2024

DELIVERABLE 4.4

REPORT ON THE BEST PRACTICES ON IMPLEMENTING OPEN INNOVATION TO ADDRESS ENVIRONMENTAL SUSTAINABILITY GOALS

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EINST4INE

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THE EUROPEAN TRAINING NETWORK FOR INDUSTRY DIGITAL TRANSFORMATION ACROSS INNOVATION ECOSYSTEMS (EINST4INE)

Grant agreement no 956745

Start date of the project: 01/01/2021

Duration: 48 months

Document information

WP	4	Orchestrating innovation ecosystems

Dissemination level[1]	PU
Nature[2]	R

Due delivery date	30/04/2024
Actual delivery date	30/04/2024

Lead beneficiary	LUISS
Contributing beneficiaries	LUT, USTUTT, RMIT EU, AU, UCAM, SSSA

Document history

Issue date	Version	Changes made/reason for this issue	Author
07/03/2024	1	First draft	N. Dux (LUISS), J. Fishburn, C. Häfliger (LUT)
15/03/2024	2	Reviewing, additional theoretical input.	C. Alaimo, N. Dux (LUISS), J. Fishburn, C. Häfliger (LUT)
30/03/2024	3	Reviewing, additional literature, case studies.	H. Chesbrough, N. Dux (LUISS) J. Fishburn, C. Häfliger (LUT)
15/04/2024	4	Final second Draft, reviewing & streamlining	All authors
22/04/2024	5	Final Report	All authors
26/04/2024	6	Internal Review	J. Dabrowska, A-L. Mention (RMIT), E. Vallejos (RMIT EU)

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Dissemination level: **PU** = Public, **PP** = Restricted to other programme participants (including the JU), **RE** = Restricted to a group specified by the consortium (including the JU), **CO** = Confidential, only for members of the consortium (including the JU)

[2] Nature of the deliverable: **R** = Report, **P** = Prototype, **D** = Demonstrator, **O** = Other

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ABOUT EINST4INE

The European Training Network for InduStry Digital Transformation across Innovation Ecosystems, also known as **EINST4INE**, is a consortium of universities, research organisations, and industry partners working in the domain of industrial digital transformation.

EINST4INE aims to develop new concepts, approaches, and methods in the area of digital transformation and brings together a unique group of world-leading experts in the areas of Open Innovation, Industry 4.0, digital transformation, and innovation ecosystems. '**Deliverable 4.4**' (D4.4) is one of the theoretical and technical reports produced from the ongoing research conducted within this network. Its purpose is to share state-of-the-art insights from both academic research and practical applications aimed at meeting forthcoming industrial and sustainability challenges. Specifically, D4.4 concentrates on the best practices for implementing open innovation to tackle environmental sustainability objectives.

Read more at: https://www.einst4ine.eu/

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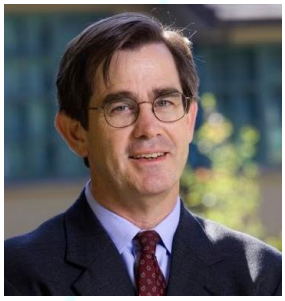

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INTRODUCTION

The United Nations Emissions Gap Report 2030 suggests that emissions are set to exceed the thresholds necessary to limit temperature rises to 1.5°C by 2030, equivalent to the combined annual emissions of the United States, China, and the European Union. The recent surge in emissions, contributing to record-breaking global temperatures, points to a widening gap between ongoing policies and the drastic measures needed to pivot towards renewable energy sources and mitigate climate impacts. This transition, while challenging, calls for international cooperation and an equitable approach, ensuring that all nations, especially those most vulnerable, are supported through technology, finance, and shared expertise.

Notably, the energy sector has been the principal driver of increased emissions in recent decades, mainly due to the global rise in coal and gas power generation (International Energy Agency, 2023). Nevertheless, it is also one of the few sectors where certain countries have successfully reduced emissions by transitioning to lower-emission fuels and expanding renewable energy sources (United Nations Environment Programme, 2023). Such progress stems from the urgent need to address significant challenges like climate change, encouraging companies to pursue innovative solutions that offer environmental, social, and economic benefits. This often involves engaging a wider network of partners and adopting innovative organizational structures.

The intersection of open innovation and environmental sustainability offers a promising avenue for organizations to drive impactful change while fostering collaboration and creativity. Open innovation (OI) is defined as a "*distributed innovation process based on purposively managed knowledge flows across organizational boundaries*" (Zobel et al., 2023; Chesbrough and Bogers, 2014). OI has expanded beyond its initial focus on integrating external ideas and out-licensing internal innovation to encompass a wider range of strategies. This broadening is driven by societal and supply chain dynamics changes, platform and circular business model adoption, and increased interactions with diverse stakeholders, including users, communities, and public institutions (Cavalli & McGahan, 2023). Such a comprehensive approach now plays a pivotal role in addressing global societal and environmental challenges, aligning closely with the objectives outlined in the Sustainable Development Goals (SDGs).

Thus, by implementing the principles of open innovation, companies have an opportunity to not only enhance their competitive edge but also contribute meaningfully to global efforts towards a more sustainable future.

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Through a comprehensive analysis of best practices, case studies, and expert perspectives, this report aims to equip readers with an overview of the knowledge and tools necessary to harness open innovation for environmental sustainability. The report outlines a comprehensive roadmap for organizations aiming to achieve their sustainability goals through open innovation. It emphasizes the importance of establishing clear environmental pledges and sustainable business practices, aligning metrics with global standards, fostering collaborative networks, and leveraging digitalization for effective climate action.

First, we introduce the principles of open innovation, what it involves, and how it can be implemented, including many of the common benefits and challenges that firms face when implementing and managing OI. Here, we also suggest how to overcome some of the common challenges based on scientific findings and illustrate them with recent examples and best practice case studies.

Next, we cover how open innovation can be implemented to help address environmental sustainability goals and challenges. Here we highlight and discuss different frameworks and tools, focussing on collaborative networks and ecosystems, digitalization and climate action, and community and crowd-based innovation.

Then, to ensure the effectiveness of open innovation in sustainability, we outline how organizations measure and report sustainable outcomes and align with official metrics. These practices help track and report on sustainability progress and ensure that innovations genuinely contribute to environmental and social objectives. Through various examples and research, we then provide some suggestions on defining and managing the responsibilities for environmental impacts. This includes establishing clear accountability measures, at both state and organizational levels and strategies to scale sustainable innovation effectively.

