S&T&I FOR 2050

Science, Technology and Innovation for Ecosystem Performance – Accelerating Sustainability Transitions

DELIVERABLE 1.1: SCOPING AND DRAFT CONCEPT PAPER

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1. SUMMARY

This report serves to initiate a dialogue on ways to integrate ecosystems flourishing into RTI orientation. As a starting point for the debate, we present three possible perspectives on ecosystem stewardship emerging from a review of recently proposed concepts. The three perspectives differ not only in the types of indicators they propose to assess ecosystems status, but also in the very notion of ecosystems and their proposed interaction with the human sphere Table 1.

	Notion of ecosystems	Motivation to promote ecosystem performance	Proposed attitude towards ecosystems performance	Type of indicator used to assess ecosystem performance
Protecting and restoring ecosystems	Distinctive nature sphere interacting with the human sphere (natural capital)	Costs and benefits of (in-)action regarding limiting effects on the environment	Manage the impact of human activities to reach a desired target	Distinctive measures of environmental pressure on the state of the environment e.g. pollinator diversity, soil organic carbon ...
Co-shaping socio-ecological systems	Complex adaptive socio-ecological systems with no clear boundaries	Steer system dynamics towards long term survival	Move specific socio-ecological systems towards more beneficial dynamics	System resilience (learning capacity), institutions of polycentric governance
Caring within hybrid collectives	Pluriverse of hybrid entities with agency emerging out of relations to each other	No other choice for humans, ethics of care	Negotiate with other inhabitants of critical zones to allow all to flourish on their own terms	Number of flourishing of life projects, pressure on other collectives

Table 1: Overview perspectives on ecosystem performance

Each of these concepts provides useful inroads for orienting RTI but also poses specific challenges (Table 2). In particular, some efforts will be needed to extend these frameworks that often focus on research and innovation that is directly dealing with ecosystem management towards other RTI arenas such as mobility, manufacturing or ICT.

	Implication for RTI orientation	Opportunities	Challenges
Protecting and restoring ecosystems	Assess and optimise the impacts of RTI on these indicators	Straightforward implementation, well established indicators	Extension to more specific RTI projects outside ecosystem management incorporating system transition perspective (EEA 2019).
Co-shaping socio-ecological systems	Focus on complex interplay of social practices and ecological flows, transdisciplinary research with emphasis on social tipping points	Systemic view especially suitable for mission oriented RTI projects	Extension to more specific RTI projects outside ecosystem management
Caring within hybrid collectives	Local focus, extremely transdisciplinary projects	Strong role for science as mediator for other voices	Include other types of knowledge (embodied, indigenous), overcome reservations towards including non-humans on equal terms, find adequate language

Table 2: Overview implications of the three perspectives for research, technology and innovation (RTI)

A similar picture emerges for the linkage of these concepts with notions and terminology of Clean Planet 2050 and the strategies associated with its vision, particularly the actions and elements of the Green Deal (European Commission 2019).

While these strategies clearly incorporate the notion of “protecting and restoring ecosystems”[1] they also move further by incorporating the “Just Transition” and “deeply transformative” policies such as the circular economy, smart mobility, sustainable building and the farm to fork strategy.

These strategies may well benefit from integrating notions from the “socio-ecological systems” or even the “caring collectives” perspective. The latter seems especially interesting for strategies like the “New European Bauhaus” initiative, which explicitly addresses cultural perspectives and the establishment of new territorial collectives.

2. OBJECTIVE & APPROACH

The objective of this task was to initiate the development of a draft concept of ecosystem performance that has the potential to function as a guiding framework permeating all science, technology and innovation efforts and thereby to establish ecosystem health as a guiding factor on par with human performance. The establishment of such a framework is obviously a major undertaking requiring many more contributions and feedback loops among the numerous research communities and wider stakeholders. Through our review and analysis of recent perspectives on ecosystem performance, we hope to provide a useful inspiration for this dialogue.

As a first step, we reviewed a number of concepts currently proposed to guide human activities towards ecosystem stewardship. We selected fourteen perspectives to be included in this review taking care to cover not only currently established but also alternative approaches as well as perspectives from different normative stances and worldviews. Accordingly, these concepts differ not only in the way they envisage ecosystem performance but also already in their very notion of ecosystems and their interplay with human activities.

We then summarised each of the fourteen concepts in a short brief and compared them with respect to their implication for guiding science and innovation efforts. Overall, three different albeit overlapping possible frameworks emerged each with a distinctive attitude towards ecosystem stewardship and type of implications for RTI orientation.

Rather than selecting one of these frameworks for the further process, we decided to present the taxonomy of approaches with the three possible orientations as a basis for the discussion in the scoping workshop and subsequent stakeholder interactions. In the following chapter, we present the overall taxonomy, the three frameworks with our assessment of their implications for RTI orientation and suggestions for possible indicators of success within these frameworks. Short summaries of the fourteen individual concepts are provided in Chapter 4.

[1] 2.1.7 Preserving and restoring ecosystems and biodiversity; 2.1.8 A zero pollution ambition for a toxic-free environment

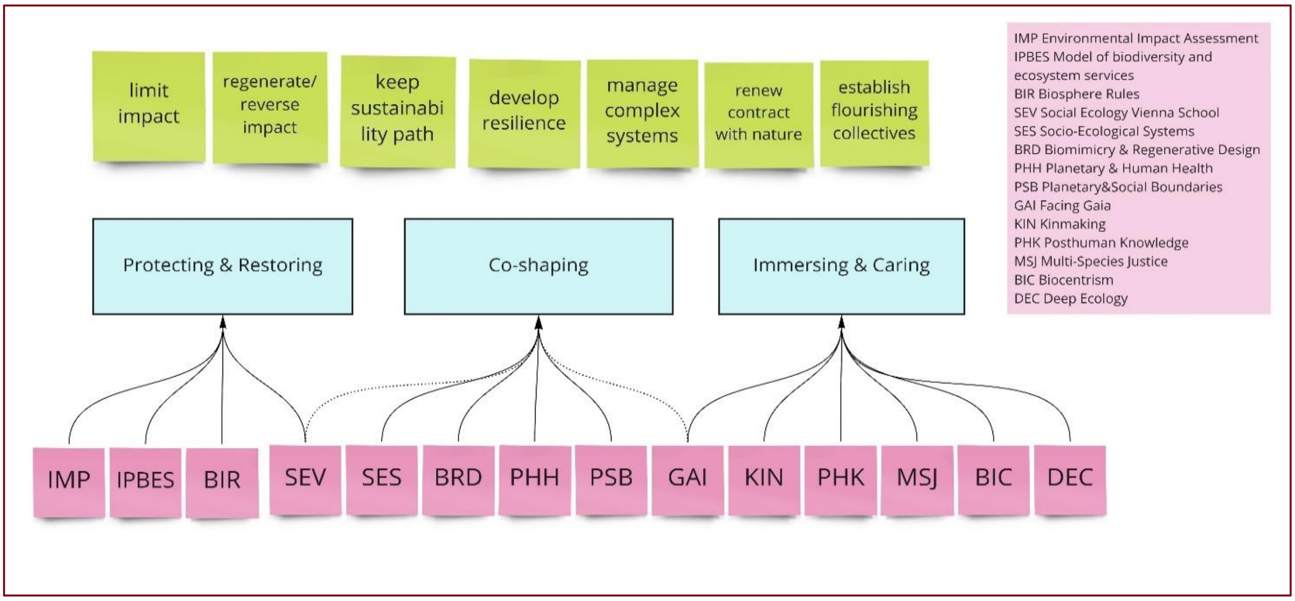

Figure 1: Taxonomy of concepts for ecosystem performance

3. PROPOSED TAXONOMY OF GUIDING CONCEPTS

Figure 1 provides an overview of the proposed taxonomy of approaches. The fourteen individual concepts that were scanned by the research team provide the basis of the framework. They feed three possible frameworks for orienting science and innovation each adopting a specific attitude towards ecosystems and targeting a specific type of outcome:

1. "Protecting and restoring" targeting preservation of ecosystems by managing the impact from human activities,
2. "Co-Shaping" targeting simultaneous development of social practices and ecological processes towards resilience and sustainability renewal,
3. "Caring" targeting the establishment of caring relationships in new collectives with humans and other entities on an equal level.

It is important to note that the assignment of the individual concepts to the groups is only a very rough one and bound to be continually shifting. As an example key actors form the socio-ecological systems (SES) community have recently expressed strong interest in relational caring approaches (West et al. 2020) and the IPBES group has increasingly adopted complexity based approaches.
In the next paragraphs, we discuss each group individually.

3.1 Protecting and Restoring Ecosystems

This group of concepts is characterised by its understanding of human/nature interaction as interplay between two separate spheres. In this understanding, societal action leads to pressure on the environment, and subsequently to impacts on eco-systems and biodiversity as well on the social and economic system functions of the environment, such as the provision of adequate conditions for health and resources availability. A key concept is the **Driving-force-Pressure-State-Impact-Response (DPSIR)** adopted by the EEA (EEA 2019) and based on the pressure-state-response framework of the OECD. This concept is outlining the causal relations and interdependencies between society and the environment, with a unidirectional relation with respect to society threatening the state of the environment and circularity when society responds with policy interventions in order to change the future state of the environment. The advantage of this concept is that it can be used to collect data and model these relations on various scales and to use it for environmental impact assessment. The **Social-Ecology Vienna (SEV)** approach conceptually considers human population, its artefacts (infrastructures) and husbandry as part as "physical compartment of society" and thus being also part of the material world. The interaction between human culture and nature is described as a transformation process of the material/substance dimension of societal metabolism and as a process of "colonization of nature” in the Anthropocene ongoing since the end of hunter and gatherer culture. The **integrated approach of assessing R&I programmes’ environmental impact (IMP)** developed by (Miedzinski et al 2013) has been taking up the DPSIR concept to differentiate between environmental pressure and environmental impact. Building on SEV, it adds a fourth environmental impact category besides impact on ecosystems and biodiversity, impacts on human health and impact on natural resources. The fourth category, “amenities and economy”, can be understood as impact on the physical compartment of society, i.e. artefacts, infrastructures as well as feedstock.

