**
  - Connection with both effects possible

**PB DRIVERS**

\* same driver shown twice for different PBs

- 1 Emission of non-CO<sub>2</sub> greenhouse gases (other pathways than fossil fuel burning)
- 2 Biomass burning
- 3 Release of untested synthetic chemicals
- 4 Fossil fuel burning
- 5 Emissions of synthetic chlorofluorocarbon molecules
- 6 N<sub>2</sub>O release to the atmosphere (in multiple contexts, mainly agriculture)
- 7 Application of industrially-fixed N to fields as fertilizers
- 8 Cultivation of N-fixing crops
- 9 Application of mined mineral P to fields as fertilizers
- 10 Industrial and household water use
- 11 Irrigation and agriculture
- 12 Expansion of livestock grazing
- 13 Expansion of cropland
- 14 Expansion of settlements and infrastructure
- 15 Introduction of invasive species
- 16 Harvesting biomass

**FIGURE 10 - The causal network of Planetary Boundary processes.** The diagram shows the most significant and best understood interconnections between Planetary Boundary (PB) processes and the most important drivers of transgression. Colored arrows indicate a connection between two PB processes, with the color denoting the source PB process. The width of the arrow represents the estimated relative strength of the connection, while the line style (solid, dashed, dotted) indicates the nature of the connection (positive, negative, or both). Numbers associated with PB processes denote the most important drivers of PB transgression, as defined above. These drivers can be linked to multiple PBs simultaneously. For a tabular overview of the considered PB connections, see [Supplementary Materials](#).

# Next step: Case Studies

We are looking for companies that wish to try:

1. The whole Starting Bundle, or
2. SusAF-SAF Toolkit integration

→ Talk to me if interested 😊



## Contact us



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