In the final section, we provide some best practices to address sustainability through open innovation based on our research and give some concluding remarks.

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OPEN INNOVATION PRINCIPLES

Open Innovation (OI) exchanges knowledge across different organizations to drive innovation. It focuses on carefully managing how information moves between these firms, using monetary and non-monetary incentives, to fit the organization's goals (Chesbrough & Bogers, 2014). In contrast, Closed Innovation confines innovation processes within the company, depending solely on internal resources and maintaining strict information control. OI embraces global collaboration, reducing risk by integrating external ideas and technologies. Also, the firm boundaries are considered to be permeable, meaning that creative ideas and developments can occur within and beyond a company's borders. This flexibility enables the incorporation of external insights and the sharing of internal innovations with the outside world. Additionally, OI facilitates the alignment of resources with external partners, enhancing efficiency, collaboration, and innovation (Chesbrough, 2003).

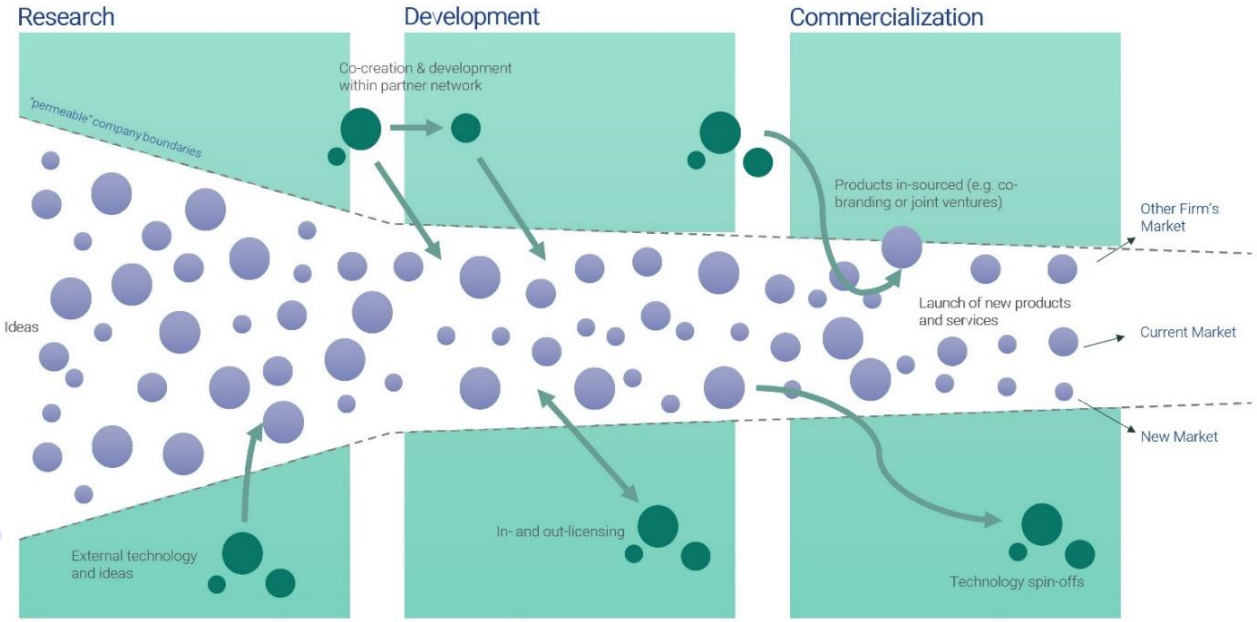

Figure 1: *Illustration of the Open Innovation process*. The dashed line represents the firm's permeable boundaries, which help ideas and technologies flow in and out of the company. (Source: own representation based on Chesbrough & Bogers, 2014; Mortara et al., 2009)

OI can extend over different company functions in the innovation process. As we can see in Figure 1, ideas are explored during the research phase, with the most viable ones advancing to development and commercialization. At the same time, less feasible options are left behind or shared on the outside. In contrast to the closed model, which maintains the secrecy of innovation activities until a product is launched, Open Innovation (OI) encourages companies to tap into

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external expertise, such as technological advancements. It could lead to the creation of spin-off companies or products. (e.g., Chesbrough, 2002).

During **the research phase,** companies explore externally, engaging in market research, forming collaborations, or participating in broader industry networks and alliances. Internally, they look for ideas across various departments that resonate with their central business objectives (Chesbrough, 2007).

The most viable ideas then transition into the **development phase**. At this point, the company can still acquire externally developed technologies to advance their projects and may even sell their own Intellectual Property (IP) licenses if they do not align with the company's strategic direction (Huang et al., 2013). On the other hand, businesses could establish new spin-offs (Chesbrough, 2007).

Upon reaching the **commercialization phase**, some innovations might have gone through a full internal innovation process, while others might have received input from external sources. The company may still consider sourcing technologies from outside through joint ventures or strategic partnerships. These innovations could push the company's current market position or help it enter new markets (Enkel et al. 2009; Savitskaya et al. 2010).

One of the core elements of implementing OI is to open the firm boundaries and to create more knowledge flows within and across companies. **Knowledge flow** refers to the exchange of ideas, information, and expertise *between internal and external stakeholders*, such as employees, customers, suppliers, partners, and competitors. This flow of knowledge can occur through various channels, including collaborative research projects, partnerships, joint ventures, licensing agreements, or open-source platforms (Gutmann et al., 2023; Chesbrough & Bogers, 2014). Figure 2 shows a matrix of open innovation knowledge flows divided between the supply and demand sides. The supply side distinguishes whether knowledge comes from within or outside the company, and the demand side showcases knowledge's internal or external application.