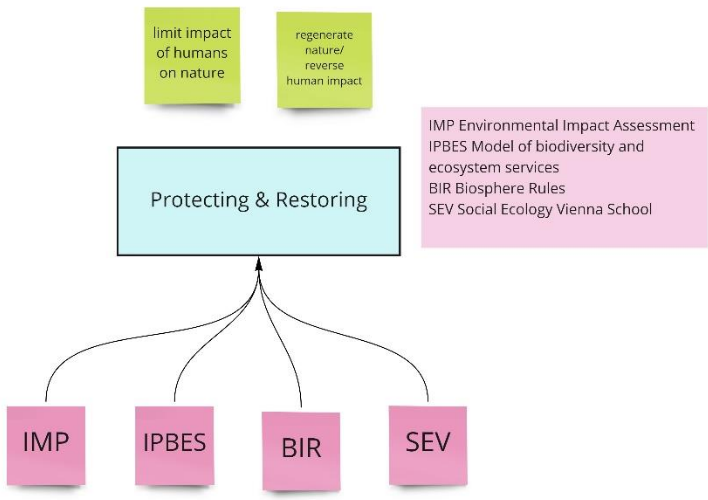

Figure 2: Protecting and Restoring Framework

The advantage **of this framework for STI orientation** is that the link between STI-policy intervention (however far from affecting the environment through its socio-economic impact) and environmental impact is explicitly addressed in its intervention logic. For instance, the pressure of emissions to the air is considered in a sequential logic from impacts on eco-systems and biodiversity to impacts on the social and economic functions of the environment, such as the provision of adequate conditions for health and resources availability.

Typical Indicators for Success: The EEA Indicator concept (Smeets und Weterings 1999) says that “performance indicators compare (f)actual conditions with a specific set of reference conditions. They measure the ‘distance(s)’ between the current environmental situation and the desired situation (target): ‘distance to target’ assessment.”

3.2 Co-Shaping Socio-Ecological Systems Renewal

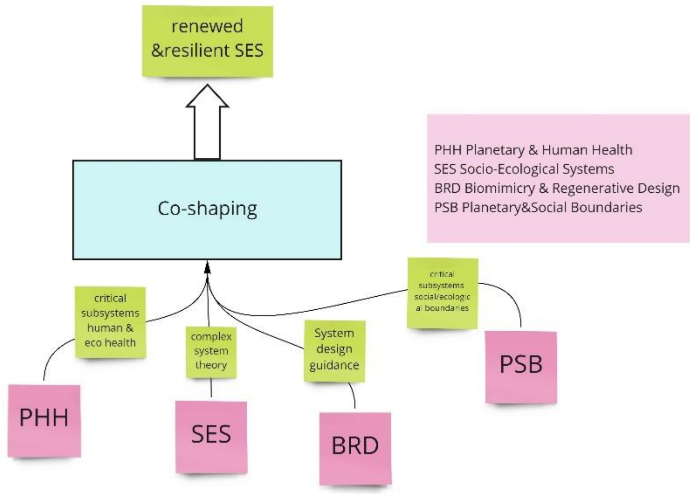

Figure 3: Co-shaping framework

This group of concepts is characterised by its use of complex system theory to understand the interaction of human practices and ecological processes as complex adaptive systems. The goal of these approaches is to move socio-ecological systems that are in instable critical condition towards renewal, resilience and sustainability in order to prevent ultimately collapse. Due to the inherent uncertainty of complex adaptive systems, this cannot be achieved by top-down steering but only by co-shaping the system dynamics in very specific contexts. Through practical approaches like biomimicry and regenerative design (4.6), designers use complex systems thinking to design community practices that are positively interacting with ecological systems. The notion of the planetary and human health discussed in 4.7 especially the EcoHealth concept could also be placed in this group as it provides a guiding framework for locating some of the critical arenas of interaction of human and ecological system elements. In a similar way, notions like the “Doughnut Economy” (Raworth 2017) allow for identification of critical social/ecological arenas within the planetary boundaries concept. What is common to all these approaches is the need to investigate the specific conditions for each individual socio-ecological system and the equal attention to cultural, social and ecological dynamics of change in the arena. Another key aspect is the focus on social change (social tipping points) as more impactful than (incremental) technical change. Finally, a core aspect is the acknowledgment that there can be no one correct view on the system and subsequently the need for negotiation procedures to mediate the different perspectives and to establish institutions for the polycentric governance of the system at stake.

As a guidance for science and innovation, this framework would ask scientists and innovators to help actors in critical arenas of socio-ecological change to map out sustainable pathways and common modes of governance. This would obviously require highly transdisciplinary research teams and methods.

Typical Indicators for Success: Typical indicators would take into account planetary health and human development in an integrated way. A recent example is the UNDP Human Development Report (UNPD 2020) that has for the first time adopted such an integrated measure of development (*Planetary-Pressures Adjusted HDI* – or PHDI). At the same time SES research emphasises the need for a multitude of local indicators that need to be explored for each specific context (Bennett et al. 2016; Bennett et al. 2021).

3.3 Caring Collectives

This framework is characterised by the prevalence of relational ontologies and epistemologies. This means they view subjects not as pre-given independent entities, but rather as being continuously (re)produced through interaction processes. Consequently, there are no predefined categories like nature and culture or human and non-human beings but a wide range of agents with diverse modes of existence and continuously emerging status. Also agency (the ability to act) is not associated with specific entities but emerges as a result of the processes within relational networks, assemblages and heterogeneous configurations (West et al. 2020). Similar to the complex system approaches, this framework would result in looking at specific arenas or “mapping out new collectives”. However, these approaches would reject the notion of a larger system with certain overarching rules serving as a guidance. As a normative guiding concept, many of these scholars use the notion of “care” as a reciprocal practice involving all types of entities including humans as one of many. These “collectives” receive uncommon names such as “pluriverse”, “Gaia” (Latour c.f. section 4.9), odd-kin (Haraway c.f. section 4.10) or zoe/geo/techno spheres (Braidotti c.f. section 4.11) to emphasise the dissolution of binary distinctions. Rather than applying overarching system rules, for each “collective” a new contract has to be negotiated that ensures a maximum of mutual care between diverse agents in a pluriverse of more than human beings. Engaging within these critical zones means “becoming earthbound” (Latour) or “staying with the trouble” (Haraway). The notion of “Multi-species-justice” (c.f. section 4.12) provides a justice theory serving as a guidance for such negotiations whereas various ethical theories like “biocentrism” (c.f. section 4.13), or deep ecology (section4.14) offer frameworks for ethical deliberation around the intrinsic worth and value of nature.

As a guidance for science and innovation these concepts would request scientists and innovators to ex-

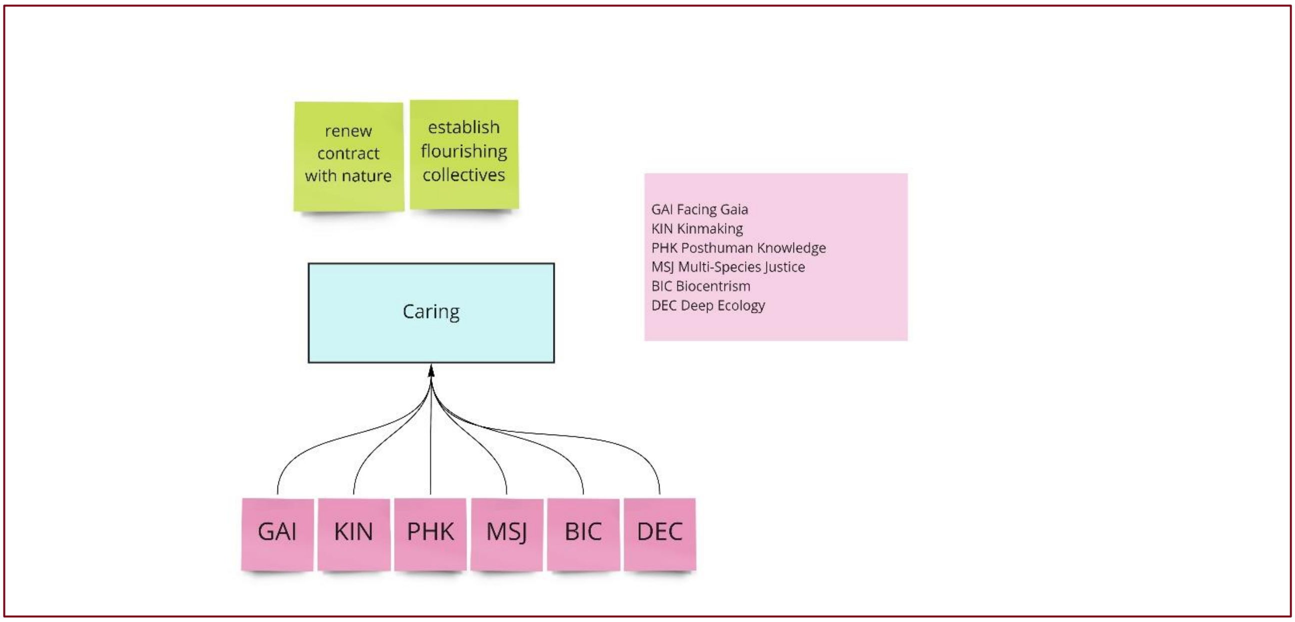

Figure 4: Caring for Collectives Framework

plore and design caring collectives by asking “What must be cut and what must be tied if multispecies flourishing on earth, including human and other-than-human beings in kinship, are to have a chance?” (Haraway 2016, p. 2). Such a multispecies perspective with its search for unexpected collaborations and combinations could reveal new solution spaces. STI development and application, including infrastructure, could be designed to assist living beings in forming and governing such collectives. Relational conceptions of care also reflect back on the practice of research itself: because the act of rethinking the world is an inherently political task, researchers should acknowledge that their own articulations of ‘good care’ are never neutral, and engage in ‘careful’ research practice attentive to possible and unpredictable effects.

