



Ethical Indicators for Environmental Robotics



Background

- Proliferation of **intelligent (i.e. AI-supported) robotic systems in environmental contexts**, e.g., agriculture & forestry, circular economy & recycling, monitoring, maintenance
- Initial RQ:** *What changes in ethical issues before and after implementing AI into environmental robotics?*
- Updated RQ:** *How to find ethical indicators for intelligent environmental robotics?*



"BRIDGE" Project:

Ethical-legal accompanying project for 16 environmental robotics development projects:

- ❖ **Enable & Support:** Orientation, workshops, and status seminars for the funded projects
- ❖ **Analysis & Orientation:** In-depth studies on law, ethics, and sustainability
- ❖ **Knowledge Transfer:** Publications, guidelines, and dialogue formats on the results

Ethical subproject:

- ❖ **Identifies ethical dimensions & challenges** for intelligent robotics in the environmental sector
- ❖ **Develops proposals** for effectively addressing these issues in the development projects

BMFTF funding initiative "Digital GreenTech: Environmental Technology Meets Robotics" (2025-2028)
<https://digitalgreentech.de/en/bridge.html>

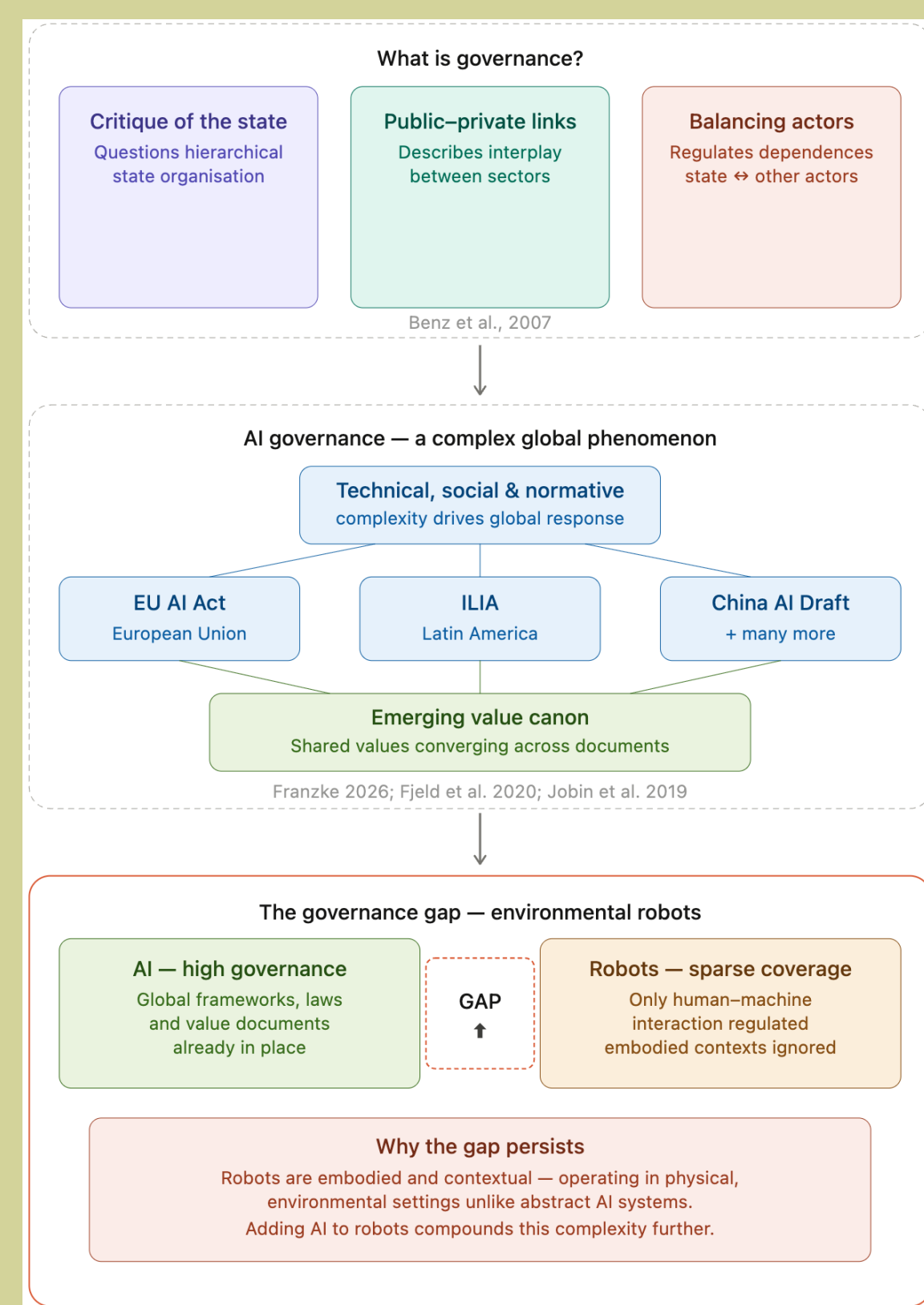
* Environmental robots:

- Programmable, sensor- and actuator-based, autonomous or semi-autonomous systems** designed to perform tasks in environmental research, engineering, protection, remediation
- Including systems that **influence environmental conditions**
- At the **intersection** of robotics, AI, and environmental systems
- Can be understood as:
 - Tools** for addressing ecological problems, and
 - Technological actors** embedded within environmental systems themselves



Research Gap

- Current regulatory landscape of **AI governance** has produced rich body of **ethical indicator sets** (Fjeld et al. 2019; Jobin et al. 2020; Franzke 2026)
 - Fine-grained **guidance for sustainability** with many regulatory documents (eg., ESRS, GRI, DNK)
 - But no **systematic guidance** on the design of analogous indicators for the **governance of environmental robots** (Winfield et al. 2019)
- **Combination** of AI Ethics and Environmental Ethics for the application of environmental robots is **missing**



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Connect and
discuss with us

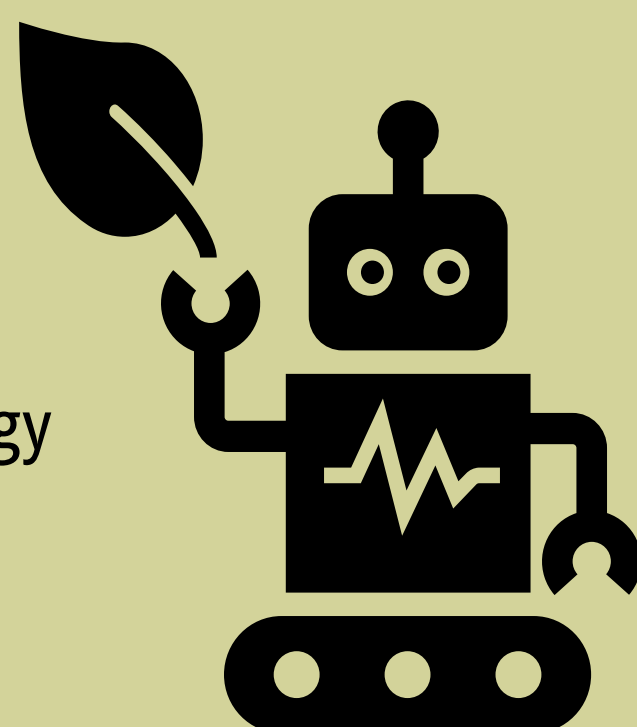
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Funded by:



Federal Ministry
of Research, Technology
and Space



Indicators for AI

Van Wynsberghe (2021): "Sustainable AI" should be:
AI to support sustainability objectives (**AI for Sustainability**)
+ Environmental measures for resource protection (**Sustainability of AI**)

VCIO Model (Hallensleben et al. 2020) (Values, Criteria, Indicators, Observables)
• VDE SPEC 90012: "Ecological Sustain Development" criterium within "Fairness"

VPCIO Model (Martin et al. 2025):

- Sustainability issues as a mid-term Principle of "Environmental flourishing"
- Subdivided into criterium of "Life cycle assessment" and "AI systems decisions enhance environmental flourishing and sustainability"

Rohde et al. (2024):

- Detailed set of criteria and indicators for a sustainability assessment of AI systems throughout their lifecycle
- Holistic perspective of Sustainable Development (SD) at the centre of the evaluation
- 18 criteria along governance, social, and ecological aspects