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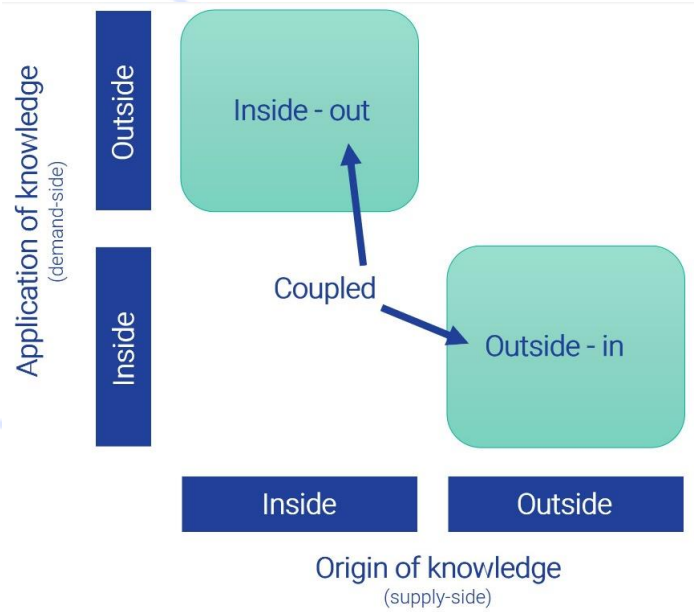

Figure 2: *Inside-out, outside-in, and coupled knowledge flows between the supply and demand side* (Source: own representation based on Gutmann et al. 2023)

In general, there are four types of OI knowledge flows that can be distinguished:

- **Outside-in (Inbound OI):** opens a company's innovation processes to external knowledge inputs. Inbound open innovation activities typically include *IP in-licensing, idea and start-up competition, and crowdsourcing* (Chesbrough & Brunswicker, 2014).
- **Inside-Out (Outbound OI):** requires organizations to allow external actors to exploit unused and under-utilized knowledge in their businesses. This could lead to scenarios such as *licensing-out IP, creating spin-offs, establishing corporate incubation programs, or forming joint ventures with external partners* (Chesbrough & Brunswicker, 2014).
- **Coupled OI:** Organizations may integrate inside-out and outside-in OI through a coupled process, which refers to "*co-creation with (mainly) complementary partners through alliances, cooperation, and joint ventures during which give and take are crucial for success*." (Enkel et al. 2009). Coupled OI involves collaboration with partners across various sectors, communities, users, and academic or research institutions (West& Lakhani, 2008; Perkmann and Walsh, 2007; Enkel et al., 2009). However, co-creation and aligning skills and resources in such partnerships may pose challenges in determining ownership and protecting the intellectual property of co-developed technologies.

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IMPLEMENTING OI

To adopt this innovation model, companies can access a variety of ***tools***, each valuable for discovering new technologies, ideas, and talent that can drive organizational innovation:

- **Idea competitions and crowdsourcing**: Idea competitions invite external parties to tackle specific challenges, offering a platform for collaboration with start-ups, research centers, and universities. Crowdsourcing involves soliciting contributions from a large group, typically through an online platform, where a community or crowd offers solutions for tasks or problems in return for rewards or compensation (Attalah et al., 2023; Brabham, 2013). Hackathons are part of crowdsourcing activities and are intensive programming events where developers compete to develop innovative digital solutions (Attalah et al., 2023; Bertello et al., 2021). These tools can also be used internally to boost interdepartmental cooperation and support intrapreneurship, encouraging employees to develop projects with business potential. For example, Enel, a multinational energy company, launched am internal platform called My Best Failure. Here, employees can share their "successful mistakes," describing initial mistakes that they were able to develop and turn into viable ideas. The platform allows employees to vote for the most successful mistakes. The winners are awarded a collaboration opportunity with Enel partner companies like start-ups or receive other rewards[1] (Enel, 2016).
- **Incubators, labs, and accelerators**: Labs focus on research, testing, and developing new ideas and technologies. Incubators support early-stage projects or start-ups, providing resources and guidance for growth. Accelerators fast-track the development of more established ventures with mentorship and sometimes funding (Chesbrough, 2006). The goal is to aid emerging businesses by offering them the necessary resources and environments for business development or to invest in them (e.g., through accelerators). Applied in OI, these tools can be used internally to foster a culture of innovation within the company and externally by collaborating with start-ups, researchers, and entrepreneurs who bring external innovations into the organization.

[1] https://www.enel.com/company/stories/articles/2016/08/my-best-failure-when-mistakes-are-valuable

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- **Digital technologies and Platforms**: Digital transformation has introduced advanced technologies such as AI, sensors, and advanced analytics, enabling companies to create smart, interconnected internal networks and broader external digital ecosystems (Jovanovic, 2021). These ecosystems are often facilitated by platforms that connect companies with external entities, crucially leveraging data as a new source of knowledge (Alaimo & Kallinikos, 2021). Additionally, these platforms foster openness through initiatives like open-source projects and open data (Bria et al., 2023). Tools like software development kits (SDKs) and Application Programming Interfaces (APIs) enable different software to interact, integrating services and data to enhance functionality and user experiences. These platforms also support third-party innovations and facilitate crowdsourcing by connecting diverse projects and challenges, linking companies with sector-specific experts (Altman & Tushman, 2017; Brabham, 2013).
- **Enhancing multilateral collaborations**: The results of the inbound and outbound exchanges can lead to collaborations through which new projects, products, and services arise, some of which are more formal than others. Some forms of collaboration are motivated by factors beyond financial transactions, including learning opportunities and shared interests, such as addressing grand challenges like climate change (Chesbrough et al., 2023; Cavalli & McGahan, 2023):

Monetary incentives	Non-monetary incentives
Strategic Partnerships: Forming alliances for mutual goals like technology development or market access.	
Acquisitions: Buying out other companies to access new ideas, technologies, and talent.	Co-Creation: Collaborating with customers or suppliers to jointly develop new products or solutions.
Joint ventures: Collaborating to create a new entity, sharing resources, risks, and rewards.	Open Source Collaboration: Contributing to or using open-source software for shared development.

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Licensing agreements: Granting or receiving rights to use IP, technology, or assets for fees.	Knowledge Sharing Networks: Participating in networks to exchange ideas and expertise with industry peers.
Equity Investments: Investing in or receiving investments for a stake in each other's business.	Public and Private Partnerships (PPPs): Government and private sector collaboration for public-benefit projects.
Contract Research: Outsourcing R&D to external partners like research institutions in exchange for payment.	Ecosystems: Broad networks with stakeholders for collaboration, knowledge sharing, and co-creation.

Table 1: Collaborative arrangements based on monetary or/and non-monetary incentives

BENEFITS AND CHALLENGES OF OI

Benefits:

Open innovation can *enhance business outcomes* by facilitating the *sharing of risks and resources*, shortening the time needed to develop new products, and fostering *greater employee engagement* (Mention, 2011). It also expands access to novel knowledge, cutting-edge technologies, and new market opportunities (Enkel et al., 2009; Rahman and Ramos, 2010). External collaborations with start-ups, universities, and research centers can also significantly *cut R&D costs* (Mention, 2011; Chesbrough & Crowther, 2006). Furthermore, OI supports firms in *strengthening their market presence* by aligning closely with consumer needs, enhancing their competitive positioning (Miotti and Sachwald, 2003). It also opens new domestic and international markets (Zhao et al., 2016). Beyond business benefits, OI facilitates *collaboration on global challenges* like environmental sustainability, promoting the sharing of knowledge and technologies for broader societal impact (Chesbrough & DiMinin, 2014).