Indicators for Success: These approaches do not usually work with indicators but possible success measures could be the number of flourishing life projects within a collective, the number of caring relationships and pressure on other collectives (which should be minimised)

3.4 Tentative Conclusions

The further assessment and elaboration of the concepts will be subject to ongoing stakeholder dialogue within this project frame and beyond. Our own assessment revealed that each of these concepts provides useful inroads for orienting RTI but also poses specific challenges. In particular, some efforts will be needed to extend these frameworks that often focus on research and innovation that is directly dealing with ecosystem management towards other RTI arenas such as mobility, manufacturing or ICT.

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[2] 2.1.7 Preserving and restoring ecosystems and biodiversity; 2.1.8 A zero pollution ambition for a toxic-free environment

4. INDIVIDUAL CONCEPTS MAPPED

4.1 Assessing R&I programmes' environmental impact (IMP)

The **integrated approach of assessing R&I programmes' environmental impact (IMP)** developed by (Miedzinski et al 2013) is motivated by the search for ex ante assessment criteria measuring the environmental impact of RTI-policy measures and instruments of Horizon 2020. It has been taking up the DPSIR concept of the EEA to differentiate between environmental pressure and environmental impact and to provide an intervention logic. Building on SEV (see 4.4), it adds a fourth environmental impact category besides impact on ecosystems and biodiversity, impacts on human health and impact on natural resources. The fourth category, "amenities and economy", can be understood as impact on the "physical compartment of society", i.e. artefacts, infrastructures as well as feed stock.

The following definition of pressure and impact, adapted from EEA (1999) apply:

Environmental Pressures refer to developments in the use of natural resources (materials, energy, water, land) as inputs to human activities, as well as the release of substances on the output side (waste, GHG emissions, air and water pollution). These pressures exerted by society are transported and transformed in a variety of natural processes and cause changes in environmental conditions.

Impact refer to the changes in environmental conditions leading to impacts on the social and economic functions on the environment, such as the provision of adequate conditions for health, resources availability and biodiversity. Impacts often occur in a sequence: for example, GHG emissions cause global warming (primary effect), which causes an increase in temperature (secondary effect), leading to a rise of sea level (tertiary effect), finally leading to loss of biodiversity.

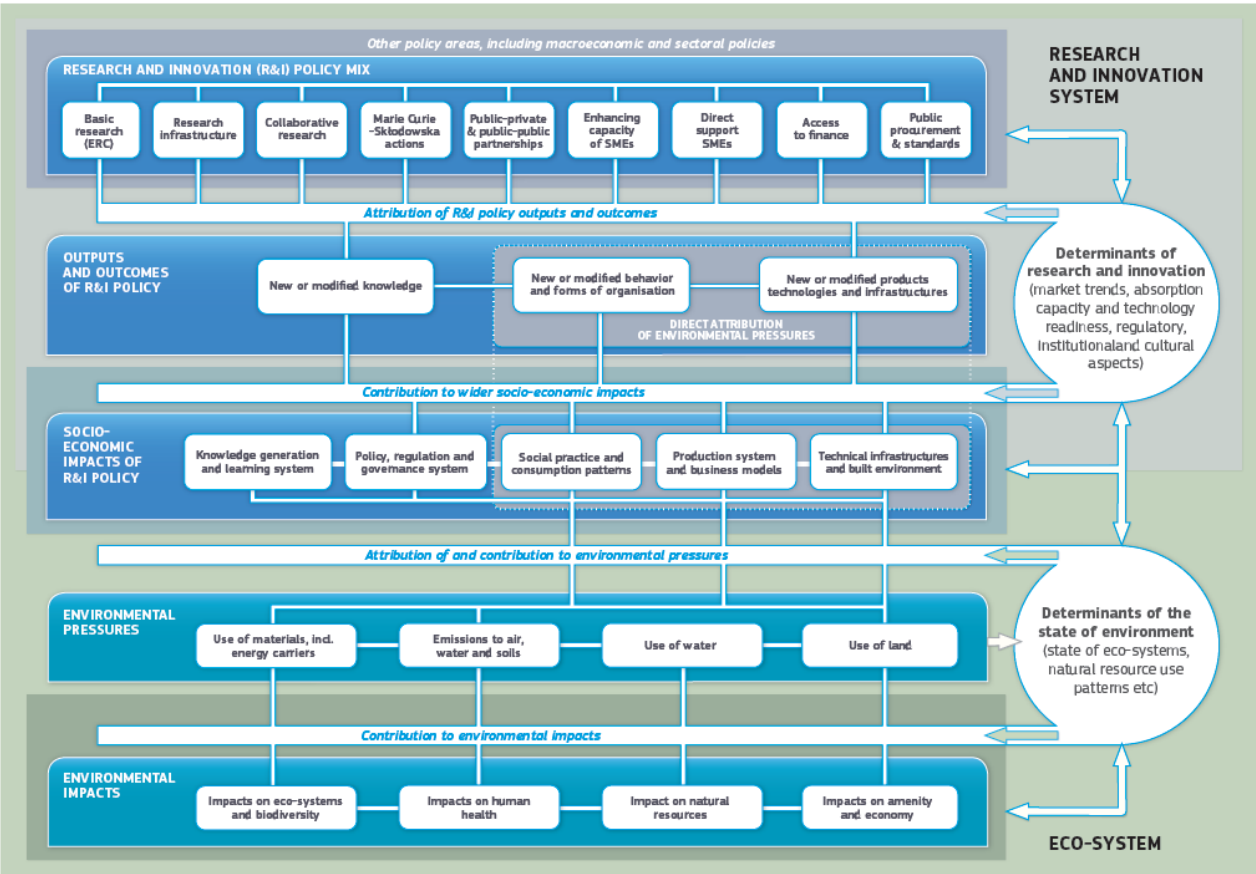


Figure 5: Impact Assessment Canvas

4.2 IPBES Model of biodiversity and ecosystem services (IPBES)

The Intergovernmental Science- Policy Platform on Biodiversity and Ecosystem Services (IBPES) can be understood as the equivalent to the IPCC with a particular focus on Biodiversity and Ecosystems. A core concept that underpins the work of the IPBES is the IPBES framework (Díaz et al. 2015)(IPBES 2016) (Díaz et al. 2019) (IPBES 2019).

The framework "underpins all IPBES functions and provide structure and comparability to the syntheses that IPBES will produce at different spatial scales, on different themes, and in different regions." (Díaz et al. 2015). The framework accounts for the anthropogenic elements (e.g. Anthropogenic Assets or Institutions and governance) to capture the relationship between the natural and human elements important for human wellbeing and environmental integrity. It provides overarching categories for different scientific concepts (e.g. Ecosystem Goods and Services in the Category of "Natures benefit to people") yet the framework is also inclusive to indigenous bodies of knowledge in relation to its different categories.

An interesting element for the purposes of this FOD project is the concepts of "nature's contributions to people (NCP)". This concept takes on a central role in the IPBES framework. In essence, the concepts links anthropogenic and natural elements that, in combination, determine the way and the extend people can benefit from the environment. IPBES (2016) highlights that NCP is "co-produced by biophysical processes and ecological interactions with anthropogenic assets." Importantly however, IPBES underlines the importance of institutions and governance as a critical mediator in these interactions.

The NCP concept involves a range of descriptions of human-nature interactions, including through the concept of ecosystem services and other descriptions, which range from strongly utilitarian to strongly relational. In total, the NCP concepts comprises eighteen categories of material, non-material and regulating contributions that can be summarised as follows:

> Natures Regulating Contributions to people refers to the "to functional and structural aspects of organisms and ecosystems that modify the environmental conditions experienced by people, and/or sustain and/or regulate the generation of material and non-material contributions (IPBES, 2019)." Examples for this category can be the benefit of vegetation in water purification or the regulation of micro-climates through bodies of water.
>
> Natures Material Contributions to people refers to "the substances, objects or other material elements from nature that sustain people's physical existence and the infrastructure (i.e. the basic physical and organizational structures and facilities, such as buildings, roads, power supplies) needed for the operation of a society or enterprise (IPBES, 2019)". Elements in this category are for example, the food that we eat or the materials that are consumed when building houses.
>
> Natures Non-Material Contributions refer to "nature's contribution to people's subjective or psychological quality of life, individually and collectively. The entities that provide these intangible contributions can be physically consumed in the process (e.g., animals in recreational or ritual fishing or hunting) or not (e.g., individual trees or ecosystems as sources of inspiration) (IPBES, 2019)"

Based on this framework and the concepts elaborates therein IPBES syntheses different scenario and modeling techniques and underscore how they can be used for assessments and decision making on Biodiversity and Ecosystem Services (IPBES, 2016). The biological scales on which these models operate range from the individual scale to entire ecosystems. The IPBES (2016) report highlights the usefulness of them for decision making support at different stages of the policy cycle. For example, exploratory scenarios are suited for agenda setting processes while target seeking scenarios are most suitable for policy design and implementation. Overall it shows that the models can be useful tool to translate alternative scenarios of drivers or policy interventions into projected consequences for nature and humans. Importantly, it underscores the importance of indigenous and local knowledge as part of scenario formulation and model application.

Opportunities for integrated RTI guiding framework

The framework is well established and draws on a range of robust and widespread scientific concepts (e.g. ecosystem services) but it also includes alternative bodies of knowledge (e.g. indigenous knowledge). Especially the notion that natures benefit to people arises in the interplay between anthropogenic assets and the natural environment but that this relationship is mediated by institutions and governance is a noteworthy conceptual element that could inform the direction of R&I policy outcomes. Indicators that relate to the concepts in the framework can be considered as established and operational. Likewise, decision support tools (e.g. models & scenarios) for different stages and requirement of R&I policy making are available and their utility is demonstrated by IPBES.