VPCIO Model (Martin et al. 2025)

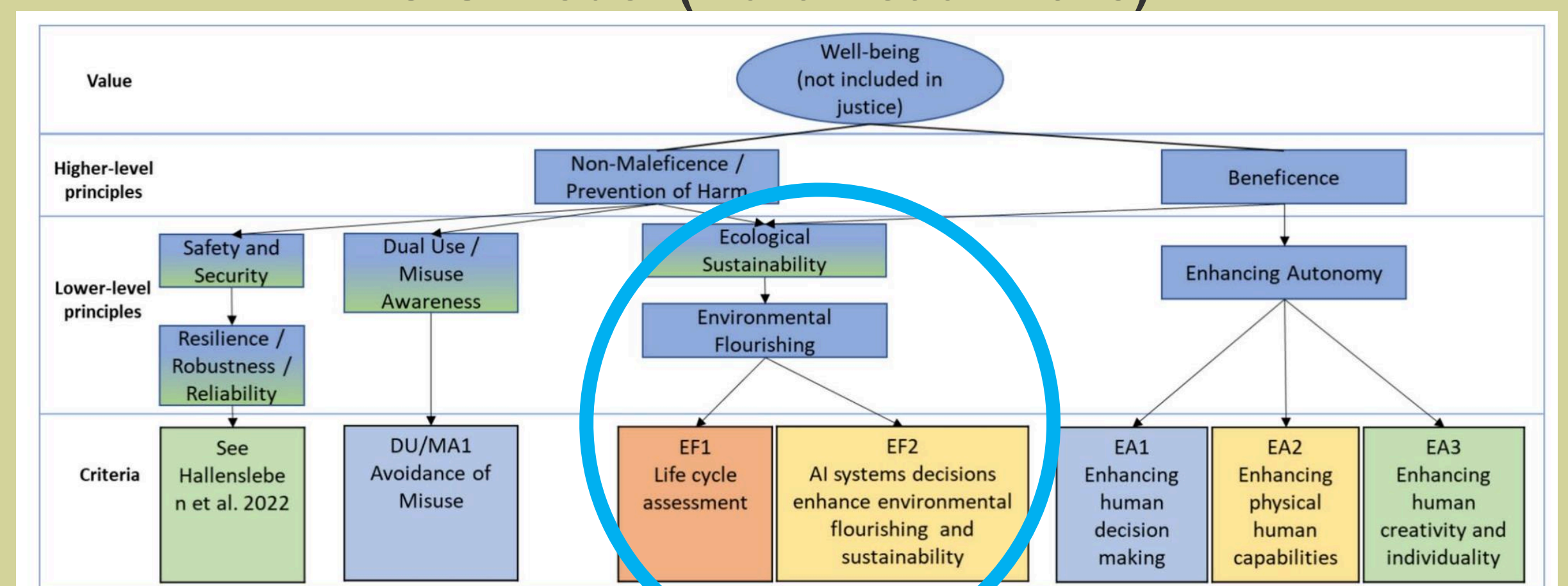


Fig. 3 VPC of well-being

Sustainability indicators (Rohde et al. 2024)



First Findings

Existing AI and sustainability indicators do not sufficiently address **crucial normative aspects** that are specific to environmental robots:

- How is the robot changing how humans interact with one another?* (**Human-machine interaction**)
- What fauna and flora will be affected by the implementation of the robot?* (**Responsibility**)
- Do the robots need Internet for their functioning?* (**Safety**)
- How is the robot changing the workplace of people?* (**Future work**)
- Does deployment require land use changes or infrastructure that may disrupt habitats?* (**Environmental impact**)

Questions

- How can we **effectively represent** aspects of Sustainable Development that **cannot be evaluated** in numeric terms or as yes/no categories?
→ E.g., impact on **biodiversity, mental health**
- How can we go beyond the notion of "sustainability = efficiency"?
→ Address as triad of **efficiency, resilience, sufficiency** (Ott, 2009)
- How can we develop further indicators for environmental robots **outside the scope of "AI"**? → Ethical challenges are mostly discussed on **abstract and conceptual** level or for specific domains (e.g., agriculture, maintenance)
→ Without **normative recommendations** and **concrete indicators**