Challenges:

Implementing open innovation (OI) brings challenges, notably the high costs. Many companies may lack the financial resources or the *internal capabilities* needed to back such initiatives (Rahman & Ramos, 2013; Radziwon & Bogers, 2019). This is often made worse by how internal knowledge gets blocked within *silos* inside the organization. This can be remedied by having *skilled personnel and strong managerial leadership* to navigate the complexities of collaborative innovation (Monteiro et al., 2017; Leckel et al., 2020). The "Not Invented Here" (NIH) syndrome, for instance, refers to a mindset where companies, teams, or individuals show a strong

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preference for internal innovations and solutions, often devaluing external ideas simply because they originate from outside the organization (Antons & Piller, 2015). Finding the right partners to share costs and complement each other's resources can be difficult. *Differences in strategic goals* can cause misunderstandings and conflicts. Managing relationships with these partners and addressing *worries about intellectual property* and trust further complicates collaboration efforts (Blomqvist et al., 2023; Chesbrough, 2019b; Bogers et al., 2017; Dahlander et al., 2021). Finally, particular *market conditions* might not be ideal for OI (Radzwion & Bogers, 2019). For instance, the military and nuclear sectors prioritize the secrecy of their technology (Gassmann, 2006).

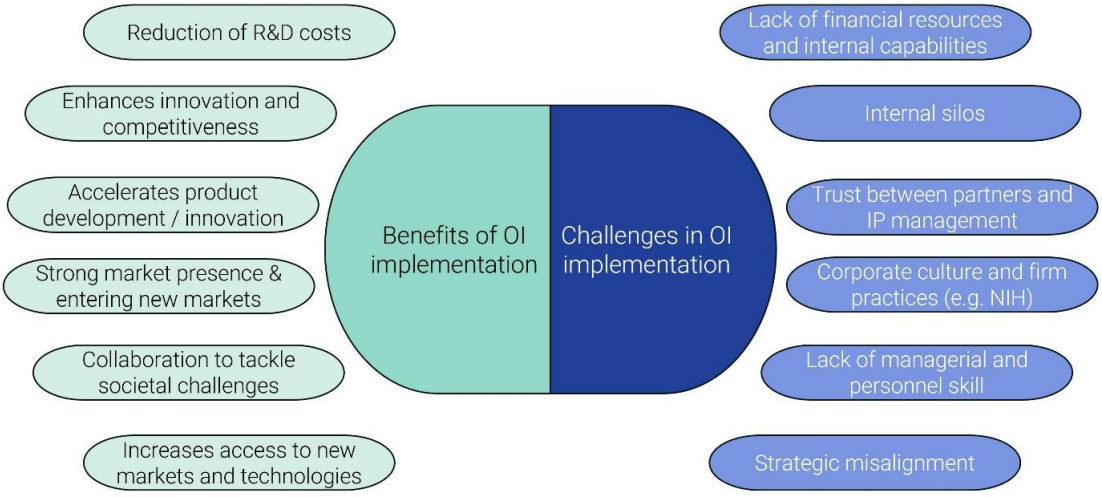

Figure 3: Benefits and challenges to OI (Source: own representation based on Gutmann et al. 2023)

Implementing OI and overcoming challenges

Implementing open innovation involves deciding who in the company is responsible for it. This can be spread out across different departments or focused on one central team. Given how complex large companies are, mature companies usually have the top management guide the process of OI implementation, with a central team managing related tasks. The open innovation (OI) team should include people with different skills who understand the company and its market well. This team's main job is to lead and support OI by involving others, providing training, and ensuring the company's strategy matches the OI goals (Mortara et a. 2009).

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However, Implementing and managing these knowledge flows isn't a one-size-fits-all process. Companies differ in nature, context, size, and objectives, influencing their capacity for decision-making and adaptability to external changes. Despite these differences, there are vital aspects all companies should consider when adopting OI:

Strategic Alignment & Network governance:

Strategic alignment and governance is particularly important in contexts where multiple organizations or individuals must collaborate to achieve common goals, such as in alliances, partnerships, industry consortia, or supply chains. It helps ensure that all participants are aligned in their objectives, activities, and outcomes, despite their individual autonomy. Furthermore, in broader contexts such as platforms and ecosystems, determining regulations and rules of participation need to be defined.

- ➔ Building and managing trustful external relationships involves identifying key players, and nurturing both formal and informal expectations by developing clear agreements and setting clear IP guidelines. Collaborations and mutual trust can be enhanced and kept through shared confidentiality and monetary practices. (Enkel et al. 2009; Salter et al. 2014)

Foster a Culture of Openness and Flexibility:

Open Innovation (OI) necessitates a cultural shift that managers must lead by promoting new thinking and guiding the integration of external knowledge. Cross-functional teams can bring together diverse perspectives and incentives to participate often go beyond monetary, embracing altruistic reasons. Strong leadership and creative and open environments (e.g. open innovation labs) can reduce resistance to external ideas by helping employees adopt new values (thus avoiding the NIH syndrome) (Mortara et al. 2009, Parida et al. 2014).

- ➔ Dedicated OI units can help with scouting and integration of external innovations that align with the company's strategic goals and filter out the ineffective innovations (this can also be automated using analytics software systems).
- ➔ Specific budgets can be allocated to OI initiatives
- ➔ Internal training programs and developing the firms absorptive capacity helps adopt external knowledge sources or innovations (Vanhaverbeke et al. 2008)

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Focusing on internal capabilities, strategic alignment, and fostering a supportive culture is a valuable starting point for addressing and potentially overcoming the complexities of OI adoption.

CASE STUDY:

ENEL – THE INSIDE-OUT SPINOFF OF ENEL GREEN POWER

Enel, an Italian energy powerhouse founded in 1962, has been a leader in the transition to renewable energy since the 2000s. In 2008, Enel launched Enel Green Power (EGP), a new division focused on renewable technologies, led by Francesco Starace. EGP quickly became a pivotal part of Enel's operations, influencing the entire group to shift away from fossil fuels under Starace's leadership as CEO. The company's commitment to sustainability was further solidified by forming strategic partnerships and adopting an "open innovability" approach with Ernesto Ciorra, who was an addition to the company as one of Italy's leading open innovation and marketing specialists. Open Innovability blended open innovation with sustainability and helped Enel expand its collaborations across innovation ecosystems, involving start-ups, academic institutions, research centers, and a broad range of community stakeholders.