4.3 Biosphere Rules (BIR)

Following the publication of the Brundtland Report in 1987, Swedish scientist Karl-Henrik Robèrt developed the Natural Step framework, setting out the system conditions for the sustainability of human activities on Earth. The framework was refined with some 50 scientists to reach consensus on what was later on labelled 'The Framework for Strategic Sustainable Development' (FSSD) (Originally The Natural Step Framework) (The Natural Step). This was first published in a peer-reviewed academic journal in 1991 under the title "From the Big Bang to Sustainable Societies" (Eriksson and Robèrt 1991)

Robèrt's four system conditions are derived from a scientific understanding of universal laws and the aspects of our socio-ecological system, including the laws of gravity, the laws of thermodynamics and a multitude of social studies. The four system conditions specify for sustainability:
"In the sustainable society, nature is not subject to systematically increasing ....

1. ... concentrations of substances extracted from the earth's crust.
2. ... concentrations of substances produced by society.
3. ... degradation by physical means.
   and, in that society ...
4. ... human needs are met worldwide."

Based on this approach, a non-profit 'The Natural Step' was founded in Sweden in 1989. The Natural Step has pioneered a "Backcasting from Principles" approach meant to advance society towards greater sustainability with numerous applications and tools to plan and design sustainable businesses. The approach has been implemented by business and other organisations around the world. Implementing sustainability can be done through the process of four steps (The Natural Step 2000):

- Awareness building and understanding - organisations are aligned with a common understanding of sustainability.
- Baseline mapping - organisations assess their material and energy flows and the impact of the organisation on society. This step uses the four system conditions.
- Create a vision and strategic plan - a long term vision is created of the organisation in a sustainable society. A strategy is enabled from a point of view of having achieved sustainability and looking backwards. This step uses backcasting and identifies step-by-step solutions to bring the organisation from the current condition to a sustainable condition.
- Down to action - organisations implement actions. Backcasting is used to continually assess decisions to ensure they meet the vision created above.

The related concept of *Biosphere Rules* were coined by Gregory C. Unruh emerging from a research program established through a 2005 partnership between the renowned eco-designer William McDonough and the Center for Eco-Intelligent Management at IE Business School. The principles were first published in 2008 (Unruh 2018). The Biosphere Rules is a framework for implementing closed-loop production processes. They imitate circular processes in nature but interpreted for—and translated to—industrial production systems. The five principles that constitute the Biosphere Rules are briefly:

1. Materials parsimony. Minimize the types of materials used in products with a focus on materials that are life-friendly and economically recyclable.
2. Value cycle. Recover and reincarnate materials from end-of-use goods into new value-added products.
3. Power autonomy. Maximize the power autonomy of products and processes so they can function on renewable energy.
4. Sustainable product platforms. Leverage value cycles as product platforms for profitable scale, scope, and knowledge economies.
5. Function over form. Fulfil customers' functional needs in ways that sustain the value cycle.

Implementing the rules in a firm requires commitment and investment. Notwithstanding, the rules were designed in a modular fashion that allows for stepwise implementation. A firm can take action to assess its inputs and move towards greater materials parsimony without having to implement all the other rules at the same time. Other rules can also be gradually which eases the disruptions to business (Unruh 2018).
The Cradle to Cradle (C2C) is, in turn, a concept originally developed by McDonough and Braungart (2002) and related to the Circular Economy (CE) school of thought (Ghisellini et al. 2016). It can be said that CE

borrows from C2C by differentiating between biological and technical loops (Blomsma and Brennan 2017). The fundamental elements of C2C design are based on the principles that drive these systems in nature (McDonough and Braungart 2002):

- *Waste equals food*: This means designing materials and products to be used over and over in either technical or biological systems, collecting and recovering their value, and leaving a beneficial legacy for human or ecological health.
- *Use renewable energy*: The quality of energy matters. Energy from renewable sources is paramount to effective design.
- *Celebrate diversity*: Nature is the most inspiring source of ecological design.

Within this concept, the systemic approach to environmental design leads to two alternative design perspectives (Braungart et al. 2007): 1) closed cycles referring to the design of the uptake of the products back to industrial production processes at the end of their useful life to produce products of equal or more value, and 2) open cycles referring to the design of products that are biodegradable and become nutrients to new cycles within the ecosystem.

According to the first perspective, the product materials, such as minerals or plastics, need not be minimized and they are used again and not thrown away as waste to provide landfill. Industry can make considerable savings by recovering valuable materials from used products and avoiding environmental sanctions. According to the second perspective, products made of natural, safely biodegradable materials can be returned to nature to feed ecosystems instead of harming them. Thus, at the end of its useful lifetime, the “disposal” of the product can become easy and even valuable (Carrillo-Hermosilla et al. 2009). Following McDonough and Braungart (2002), these two approaches need to be applied in an intelligent way, taking into consideration the impacts of the whole lifetime and life-cycles of products.

Opportunities for integrated RTI guiding framework

These principles of alignment with nature have been applied in diverse contexts, especially in business but also increasingly in policy largely thanks to the recent attention to the circular economy. The principles can orient RTI towards the development of practices benign to human and planetary health and the exclusion of harmful activities. While the approach provides guidance to natural sciences and business, it is not clear how this relates to social sciences and social impacts.

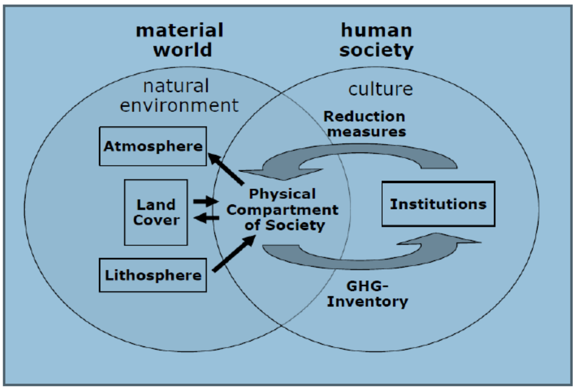
4.4 Social Ecology Vienna School (SEV)

The Vienna School of Social Ecology (Fischer-Kowalski and Hüttler 1998; Kramm; Kramm et al. 2017; Haberl et al. 2016) aanalyses the material world with respect to **the colonization of nature** (e.g. appropriation of net primary production (of the biome) and resources from the lithosphere) and the material stocks and flows of societal metabolism.

Society -Nature Interaction for Climate Policy

The figure shows the overlaping of the material world and human society. We can distiguish the natural environment, the physical compartment of society (PCS) and culture. The PCS represents the material part of society and consists of the population, artefacts (capital goods) and livestock. The cultural part of human society consists of institutions.

The relevant natural environment consists of the atmosphere,



land cover (including soil), the lithosphere and the non-appropriated terrestrial biosphere.

GHG inventory is the representation to translate the material activities (pressures) of societies into information that can be translated by institutions into reduction measure. The reduction measures themselves form part of the driving forces to counteract climate change.

Figure 6: Social Ecology System View (Kubeczko 2004)

Source and sink relations are considered through the concept of **society nature interaction** – and the method of material flow analysis (MFA) – looking into structures of society nature interaction and the over-exploitation of resources such as materials, water. Humans as population, their artefacts and infrastructures as well as livestock are seen as part of the material world as physical compartment of society thus forming the hybrid area between nature and culture.

Opportunities for integrated RTI guiding framework

As the material flow analysis is an established method and is closely linked with economic national accounting systems, it is easily connected to the socio-economic impact of RTI-policy measures. Given the normative connotation of “colonization” one could assume that nature is considered to “suffer” from human society through its use as source and sink of societies metabolism,

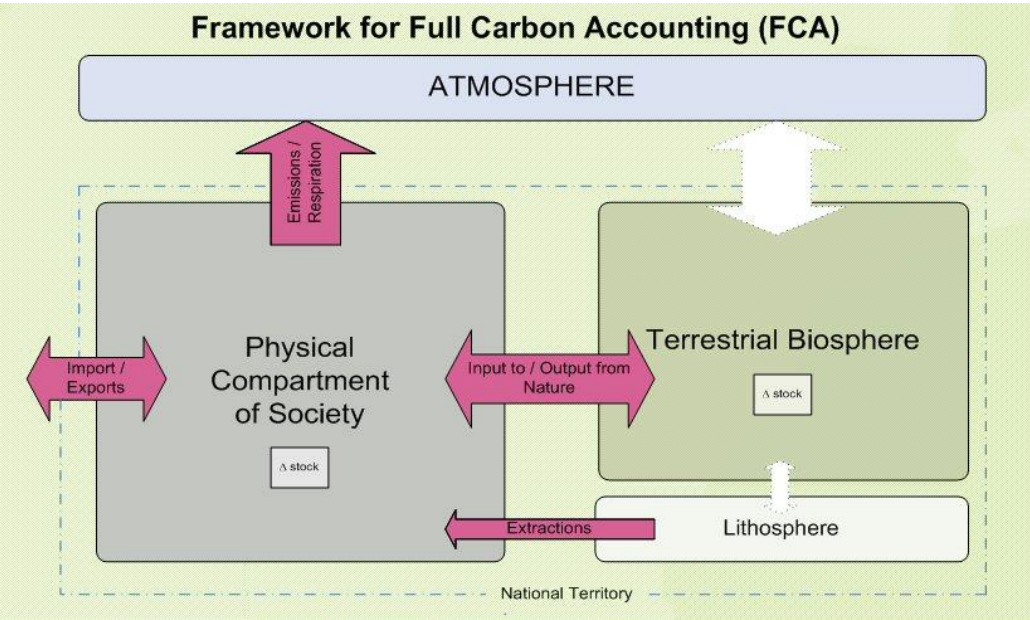


Figure 7: Example for Material Flow Analysis (Kubeczko 2004)

4.5 Socio-ecological Systems Thinking (SES)

Socio-ecological systems thinking uses **complex system theory** to bridge social and biogeophysical sciences for understanding dynamics of interaction of social and ecological systems and ultimately enabling sustainability transformations. (O'Brien and Selboe 2015; O'Brien et al. 2018; Olsson et al. 2015; Berkes et al. 2003; Bennett et al. 2016; Deutsch et al. 2003; Folke et al. 2010; Wise et al. 2014; Fazey et al. 2018)

Socio-ecological systems (SES) are described as **complex adaptive systems** characterised by non-linearity, uncertainty, emergence and self-organisation. They reach across multiple scales through nested subsystems from local to global with coupling and strong feedback between scales. A complex system organises around several equilibrium states (attractors) and can flip towards another attractor when certain thresholds are passed. Open systems will re-organize at critical points of instability. Complex systems cannot be understood by looking at parts in isolation, their pathways are inherently unpredictable but not random. According to this theory, SES develop in **adaptive renewal cycles** nested across scales. The cycles are characterised by **distinct phases**: exploitation, conservation, release and reorganisation/renewal. The phases are linked by **windows of opportunity**, which can either be used by vested interests to stabilise (and ultimately collapse) or to initiate transformations towards renewal.