To facilitate this broad engagement, Enel employs a variety of tools designed to involve these diverse groups in the open innovation process, highlighting their key role in the ecosystem:

- **Sustainability Management activities** aim to directly engage with communities to understand better and address their social and economic needs.
- **Innovation and Hubs and Labs**: Enel has various hotspots centered around research, with labs in Europe and the US. The hubs connect to broader ecosystems, while labs provide resources for testing new technologies.
- **Internal informal training activities and entrepreneurship programs**: The internal culture at Enel is designed to promote creativity and learning from past mistakes. This is exemplified by programs like “My Best Failure”, where employees are encouraged to share failed ideas.
- ***Open Innovability*** **crowdsourcing platform**: The concept lies in the publication of challenges for innovation and in the relative reception of responses from the audience of innovators.

By combining all these tools, Enel can gather and centralize diverse sources of knowledge, using OI tools to address different stakeholders. Enel has significantly expanded its knowledge in renewable energy, placing it in a favorable position to achieve a more sustainable and green future.

Key lessons:

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- ➔ **Business model changes**: Enel integrated openness and sustainability through a separate entity with EGP. Venturing into new markets with new technologies, environmental pushes, and fast-changing dynamics often require new business models.
- ➔ **Cultural & organizational readiness**: Following the integration of EGP into Enel, Starace leveraged his youthful EGP team, who shared his vision, to drive the changes internally. This transition was marked by a strong dedication from the leadership and the individuals responsible for overseeing the change process.
- ➔ **Digital and physical facilities reach**: Enel has multiple tools that help connect with different actors. Hubs and labs are used for start-ups and research institutions, as well as crowdsourcing platforms for communities that can participate online.

(Chesbrough, 2019; Chesbrough 2020; Lippolis et al. 2023)

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IMPLEMENTING OPEN INNOVATION FOR SUSTAINABILITY

The Open Innovation movement has evolved from its original emphasis on outsourcing corporate R&D and mechanisms like licensing agreements and bilateral collaborations to include broader open innovation strategies. This expansion has been fuelled by shifts in supply chain and society dynamics, integrating platform and circular business models, and enhancing multi-lateral interactions with various stakeholders, including users, communities, and public entities, influenced by evolving supply-chain dynamics (Cavalli & McGahan, 2023). This increased interaction with external players has made it an instrumental approach in tackling societal and environmental as outlined by the Sustainable Development Goals (SDGs) (see figure 4). The SDGs aim to foster such innovative collaborations across all sectors, including government, business, NGOs, faith-based groups, healthcare, education, cooperatives, and community organizations, all united to enhance the quality of life globally (United Nations, 2015).

The Sustainable Development Goals (SDGs), adopted by UN Member States in 2015 as part of the 2030 Agenda, aim to address global challenges with 17 interlinked goals for a sustainable future. The SDGs are now viewed as a longer-term agenda that covers social, economic, and environmental issues, potentially extending to 2035 or 2050 (Cavalli and McGahan, 2023 - chapter 34).

Figure 4: *SDG goals defined by the United Nations* (Source: United Nations[2])

[2] https://sdgs.un.org/goals

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Climate change, aiming for net-zero emissions by 2050, reducing carbon emissions, and promoting sustainable practices are among today's most urgent challenges. Industries are vital in addressing these issues (Falcke et al., 2023). Regulatory pressures to comply with the Sustainable Development Goals (SDGs) have prompted companies to adopt sustainable strategies and take a strategic approach to **Corporate Social Responsibility (CSR)** (Cavalli & McGahan, 2023). CSR encompasses corporate practices and policies aimed at minimizing environmental and societal impacts. For example, companies actively work to reduce their carbon footprints, manage waste, utilize sustainable resources, and operate transparently and ethically. These initiatives are essential for generating long-term value and a competitive advantage (Porter & Kramer, 2011).

On *5 January 2023*, the **Corporate Sustainability Reporting Directive (CSRD)** entered into force. This new directive updates the rules concerning the social and environmental information that companies have to report. Companies subject to the CSRD will have to report according to **European Sustainability Reporting Standards (ESRS)** – which took effect as of *1 January 2024*. ESRS take a "double materiality" perspective – companies are obliged to report both on their impacts on people and the environment, and on how social and environmental issues create financial risks and opportunities for the company.

Relatedly, another movement has developed parallel to the SDGs and OI, which is concerned with preserving technical and biological products and resources over time – the **Circular Economy (CE)**. CE presents a new model of sustainable production and economic activity, in contrast to the "take-make-dispose" model of the linear economy, and has seen significant uptake over the last decade, evident in the proliferation of emerging policy and corporate commitment. The Ellen MacArthur Foundation[3], a charity that works to support businesses with their CE initiatives (among other activities), is often remarked as one of the key drivers in accelerating the transition to a CE, implementing open innovation through their facilitation of a strategic network, knowledge exchange, and promoting institutional engagement. Companies can implement CE to help achieve SDGs, particularly for economic and environmental goals. It is an important source of innovation in start-ups and their wider ecosystems (Henry et al. 2020; Klofsten et al. 2024).

Environmental sustainability can also drive new business opportunities and innovation resulting from increasingly open and shared research and development processes (George et al., 2016). Achieving goals such as building sustainable cities and communities (SDG 11) or taking action on climate change (SDG 13) requires a combination of technical, organizational, cultural, and social collaborations, where Open Innovation (OI) can be beneficial (Cavalli & McGahan, 2023).

[3] https://ellenmacarthurfoundation.org

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In addressing such goals, companies are transitioning towards a broader, socially driven collaboration model, extending beyond specific technological advancements to include partnerships across various sectors for societal and environmental objectives. Firms have been embracing models such as networks and ecosystems in order to innovate and co-create value sustainably (both economically and environmentally). Even governments and municipalities are embracing openness and more transparency, aiming to co-create sustainable urban environments. They are establishing public data repositories to spur innovation and knowledge creation. Smart cities exemplify this shift, integrating open innovation by collaborating with citizens, businesses, and research institutions to co-create solutions for urban challenges (Chesbrough, 2019). They utilize advanced AI technology and data analytics to improve infrastructure, sustainability, and quality of life, encouraging a participatory approach through platform business models where stakeholders contribute ideas and innovations. Platforms have also been applied to leverage the knowledge of external crowds through crowdsourcing or open innovation competitions (Brabham, 2013), mobilizing various communities and societies across time and space. ***Data*** plays a large role in the digital realm as knowledge carriers and have specific characteristics, providing companies with an additional and abundant source of external and internal knowledge, composing accurate prediction analyses, and reporting about sustainable performances (e.g., measures in corporate sustainability reports) (Siew, 2015).