For SES thinking there is no one correct view on the system, rather one needs to understand each specific history and context and recognize multiple perspectives on the system. Social systems are characterised by values, beliefs, governance and knowledge towards ecological systems, while ecological systems are self-regulating communities of organism interacting with their environment. This distinction however is seen as artificial and irrelevant in practice (human in nature).

SES thinking conceptualises **sustainability as a dynamic process** that requires capability for learning, adaptation, self-organisation and transformation (=**resilience**) from societies. To strengthen these capacities SES thinking proposes **adaptive management** rather than top down steering. Adaptive management enables SES self-organisation capacity through mutual feedback and thereby allows deliberately navigating transformations towards more beneficial states. Important aspects of **resilience** are diversity, variability, slack, flexibility, redundancy, common institutions and polycentric governance.

SES distinguishes three **spheres of transformation**: practical (behaviour, technical), political (systems and structures), personal (values and beliefs). The latter is the most powerful sphere for system transformation in contrast to incremental technical change. Because of the strong influence of the personal sphere, collecting weak signals for social change (**social tipping points** i.e. conditions for humans to collectively change practices) is an important element of SES analysis.

SES sustainability science uses a fundamentally different approach to classical science, as humans are seen as part of the system under investigation. Typical features are case studies and **transdisciplinary participatory action research** with practitioners and system stakeholders. In line with the theory, the focus is on processes and interlinkages rather than on individual entities. SES investigates social, cultural, institutional and economic aspects of systems as well as biological and geological and physical ones.

Opportunities for integrated RTI guiding framework

Following SES as a guiding framework would mean to focus RTI efforts on strengthening resilience of socio ecological systems at critical system bifurcations. Especially, funding would look for windows of opportunity that link change between system phases: where can we invest to allow some systems to collapse and others to move into renewal to avoid whole system collapse?

The challenge would be to identify these critical arenas or windows of opportunity/“Seeds of a good Anthropocene” (Bennett et al. 2016). Examples from the literature are agroecology, climate smart agriculture, permaculture, urban commons, food-water-energy nexus, rewilding, land ownership, heritage conflicts and reskilling. A focus of research would need to be on potential social tipping points (values, belief systems).

Challenges

- In many SES case studies, the ecological system component is dominant. Examples are often in the management of natural resources (oceans, forests, agriculture etc.) this may be difficult to expand to other RTI topics such as e.g. manufacturing or ICT.

- It is sometimes criticized that social science theories e.g. on power relations and the political sphere are not well integrated in SES. At the same time, institutions, governance and social practices play a key role.
- In spite of the claim for integration social scientists are mainly in social system analysis and natural scientists in ecosystem analysis (earth science)
- There may be a tension between the emphasis on system uncertainty and the wish to deliberately initiate transformations

4.6 Biomimicry and Regenerative Design (BRD)

Regenerative design is based on systems theory and as the name says focuses on the design stage of solutions. It aims at creating resilient and equitable systems that integrate the needs of society with the integrity of nature. The regenerative stands for the possibility of renewing and revitalizing used energy and materials (Cole 2012) and becoming completely waste free.

The origins of the approach can be related to the history of agriculture. For instance, the term permaculture (Fukuoka 1978) that originally referred to "permanent agriculture", but was expanded to stand also for "permanent culture", as it was understood that social aspects were integral to a truly sustainable system, in which consumption focuses on services instead of goods. The concept of regenerative design was developed by the architect Lyle, who aimed at creating a framework for a community that can function with the locally available renewable resources without destroying them, while reducing unnecessary transportation efforts (Lyle 1994).

Designers use systems thinking, applied permaculture design principles, and community development processes to design human and ecological systems. The development of regenerative design has contributed to and been influenced by other circular approaches. For instance, Lyle who coined the term used to worked with William McDonough one of promoters of Cradle-to-Cradle concept.
The related term *biomimicry*, from the Greek *bios* (life) and *mimesis* (imitation), had been only used in the fields of sciences and robotics until the natural sciences writer and innovation consultant Janine M. Benyus popularized it in her book *Biomimicry: Innovation Inspired by Nature*. (Benyus 1997) discussed how nature's solutions to situations have been the creative jumping-off points for individuals seeking solutions, developing, or simply revitalizing processes or products (Cramer 1997). Benyus identified a set of ten nature-inspired strategies to apply when designing an artefact, named the “Ten Commandments of Mature Ecosystem”:

- Use waste as a resource
- Diversify and cooperate to fully use the habitat
- Gather and use energy efficiently
- Optimize rather than maximize
- Use materials sparingly
- Don't foul their nests
- Don't draw down resources
- Remain in balance with biosphere
- Run on information
- Shop locally

Janine Benyus, together with Bryony Schwan, founded in 2006 the Biomimicry Institute[3], which purpose is to naturalize biomimicry in the culture by promoting the transfer of ideas, designs, and strategies from biology to sustainable human systems design. Their current definition of biomimicry reads as follows (Biomimicry Institute 2020)
“Biomimicry offers an empathetic, interconnected understanding of how life works and ultimately where we fit in. It is a practice that learns from and mimics the strategies used by species alive today. The goal is to create products, processes, and policies — new ways of living — that solve our greatest design challenges sustainably and in solidarity with all life on earth. We can use biomimicry to not only learn from nature’s wisdom, but also heal ourselves — and this planet — in the process.”

They propose three essential elements when translating nature’s strategies into design (Biomimicry Institute, 2020):

- *Emulate*: learning from and then replicating nature’s forms, processes, and ecosystems to create more regenerative designs.
- *Ethos*: understanding how life works and creating designs that continuously support and create conditions conducive to life.
- *(Re)Connect*: spending time in nature to understand how life works so that we may have a better ethos to emulate biological strategies in our designs.

3 http://biomimicry.org/

Opportunities for integrated RTI guiding framework

Following regenerative design and biomimicry as a guiding framework would mean to focus RTI efforts on focusing on understanding the nature to mimic it in our activities.

Researchers, designers, managers and policymakers can use the resilient models observed in systems ecology recognizing that ecosystems are resilient largely because they operate in closed loop systems. Using this model regenerative design and biomimicry seek feedback at every stage of the design process. Regeneration, in contrast to the emphasis on 'doing less harm', carries the positive message of considering the act of building as one that can give back more than it receives and thereby over time building social and natural capital. While the approach provide guidance to natural sciences and business, it is not clear how this relates to social sciences and policy.

4.7 Planetary and Human Health (PHH)

Linking planetary health and human health has been pushed forward significantly by the Lancet Commission of the Rockefeller Foundation (Whitmee et al. 2015). The authors claim that humans' influence on the Earth threatens the long-term survival of our species not only through the biophysical destabilization of systems and processes, as captured by the planetary boundaries approach, but also from an environmental health perspective: through "the critical links between human health and the food we eat, the water we drink, and the air we breathe" (Seltenrich 2018, p. 1). Beyond the scope of environmental health, **planetary health** "accounts for the importance of natural systems in terms of averted cases of disease and the potential harm that comes from human-caused perturbations of these systems" (Seltenrich 2018, p. 1). In that sense, the planetary health and human health linkages have become a vivid research field.

In view of the development of an ecosystem performance concept, accounting for the linkages between planetary and human health may illuminate areas of double dividend and the conceptual foundations that are conducive to their identification.

According to the Lancet Commission, the „ concept of planetary health is based on the understanding that human health and human civilisation depend on flourishing natural systems and the wise stewardship of those natural systems" (Whitmee et al. 2015, p. 1974). Simply expressed, "planetary health is the health of human civilisation and the state of the natural systems on which it depends" (Whitmee et al. 2015, p. 1978). **Planetary health** can be positioned as one out of several holistic health concepts such as One Health and EcoHealth (Lerner and Berg 2017).

The concept of **One Health** combines public health and veterinary medicine (and its interdisciplinary research areas), while the **EcoHealth** approach focuses more on biodiversity, with an emphasis on all living creatures, including parasites, unicellular organisms, and viruses that have a value and should be protected. Planetary Health, deals with growing threats in the health area at various scales up to the global scale. As illustrated in Table 4 the concepts not only differ in who is covered (animals, humans, ecosystems), but also in the sciences and knowledge types involved.

Table 4: Comparison of the three health concepts One Health, EcoHealth and Planetary Health (Lerner and Berg 2017, p. 5)

		One Health		EcoHealth	Planetary Health	
		Narrow	**Wide**		**Narrow**	**Wide**
Core contributing sciences	Human	Public health	Public health Human medicine Molecular and microbiology Health economics Social sciences	Public health Human medicine Rural and urban development and planning Social sciences Anthropology	Public health Human medicine	Human medicine Economy Energy Natural resources
	Animal	Veterinary medicine	Veterinary medicine	Veterinary medicine	–	Agricultural sciences (including plant and animal production sciences)
	Ecosystem	–	Environmental health Ecology	Conservation and ecosystem management	–	Ecology Other environmental sciences (including climate and biodiversity research) Marine sciences
Knowledge base		Western scientific	Western scientific	Western scientific Indigenous knowledge	Western scientific	Western scientific
Core values	Health	Individual health	Individual and population health	Population health	Individual and population health	Individual and population health
	Groups	Humans Animals	Humans Animals Ecosystems	Humans Animals Ecosystems	Humans	Humans
	Other			Biodiversity Sustainability (for humans, animals, ecosystems)	Sustainability (for humans)	Sustainability (for humans)

The Lancet Commission report enumerates a long list of planetary and human health interrelations, among them effects of global environmental change on the occurrence and spread of zoonotic and vector-borne diseases and effects of global environmental change on mental health. In its analysis it distinguishes three types of failure that cause phenomena such as improved human health and deteriorating planetary health at the same time (Whitmee et al. 2015):

- conceptual and empathy failures,
- knowledge failures, and
- implementation failures

The authors conclude that “the unfinished agenda of ill health that is mainly related to poverty, to adapt to environmental change that cannot be prevented, and to achieve equitable human development within finite environmental limits“ needs to be addressed (Whitmee et al. 2015, p. 1997). Societies have to promote sustainable and equitable patterns of consumption, to reduce population growth, and to harness the power of technology for change. An essential role in the achievement of planetary health is assumed for health professionals (Whitmee et al. 2015).

In terms of guidance with respect to STI development and application, the Lancet Commission’s agenda and policies (Whitmee et al. 2015) illustrate, which kind of hybrids between planetary and human health could be aspired. Examples include concepts like sustainable intensification of food production within environmental limits and the interrelations of land use change with public health. Policies should seek to stimulate co-benefits between health and the environment.

4.8 Planetary and Social Boundaries (PSB)

Since the pioneering work “A safe operating space for humanity” appeared (Rockström et al. 2009), the planetary boundaries approach has received wide attention in research and policy-making. The focus is on the biophysical preconditions for human development. The approach has experienced a variety of internal and

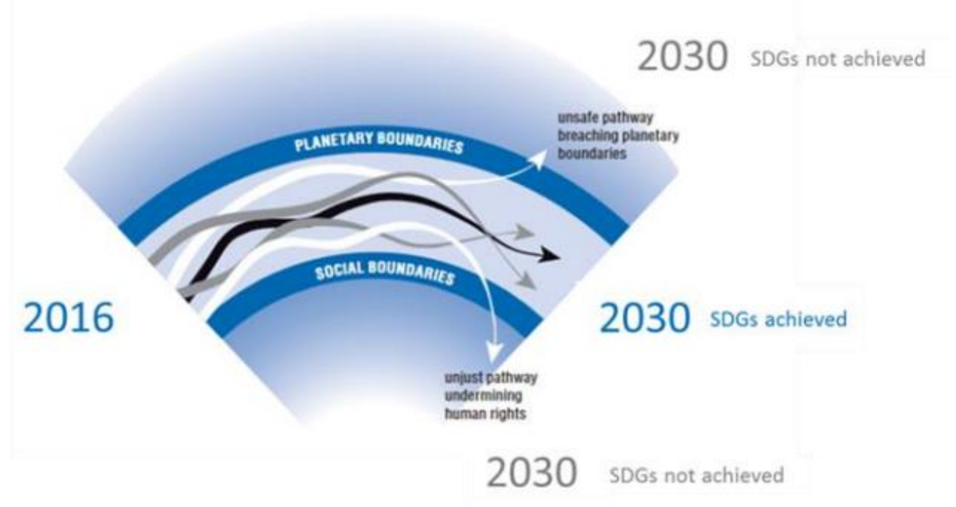


Figure 8: The interlinkages of planetary and social boundaries with the Sustainable Development Goals (Leach et al. 2013); from (Keppner et al. 2020, p. 160)

external critique, modifications and extensions. Among the notable extensions is the concept of the Doughnut Economy (Raworth 2017), fully incorporating the planetary boundaries approach and amending social boundaries derived from the Sustainable Development Goals (SDGs). The interlinkage of planetary and social boundaries with the SDGs is illustrated in Figure 8.

The planetary boundary approach has been accounted for in previous STI programming activities. For this project, a review of the planetary and social boundaries approach depicts selected points of critique and operationalization issues that could be relevant for the development of an ecosystem performance concept. Planetary boundaries define the **safe operating space for humanity** associated with the planet’s biophysical subsystems or processes. “Planetary boundaries are values for control variables that are either at a ‘safe’ distance from thresholds [...] or at dangerous levels” (Rockström et al. 2009, p. 472). Per entity, there are one to several control variables with a respective value (planetary boundary) per entity (e.g. 350 ppm Atmospheric carbon dioxide concentration and 1 W/m^2 Change in radiative forcing for the entity Climate Change). The planetary (and social) boundaries, listed below, are tightly coupled:

- Planetary boundaries: Climate change, Biosphere integrity, Stratospheric ozone depletion, Ocean acidification, Biogeochemical flows, Land use change, Freshwater use, Atmospheric aerosol loading, New entity introduction (Rockström et al. 2009; Steffen and et al. 2015)
- Social boundaries (‚foundations‘): Food security, Health, Education, Income and work (the latter is not limited to employment but also includes things such as housekeeping), Peace and justice, Political voice, Social equity, Gender equality, Housing, Networks, Energy, Water (Raworth 2017)

Today, some planetary boundaries are already transgressed (e.g. genetic diversity as part of the integrity of the biosphere and biochemical fluxes)

In a recent **review** of the planetary boundary concept (Keppner et al. 2020), concerns emerged in particular over (1) the perceived static nature of the boundary, (2) some of the boundary definitions (e.g. N-boundary, biosphere boundary, ozone boundary), (3) the choice of control variable and position relative to boundary, (4) the treatment of the biosphere as static, (5) the pre-dominantly local nature of some boundary-related environmental problems (e.g. water), and (6) the perceived over-simplification of some problems (e.g. aerosol loading) reducing them to one control variable.

In addition to this community-internal critique it can be mentioned, that biophysical preconditions are not the only entities affecting a safe operating space for humanity. The incrementally changing **social SDGs** could be complemented by **disruptive events and developments** as debated in the global existential risk community. Some planetary boundaries such as climate change, fresh water cycles and ocean acidification correspond over coupling with food and water supply with global existential risk, others not (Kareiva and Carranza 2018). Global existential risks are not obviously coupled to the biophysical conditions of human development such as natural catastrophes (e.g. asteroid impact, volcanic super-eruption, natural pandemics), man-made catastrophes (e.g. bioengineered pandemics, nuclear war) or unintended technological catastrophes (e.g. artificial intelligence out of control, geoengineering-related disasters) (Avin et al. 2018; Torres 2019).

Opportunities for integrated RTI guiding framework

In view of the development of an ecosystem performance concept, the planetary and social boundaries approach could serve as an impact assessment compass for STI. The different nature of planetary and social boundaries may prompt scientific controversies to treat them analogously. In order to be operational, the planetary boundaries need to be scaled down to the relevant scale, a temporal dynamics need to be added to the downscaling and production-based environmental performance needs to be benchmarked against the downscaled planetary boundaries (Keppner et al. 2020).

4.9 Facing Gaia (GAI)

The Facing Gaia concept (Latour 2017; Lenton et al. 2020; Latour and Weibel 2020; Latour 2018; Latour et al. 2017) starts from the assumption that in the "New Climate Regime" (Anthropocene) the differentiation between nature and culture is finally shattered. A division between human agency and passive nature is no longer feasible and the need for a redistribution of agency is now obvious. The Earth fights back and becomes touchy and responsive, nature becomes world again. The result is a **pluriverse inhabited by a wider range of agents with diverse modes of existence** (e.g. mountains, rivers, cities ...): Gaia. Gaia is different from Earth System as it is not one unified system but consists of "critical zones": patchy, heterogeneous, discontinuous territories where the diverse agents of the pluriverse fight for their rights over the territory.

Humans need to "face Gaia" by becoming "Earthbounds" i.e. repoliticizing ecology and reterrestrialising their existence. Nation States should give up their claim over territories, and instead **treat other entities like land, water, cities as actors and negotiate with them**. This will result in a new constitutional order that is endowed with a complex system of counterforces. Through this re-articulation of sovereignty, the externalised aspects will finally be internalised and new collectives will emerge. Plus intra replaces Plus Ultra as humanities motto. Scientists have a special role in this process. Earthbound scientists belong to the territory outlined by their instruments, they represent the other agents who have no other voice.

Learning these new ways to inhabit the Earth is our biggest challenge. Bringing us down to earth is the task of politics today. Recognising Life's (=all living beings) impact on Earth (habitability) and learning from it could be critical to understanding and successfully navigating the Anthropocene. The pluriverse of entities should be characterised by **dependencies instead of identities** (also humans). We need triple sensitivity to the existence of other ways of life: Politicians are supposed to hear voices previously unheard, scientists to become attuned to phenomena so far invisible, artists are challenged to render us sensitive to the shape of things to come.

Opportunities for integrated RTI guiding framework

The Gaia concept could well provide an inspiring framework for science orientation as it entails a strong role for science.

The "Earthbound" have to be able to map the territories on which they depend for their existence. "Gaia requires the sciences to say where they are situated and what portion of Earth they inhabit" (Latour 2017, p. 289). Sciences are multipliers of agency and could enable comparison of collectives by mapping out the collectives in the new constitutional order. They could install "critical zones observatories" map them element for element to finally identify common ground to govern them.