With all of these advancements, sustainable open innovation is considered an approach that strategically manages knowledge exchange internally and externally through financial and non-financial methods aligned with the company's business strategy. It does so while ensuring decisions do not compromise future generations' well-being (Bogers et al., 2020).

Building on OI's expansive role and tools in addressing societal and environmental challenges, the subsequent sections will illustrate some practical applications and OI formations, highlighting how OI has evolved to include more informal modes of collaboration with a different goal than monetary achievements. We outline the rise of cooperative ventures like collaborative networks and ecosystems and how digital technologies and platform business models support collaborative and sustainable innovation. We also discuss the roles of various actors, including crowds and communities, with examples like hackathons and crowdsourcing initiatives that harness collective intelligence.

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COLLABORATIVE NETWORKS AND ECOSYSTEMS

Since sustainability is such a systemic issue, collaborative networks and ecosystems play a key role in implementing open innovation for sustainability (e.g., Behnam et al., 2018; Rauter et al., 2019). The various frameworks for collaborative networks and ecosystems help to facilitate knowledge sharing, resource pooling, and collective problem-solving, thus accelerating the development and adoption of sustainable solutions. There are many ways in which collaborative networks and ecosystems can form. Here are a few of the most common frameworks:

Public-Private Partnerships (PPPs) leverage the strengths of both sectors to achieve sustainability objectives. Initiatives like the European Innovation Partnership on Agriculture Productivity and Sustainability [4] demonstrate how governments and private enterprises collaborate to address agriculture, food, and forestry-related challenges through innovative solutions. Extended partnerships include Smart cities, which harness open innovation to address sustainability effectively by combining the regulatory and civic oversight of the public sector with the technological expertise and efficiency of the private sector. This model leverages external ideas and incorporates a wide range of stakeholders, including academic institutions, nonprofits, and the public, which enriches the innovation process. Digital solutions like IoT sensors can monitor and optimize urban operations, from traffic management to energy usage, significantly reducing environmental impact. Private companies often provide these technologies. Citizens are often also engaged in the development process.

- ➔ However, PPPs face challenges such as aligning the interests of both public and private partners to prioritize sustainability alongside profitability. Data privacy and security concerns, as well as data quality and integrity, must also be addressed through governance structures, particularly with the extensive use of data-driven technologies like citizen data and health data (Appio et al., 2019; Bria et al., 2023).

Industry consortia are collaborative arrangements where multiple businesses, often including competitors, work towards common objectives that benefit the industry. These objectives range from research and development, standard setting, and sharing best practices to creating new market opportunities. Consortia are increasingly forming to address sustainability challenges collaboratively. For instance, the Circular Economy 100 (CE100) initiative, led by the Ellen MacArthur Foundation, brings together companies, governments, and academia to accelerate the transition to a circular economy, grouping and connecting stakeholders within the respective and relevant industries.

[4] https://ec.europa.eu/eip/agriculture/en/

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➔ Industry consortia often face challenges such as managing intellectual property (IP), aligning expectations, and ensuring equal time, money, and resource contributions from all members. Maintaining long-term engagement and setting clear, measurable goals are also crucial for measuring the success of these collaborations.

Innovation clusters are typically geographically concentrated groups of interconnected companies and institutions. Their purpose is to foster collaboration and knowledge exchange, which are increasingly used to drive sustainability innovation. Silicon Valley serves as a well-known example, where a dense network of tech companies, research institutions, and startups continually innovate – including clusters such as 'Sustainable Silicon Valley' [5] aimed at decarbonizing the Bay area.

Innovation ecosystems encompass a broader range of stakeholders, including businesses, start-ups, government agencies, research institutions, and non-profit organizations, collaborating to address sustainability challenges holistically to co-create value towards a shared vision or goal.

Ecosystems differ from other collectives like supply chains, clusters, alliances, and networks because of four key characteristics: the outcomes at a system level, the diversity of participants, the interdependence among members, and the methods used for coordination.

Example:

The ExpandFibre ecosystem is comprised of organizations and projects jointly tackling a shared vision; the 'ExpandFibre Mission'. This mission exists to meet the growing demand for sustainable bioproducts by developing groundbreaking materials and technologies and smart business concepts. A 50 M€ R&D entity was launched and implemented by Fortum & Metsä Group and co-funded by Business Finland. In the Programmes, Fortum and Metsä work together and separately on various projects that can link with Ecosystem members and projects. This shared vision, addressing more sustainable production, has driven various organisations to open up their R&D and collaborate to generate new sustainable innovations, and has been enabled by the financial and institutional support provided by Fortum, Metsä, and Business Finland.

Despite the benefits of collaborative networks and ecosystems for driving open innovation implementation for sustainability, they also face significant challenges. Challenges often include coordination issues, intellectual property concerns, and differing priorities among participants. Overcoming these challenges requires effective governance structures, transparent

[5] https://www.sustainablesv.org/

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communication, and mechanisms for equitable benefit-sharing, which can take considerable time and effort from all parties involved.

SPINVERSE

CASE STUDY: USING SERVICE DESIGN AS AN IMPLEMENTATION TOOL FOR OPEN INNOVATION ECOSYSTEMS TO DRIVE SUSTAINABLE GROWTH

Spinverse are an innovation consulting firm who believe in innovation for growth and for a better world. Their business and expert teams are organised by Digital Industries and Sustinable Industries – the driving needs for organisations to renew and grow, and often need to collaborate for. They have been working with OI since 2016, and through their experience, they discovered that applying design thinking and acting as a service designer in orchestrating the OI process in an innovation ecosystem has been very effective. Service design is a human-centered approach that focuses on customer experience and the quality of service encounter as the key value for success.

Often, very few ecosystem partners are structured to deliver products and services in a synchronized way that's attractive from a customer's perspective, hence the need for service design for innovation ecosystems. To do so, Spinverse identified six key elements for building and managing open innovation ecosystems for digitalization and sustainability:

Key element	Role of Service Design
1. Joint visioning with the dream team partners	*Ensuring shared view of the partner needs and the ecosystem journey*
2. Co-create Win-win Business models	*Creating optimal "flow of services" for the common customer journey*
3. Set transparent and clear enough Roles & Responsibilities	*Designing a "minimum viable ecosystem operating model"*
4. Lead in complexity	*Ensuring coordination and commitment over authority*
5. Facilitate interactions and dialogue	*Transparency, competencies, skills and tools*
6. Manage the balance between discipline and creativity	*Using customer journey as a management tool for collaboration*

Read more from their reports and findings here:

https://news.spinverse.com/key-insights-into-building-and-leading-open-innovation-ecosystems

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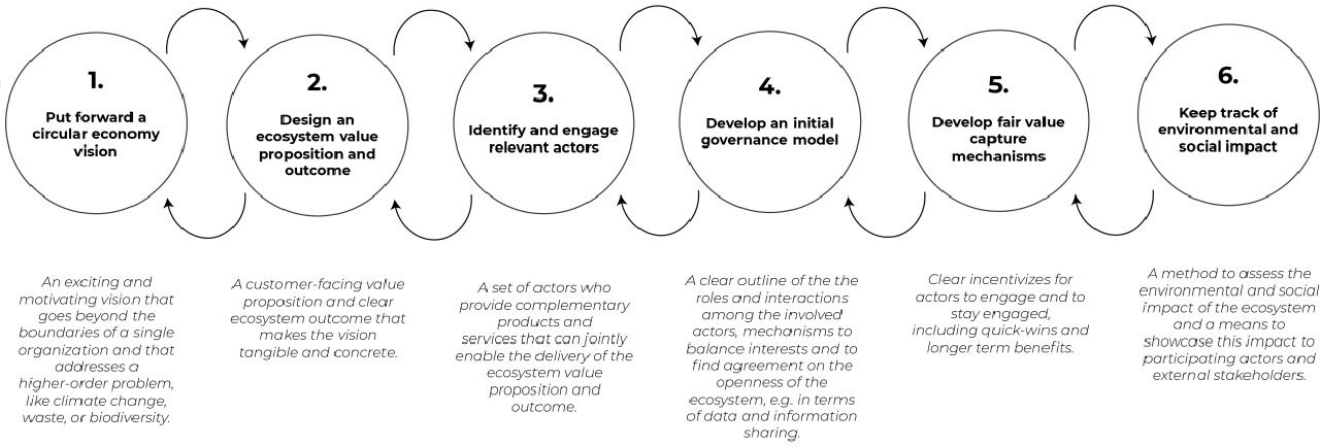
Ecosystem-level innovation is perhaps the most complex of the different types of innovation since it involves many other actors, commanding a need for high-levels of open innovation. Particularly for sustainability initiatives such as transitioning to a circular economy, ecosystem-level innovation requires high circular economy ambitions and potentially complex governance models (Konietzko et al., 2020; Aarikka-Stenroos et al., 2021). Therefore, Konietzko et al. (2024) propose a framework for a Minimum Viable Ecosystem for Circularity (see Figure 2) that includes



key activities to perform when building ecosystems for a circular economy. These activities provide a useful roadmap for scholars and practitioners to establish and assess ecosystems for circularity.

Figure 5: Initiating a Minimum Viable Ecosystem for Circularity (Konietzko et al., 2024)

To summarise, collaborative networks and ecosystems are effective enablers of open innovation for sustainability. They help to foster synergies among diverse stakeholders to address complex sustainability challenges effectively. By leveraging collective intelligence and resources, these frameworks help to drive meaningful progress toward a more sustainable future. However, they must be supported and facilitated effectively to realise value from their goals and vision.

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DIGITALIZATION AND CLIMATE ACTION

The convergence of digitalization and sustainable business and societal changes causes major shifts. These interconnected shifts are collectively known as the 'twin transition.' The twin transition and interplay between digitalization, climate action, and renewable energy in developing economies can be supported by focusing on digital infrastructure and climate resilience (GIZ, 2023). Developing countries are particularly vulnerable to climate change impacts and face limited digital access. As digital technologies can play a crucial role in climate mitigation, adaptation, and sustainable growth, collaborative action is essential.

Digitalization and climate action are connected, as information and communication technologies (ICTs) significantly contribute to environmental emissions. Yet ICTs can be used for efficient climate solutions, such as smart grids, precision agriculture, or intelligent transport, to reduce emissions. *Development, digitalization, and climate action* are related, as the shrinking digital divide between developed and developing countries supports digital technology growth.

Industry 4.0 Technologies like *cyber-physical systems, the Internet of Things (IoT), cloud computing, and artificial intelligence* (AI) (Zheng et al., 2021) are increasingly crucial as they can help prevent or reduce environmental footprints. *Operational processes* are also changing with integration of smart factories where interconnected machines and systems can autonomously analyze data and make decisions (Jovanovic et al., 2021). Automation and real-time data analytics have led to more efficient resource use, notably reducing waste and energy consumption. Technologies like predictive maintenance prevent equipment failures and minimize downtime, while smart energy management systems optimize energy use, reducing costs and environmental impact.

IoT, for instance, can track product lifecycles, aiding in better recycling and reuse practices. Similarly, *blockchain* enhances supply chain transparency, ensuring sustainable sourcing practices by allowing companies to monitor the environmental impact of their supply chains in

CODES
COALITION FOR DIGITAL ENVIRONMENTAL SUSTAINABILITY

Example: The UN-led Coalition for Digital Environmental Sustainability (CODES) is a multi-stakeholder digital movement for sustainable development. The global coalition offers resources and opportunities to our contributors worldwide to foster actions, and capacity development, and drive a sustainability-focused digital transformation. CODES advances environmental digital sustainability.

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real-time. *Digital twin technology*, which creates virtual replicas of physical products or processes, allows companies to simulate and analyze product performance under various conditions, reducing the overall environmental footprint by improving product lifecycle management. *Additive manufacturing, or 3D modeling and printing*, promotes customization and on-demand production, reducing overproduction and inventory waste. It also facilitates the local production of parts, thereby reducing transportation emissions associated with global supply chains. Additionally, *AI and big data analytics* have advanced the predictive maintenance performance of assets and processes. AI technologies have the advantage that they are self-learning and self-improving (Waardenburg & Huysman, 2022), which can potentially accelerate the pace of sustainable solutions.