Challenges

Latour emphasises the need to give up hope for saving the planet as the window for this has passed. He claims that as long as there is hope that this will somehow be solved, humans will never act. His approach is targeting partial survival in some areas of the warzone of the "new climate regime". This perspective may be rejected by many actors.

4.10 Kinmaking (KIN)

From the perspective of overpopulation, environmental crisis, feminism and reproductive justice Donna Haraway develops an original concept of kinship pointing at multispecies conviviality, characterised by “odd familiar relations” and “composting” of such assemblages (Haraway 2016). Haraway’s work has been referred to directly, e.g. from a care perspective (Dow and Lamoreaux 2020) or indirectly under the broader umbrella of conviviality, e.g. “A declaration of interdependence” (Centre For Global Cooperation Research 2014). Haraway does not provide easy solutions to the environmental crisis intertwined with other aspects of life. The value of her way of thinking for the development of an ecosystem performance concept can be sought in the dissolution of allegedly obvious distinctions also encountered in the ecosystem research and policy community.

Key to her way of thought are the related concepts of “chtulucence” and “tentacular thinking”. Referring to time diagnoses such as the anthropocene or capitalocene Haraway criticises any binary life stories and unfolds the necessity to enter an era that she denotes as the “chtulucene”. Chtulu refers to the diverse earth-wide tentacular powers and forces, entangling countless temporalities (past, present and to come), spatialities and intra-active assemblages (including more and other than human, inhuman and human-as-humus) (Haraway 2016, p. 101). The **chtulucene** is “a kind of a timeplace for learning to stay with the trouble of living and dying in response-ability on a damaged earth” (Haraway 2016, p. 2). Staying with the trouble requires making “odd-kin relationships”.

Binary life stories, such as the distinction of humans and environment or monetary and non-monetary value, are discarded and replaced by the concept of **kinship**. Haraway states that kin is a wild category potentially encompassing all earthbound entities (Haraway 2016). Making kin in the chtulucene is to be based on reflections who actually lives and dies on earth and it has to be clarified to whom one is actually responsible. In terms of orientation of action Haraway asks: “What must be cut and what must be tied if multispecies flourishing on earth, including human and other-than-human beings in kinship, are to have a chance?” (Haraway 2016, p. 2).

Among the major cuts she suggests are the separation of social relations from fertility path dependencies and the ties that should be intensified are those to transgress any binary relationship norms (see Figure 9). Spelled out for children this could mean, that “every new child has at last three human parents; and the pregnant parent exercised reproductive freedom in the choice of an animal symbiont for the child, a choice that ramified across the generations of all the species” (Haraway 2016, p. 8). More generally spoken, “we require each other in unexpected collaborations and combinations, in hot compost piles” (Haraway 2016, p. 4). Over the generations, according to Haraway, “communities of compost” emerge.

8.2. Make Kin Not Babies. Sticker, 2 × 3 in., made by Kern Toy, Beth Stephens, Annie Sprinkle, and Donna Haraway.

Figure 9: Make kin, not babies (Haraway 2016, p. 139)

Other scholars elaborated Haraway's concepts with regard to reproductive justice. Dow and Lamoreaux sharpen the motivation of other kinds of kinship by attributing "the kinship system that accompanies global capitalism and its buttressing ideologies of class, gender, race, nation, ability, and sexuality, is one of the drivers of climate change and environmental degradation" (Dow and Lamoreaux 2020, p. 487). Reproductive infrastructures extend beyond bodily and familial boundaries; to make varied kinship also requires infrastructural support ranging from housing, over employment practices to education (Dow and Lamoreaux 2020, p. 488). In their opinion, the interdependence when feeding and caring for ourselves and one another must be given more attention, encompassing not only the production and distribution of food, but also individualism and (over)consumption.

Opportunities for integrated RTI guiding framework

In view of the development of an ecosystem performance concept in this project, two major argumentation lines of Haraway have the potential to contribute to STI programming. First, a multispecies perspective with the search for unexpected collaborations and combinations could reveal new solution spaces. Second, STI development and application, including infrastructure, could be designed to assist living beings in staying with the trouble and making generative odd-kin.

4.11 Posthuman Knowledge (Zoe/Geo/Techno-Materialism) (PHK)

(Braidotti 2019a) states a convergence of posthumanist and post-anthropocentric approaches leading to a qualitative change in knowledge production, called posthuman knowledge production. At the core of posthumanism, there is a new vision of the posthuman subject. Accounting for the "zoontological" turn and the "techno-ecological" turn, a school of thought denoted "Zoe/Geo/Techno-Materialism" is suggested building part of a new agenda for the Critical Posthumanities (Braidotti 2019b). Possible implications of posthuman approaches for climate policy and action haven been sketched recently (Fox and Alldred 2020).
In view of the development of an ecosystem performance concept, posthuman approaches challenge the established concept of humans. An exemplary analysis of the posthuman knowledge approach (Braidotti 2019a) and its application to climate change research (Fox and Alldred 2020) demonstrates its potential value added.

The concept of **zoe/geo/techno materialism** stresses the dimensions of humans with regard to the mediating technology ("techno"), relatedness to other humans and non-human living beings ("zoe") and the boundedness to earth ("geo") (Braidotti 2019b). The technological intrusion is seen as a "second nature", the relational interconnections range from eco-others to the technological apparatus and attention needs to be tied to the earth. The term "dynamic neomaterialism" takes account of humans, that are materialistically embedded subjects in the being, their nomadic circulation in relational networks with powers, beings and encounters of human and non-human kind (Braidotti 2019b). "Neo-materialist immanence expands this transversal collective ability to produce knowledge otherwise, to other species" (Braidotti 2019a, p. 91).
Braidotti conceives the subject as a transversal being, completely incorporated in networks of human and non-human (animal, plants, viruses) relations (Braidotti 2019b). In this view, **the human in posthuman times** "needs to be assessed as materially embedded and embodied, differential, affective and relational" (Braidotti 2019a, pp. 11–12):

- materially embedded "means to take distance from abstract universalism."
- To be embodied "entails decentring transcendental consciousness."
- differential implies "to extract difference from the [...] logic that reduces difference to being different from [...]"
- The emphasis on affectivity and relationality "is an alternative to individualist autonomy."

In another source, the human in posthuman times is described as bodily-anchored, context-embedded, bearing a relational and affective structure of a varying nomadic, transversal, extended self (Braidotti 2019b). Other slightly modified characterisations of the posthuman subject can be found, that may be best captured by the clause: "We are (all) in this together, but we are not one and the same" (Braidotti 2019a, p. 52). Critical Posthumanities, according to Braidotti, thus hold the same position of the earth, of information networks and of human subjects in their research designs (Braidotti 2019b). **Post-human knowledge** is considered a flexible ontological fundament for posthuman knowledge production (Braidotti 2019b). Braidotti's oeuvre is considered an "examination of critical possibilities for the needed subjectivities, collectivities, and knowledges" according to Donna Haraway's statement on the Backcover of "Posthuman Knowledge" (Braidotti 2019a).
The usability of such a posthuman approach for STI programming can be illustrated by presenting a posthuman assemblage with regard to climate change. Established climate change approaches are said to address the easy actions, such as energy-efficient household appliances, while ignoring the hard aspects, such as climate injustice. A **posthuman assemblage**, allegedly encompassing the entirety of the phenomenon is suggested (Fox and Alldred 2020, p. 278):

> *"Earth; Sun; atmosphere; oceans; resources; animals; plants; (post)humans; industry; consumption; greenhouse gases; market; capitalist economic model; profit; growth; nations; governments; global North; global South; ideologies; wealth and health inequalities"*

Some authors claim that such a posthuman policy assemblage is necessary to capture "the complexities of the affective movements [...] and to formulate actions that will address adequately and appropriately both climate change and climate justice" (Fox and Alldred 2020, p. 279).

4.12 Multi-Species Justice (MSJ)

Multi-Species Justice[4] (MSJ) (Celermajer et al. 2020b; Celermajer et al. 2020a; van Dooren et al. 2016) seeks to understand the types of relationships humans ought to cultivate with more-than-human beings so as to produce just outcomes. At the core of MSJ is a **justice theory that recognizes rights of non-human nature** ("more than humans"). Beyond rejecting the belief that humans alone merit ethical or political consideration, multispecies justice rejects three related ideas central to human exceptionalism:

a) that humans are physically separate or separable from other species and non-human nature (=relational ontology),
b) that humans are unique from all other species because they possess minds (or consciousness) and agency and
c) that humans are therefore more important than other species.

MSJ rests on a number of background theories and roots in particular animal rights, political ecology, posthumanist (feminist) theories, actor network theory (ANT), new materialism and indigenous philosophies. It is however unique in its focus on justice theory and aims to resolve tensions between individual rights and ecosystem perspective which are problematic e.g. in animal rights through concepts like sympathetic imagining and shared vulnerabilities.

Key aspects of MSJ are:

- **Relational ontologies**: In MSJ understanding all beings are entangled in "thick relational webs" or "ecological arrays" and therefore equally entitled to justice and dignity.
- **Recognition**: MSJ recognizes the multiplicity of different types of being, in their own terms. Misrecognition and disrespect are seen as the reasons for maldistribution of rights. This entails **radically rethinking the subject of justice**: Human and nonhuman animals, species, microbiomes, ecosystems, oceans, and rivers – and the relations among and across them – are all seen as subjects of justice. All ecosystems merit **capabilities-based conception of flourishing** i.e. the right to actualize their capabilities and follow their life projects.
- Consequently, **multispecies injustice** comprises all the human interruptions of the functioning of this broad array of relations. If human practices create conditions that undermine the integrity of ecological systems, and harm their basic functioning, those practices should be considered unjust status injuries.
- **Non- anthropomorphism**: MSJ emphasises sensitivity to how different beings experience the world and recognises the limits of our capacity to understand.
- **Modes of immersion**: To enact MSJ humans need to strive to do better at knowing and understanding others and cultivate "arts of attentiveness": modes of both paying attention to others and crafting meaningful response. Approaches range from researching communication systems of non-humans such as plants, recognizing alternative ways of knowing about non-human systems e.g. embodied knowledge, theory based practices like sympathetic imagining or intimacy through art practices.
- **Decolonization:** MSJ recognizes indigenous knowledge as critical intellectual resource but at the same time refrains from its appropriation.
- **Transformative Orientation**: MSJ is aware of the risk that minor changes (e.g. personhood for some human like animals) obstruct larger transformation and aims to avoid such a lock-in.

Opportunities for integrated RTI guiding framework

- Investigation of more than human communication systems could be included in research programs.
- Exploration of just multi species systems could become a funding area in its own right.
- A methodology to reflect on questions of MSJ could be integrated into every research & innovations project similar to "ethics check" or gender sensitivity: does your research undermine the integrity of ecological systems, and harm their basic functioning?
- In a more positive way the capability based view on ecosystems flourishing could orient a wide range of RTI projects.
- Within the European Green Deal the notion of "Just transition" could be extended to "more than humans". This would entail a radical extension of the negotiation arena.

4 Some authors prefer multibeing justice due to reservations about the Linnaean implications of the term 'multispecies'

Challenges

- The notion of MSJ is not yet widely accepted its uptake may alienate some RTI stakeholders (which however is a necessarily the case with far reaching shifts in belief systems).
- Thinking on institutions for implementing MSJ is only just emerging and subject to debate even among the field

MSJ can be seen as an element of post humanist approaches, focussing too much on the justice aspect alone, may dilute the more general change of framing

4.13 Biocentrism (BIC)

The principal book on biocentric environmental ethics, „Respect for Nature: A Theory of Environmental Ethics“, was published first in 1986 and the latest 25th edition appeared in 2011 (Taylor 2011). In this work Paul W. Taylor develops the foundations of a biocentric or life-centred environmental ethics.[5] Taking the perspective of biocentric ethics requires the denial of human superiority and an attitude with respect for nature instead of an exploitative attitude. Taylor is said to provide “a rational, coherent perspective on nature that will allow us to accurately perceive (not deduce) the inherent worth of all living beings“ (Inja 2019, p. 65). Taylor’s theory has served as a point of reference in the vast majority of contributions to environmental ethics (Attfield 2013).

In view of the development of a conceptual framework for capturing ecosystem performance, Taylor’s seminal work contributed to both, major definitions of terms and a set of principles to decide in case of conflicting goals.

Biocentric environmental ethics is opposed to human-centred environmental ethics. While in **human-centred environmental ethics** our moral duties with respect to the natural world “are ultimately derived from the duties we owe to one another as human beings”, in **biocentric environmental ethics** “the living things of the natural world have a worth that they possess simply in virtue of their being members of the Earth’s Community of life”, including humans (Taylor 2011, p. 13).

Taylor distinguishes between moral subjects and moral agents. A **moral subject** is “any being that can be treated rightly or wrongly and toward whom moral agents can have duties and responsibilities,” whereas a **moral agent** is “any being that possesses those capacities by virtue by which it can act morally or immorally, can have duties or responsibilities, and can be held accountable for what it does” (Taylor 2011, pp. 19–20).

<table>
<tr><td>Wild Animals and Plants</td><td>Harmful to Humans</td><td colspan="3">Harmless to Humans
(Or: their harmfulness can reasonably be avoided)

Basic Interests   Basic Interests</td></tr>
<tr><td>. . . in conflict with . . .</td><td></td><td colspan="2">. . . in conflict with . . .</td><td>. . . in conflict with . . .</td></tr>
<tr><td rowspan="2">Humans</td><td rowspan="2"></td><td colspan="2">Nonbasic interests</td><td rowspan="2">Basic interests</td></tr>
<tr><td>Intrinsically incompatible with respect for nature.</td><td>Intrinsically compatible with respect for nature, but extrinsically detrimental to wildlife and natural ecosystems.</td></tr>
<tr><td rowspan="2">Priority Principles</td><td rowspan="2">(1) Self-defense</td><td rowspan="2">(2) Proportionality</td><td>(3) Minimum wrong</td><td>(4) Distributive justice</td></tr>
<tr><td colspan="2">. . . when (3) or (4) have been applied . . .
(5) Restitutive justice</td></tr>
</table>

Figure 10: Priority principles to deal with conflicts of interest between human and wild plants’ and animals’ interests (Taylor 2011, p. 170)

The attitude of respect for nature means to acknowledge that wild plants and animals of the Earth’s natural ecosystems possess **inherent worth**; This means a living being is worthy of the respect of all moral agents and possess worth “regardless of any instrumental or inherent value it may have, and without reference to

5 Ethics of bioculture is excluded from Taylor’s detailed considerations.

the good of any other being” (Taylor 2011, p. 52). Inherent worth must not be confused with inherent or intrinsic values that are both being placed on objects. If conscious beings place positive value „on an event or condition in their lives which they directly experience enjoyable in and of itself“ this should be denoted an **intrinsic value**; if they believe something should be preserved, „not because of its usefulness or commercial value, but simply because it has beauty, or historical importance, or cultural significance“ **inherent value** is placed on it (Taylor 2011, p. 51).

Taylor suggests priority principles to decide in the case of conflicting goals, depending on whether basic or non-basic interests of humans are in conflict with those of wild animals and plants (see figure Figure 10).

Opportunities for integrated RTI guiding framework

If we think “of the place of humans in the system of nature in the same way we conceive of the place of other species” (Taylor 2011, p. 68), such an egalitarian biocentrism could stress the natural characteristics of humans in ecosystems. In this project, Taylor’s concepts and priority principles could assist in the identification of emerging or latent conflicts between moral subjects arising from STI development and application.

4.14 Deep Ecology (DEC)

Deep Ecology refers to both, a philosophy and a social movement. The philosophy was founded by the Norwegian philosopher Arne Naess, distinguishing deep ecology from shallow ecology (Naess 1995). The concept has been criticised and modified over the years. Today, the Deep Ecology movement appears to have merged into two social movements often led by former Deep Ecology protagonists (Scerri 2016): First, those who develop and collaborate in finding practical solutions for issues such as climate change (Reformist Groups), and second, those who obstruct action that causes environmental harm, such as blocking open pit lignite mining or living in woods destined to be cut-down for transport infrastructure (Green Anarchism).
The potential value of the analysis of the Deep Ecology concept for this project may be rooted in acknowledging the historical legacies, the societal embeddedness, interrelated dynamics, the impact scope and practical consequences of any transition action.

The essence of the Deep Ecology movement can be retrieved from an internet-based platform, run by the Foundation for Deep Ecology, referring to eight points developed by two major protagonists (Naess and Sessions 1984), among them:

- The well-being and flourishing of **human and nonhuman life** on Earth have **value in themselves** (synonyms: inherent worth, intrinsic value, inherent value). These values are independent of the usefulness of the nonhuman world for human purposes.
- **Richness and diversity of life forms** contribute to the realization of these values and **are also values in themselves**.
- Humans have no right to reduce this richness and diversity **except to satisfy vital needs**.
- The flourishing of human life and cultures is compatible with a substantial **decrease of the human population**. The flourishing of nonhuman life requires such a decrease.
- The ideological change is mainly that of **appreciating life quality (dwelling in situations of inherent worth)** rather than adhering to an increasingly higher standard of living. There will be a profound awareness of the difference between big and great.

The tailoring of these points to the needs of a social movement becomes apparent in using the terms inherent worth, intrinsic value, inherent value – differentiated and explained by other scholars ((Taylor 2011) (Rea and Munns 2017)) – synonymously. “They are meant to express important points which the great majority of supporters accept, implicitly or explicitly, at a high level of generality” (Naess 1995, p. 68).
In terms of developing a novel concept of ecosystem performance, the distinction of shallow and deep ecology with regard to sustainability categories illustrates potential implications for STI planning:

Table 5: Comparison of shallow and deep ecology (Naess 1995, pp. 71–76)

Category	Shallow approach	Deep approach
Pollution	Purification technology and pollution diffusion, permissible pollution, polluting industries relocated to developing countries	Evaluated from a biospheric point of view, focusing on human health & life conditions of every species and system; fight deep causes of pollution, no relocation of polluting industries
Resources	Resources for humans, including plants, animals and natural objects	Resources and habitats for all lifeforms for their own sake (ecosystem)
Population	Problem of developing countries, human population not seen as a problem for other populations	Excessive pressures on planetary life stem from the human population explosion; Population reduction in industrial societies
Cultural Diversity and Appropriate Technology	Industrialization of the Western industrial type as a role model for developing countries, low estimate of deep cultural differences in non-industrial societies	Protection of non-industrial societies and limits to the impact of Western technology, favoring of subcultures in industrial societies; local, soft technologies
Land and Sea Ethics	Fragmentation of landscapes, ecosystems, rivers, etc., fragments assigned	The earth does not belong to humans, humans only inhabit the lands to satisfy vital needs (invital human needs

	as properties and resources of individuals, organizations, and states; wildlife conservation for future generations	must not oppose to vital needs of others)
Education and the Scientific Enterprise	Experts advising on combining economic growth with maintaining a healthy environment; “manage the planet”, high educational standards with intensive competition	Sensitivity to non-consumptive goods, and on such consumables where there is enough for all, world conservation strategy

The Deep Ecology philosophy does not reject technology as such. However, some Deep Ecology scholars engaged in “Turning away from Technology” (Mills 1997), yielding a catalogue of 78 questions to ask about any technology. This catalogue goes beyond conventional technology assessment approaches in also featuring the health of the planet and of the person, the bond of renewal between humans and nature, the perception of needs, conviviality, different types of knowledge (including indigenous knowledge), metaphysical aspects and aesthetics. Despite the misleading title of the book, the catalogue may provide useful aspects of STI programming under the ecosystem performance concept to be developed.

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