Digital platform ecosystems facilitate Industry 4.0, embodying this complex network of digital technologies and systems. (Veile et al., 2022; Gawer, 2021; Jacobides et al., 2018). Platform ecosystems are multisided markets connecting multiple parties, such as buyers with sellers or service providers (Ritala, 2024). These new organizational structures benefit from economies of scale and scope, connecting different markets and gathering insights from a broader network of contributors to tackle global challenges. Growth in these ecosystems is mainly powered by network effects using a mix of financial and sustainability incentives to help scale solutions for grand challenges (Cennamo, 2021; Kretschmer et al., 2022; Ritala, 2024; Ritala, 2021).

The platform allows external actors to connect to the platform through Application Programming Interfaces (APIs), often centered around a central hub, or orchestrator, that defines core platform features (Kretschmer et al., 2022; Constantinides et al., 2018; Tiwana, 2014). The shift towards software-based platforms allows for the development of products and services across sectors, challenging traditional supply chains or pipeline models (Yoo et al., 2010; Van Alstyne et al., 2016).

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Example:

Insight Hub, formerly known as Siemens's MindSphere IoT platform enables access to various AI and machine-learning enabled applications of the platform. The system is mostly used in Business to Business contexts, in applications such as automated production as well as fleet management of industrial machinery. Siemens's insights Hub, leverages advanced technologies which can be installed and integrated into different types of machines and for different purposes (e.g. medical sector, energy, etc.). These assets can be securely connected to the platform, gathering geographical and performance data, which can also be used for predictive maintenance or to develop new analytical tools. Notably, through its open Application Programming Interfaces (APIs), its utility is enhanced by enabling the broader ecosystem players to develop complementary products and services (Petrik & Herzwurm, 2019).

These platforms come equipped with a variety of tools designed to protect the core infrastructure and can foster the development of new sustainable products and services.

As an **inside-out OI mechanism**, companies offer tools such as APIs—communication bridges that enable the exchange of data among a diverse range of applications, devices, and platforms, or Software Development Kits (SDKs), which are made available for external innovators (Alaimo et al. 2020; Parker et al. 2023; Cenamor & Frishammar, 2021). It allows them to build upon the digital platform without disclosing their proprietary ideas. This arrangement protects the developers' or innovators' IP and enhances the platform's value as more users engage with its tools (Parker et al. 2023).

From an **outside-in OI perspective**, the platform owner receives new input and ideas, gaining a clearer understanding of market trends and ecosystem dynamics. The external platform usage and development tools enable the company to tap into new data. Most viable and successful innovations can be acquired or copied and added to the portfolio of the platform, or functions of the platform can be extended. Here, platforms need to define innovation ownership clearly and to which end the platform and its tools can be used (Parker et al., 2023; Cenamor & Frishammar, 2021).

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The role of data

Data play a crucial role in these ecosystems, acting as both a resource and a medium for business relations, with data management practices being pivotal for innovation and the emergence of new organizational forms (Aaltonen et al., 2023; Alaimo et al., 2020). This transformation is largely due to data's inherent characteristics, as it retains its value despite being used multiple times across different contexts. Moreover, the data's adaptability allows for continuous updates and reconfigurations, facilitating its integration into diverse applications. The ease of replicating data and the low cost of generation further amplifies its utility, enabling the development of complementary, data-driven services across industries.

CASE STUDY:

USING DATA TO PROMOTE SUSTAINABLE BANKING

Flowe[6] , launched in June 2020, is an innovative Italian fintech startup and benefit corporation that blends financial objectives with social and environmental impacts. As a digital financial service regulated by the Bank of Italy, the Flowe platform provides users with digital payment accounts integrated with Mastercard, facilitating online transactions, money transfers, and simplified personal finance management. Flowe operates as an online-only financial provider and offers an eco-conscious wooden debit card in partnership with ZeroCO2, supporting reforestation projects in Guatemala and enabling users to engage in carbon offsetting. The platform's commitment to ecological restoration is further enhanced through its collaboration with Doconomy, introducing the "Ecobalance" feature to track the CO2 impact of user transactions, promoting environmental consciousness among its over 670,000 users and 50 partners.

How data is used at FLOWE:

- **Data Sharing and Open Banking**: Flowe leverages the principles of open banking, which rely heavily on the effective use of data. Through APIs, Flowe facilitates third-party providers' (TPPs) access to financial data to offer enhanced services to users. This open access allows for a more integrated financial services environment where users can benefit from a seamless blend of services from different providers.

[6] https://www.flowe.com/

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➔ **User Engagement and Experience**: Data about user interactions on the platform is continuously collected and analysed. This information improves the user interface and personalizes the experience, ensuring that the services remain relevant and engaging. For instance, user transaction data helps tailor savings or investment advice, enhancing personal finance management.

Creating Sustainable Products and Services

The integration of sustainability into Flowe's data-driven approach is a key differentiator. Here is how data supports the creation of sustainable products and services:

➔ **Ecobalance Feature**: By converting transaction values into estimated CO2 emissions, Flowe provides users with actionable insights into their environmental impact. This feature encourages users to make more environmentally friendly choices.
➔ **Partnership-Driven Sustainability**: Flowe partners with organizations like ZeroCO2 to facilitate tree planting based on user activities. Data about users' participation in these activities is tracked and shared with partners to coordinate the sustainability efforts effectively.
➔ **Gamification for Sustainability**: Flowe uses data to drive gamified experiences that promote sustainable behaviors. For example, users can earn rewards for participating in environmental activities, tracked and managed through data analytics to ensure users are engaged and motivated.
➔ **Community Building**: Data is also used to foster a sense of community among users around shared values of sustainability. The platform tracks and displays collective achievements in sustainability efforts, such as total CO2 offset or trees planted, creating a shared sense of accomplishment and encouraging continued participation.

FLOWE is an example of how digital technologies and platform business models transgress industry boundaries. Linking the tech and the financial sector, the Flowe navigates the fintech sector, harnessing data that spans across enhancing user financial management, promoting sustainable practices, and fostering community engagement. (Alaimo et al., 2022)

Open Source movement

As commercial companies profit from economies of scale and scope and the network effects of digital platforms, the public sector is harnessing these technologies to address the UN's Sustainable Development Goals. This shift involves regulatory roles in the digital economy and encourages open collaboration. The embrace of open standards, open-source software and hardware, and open data serves as a bridge, inviting widespread participation from various sectors to contribute to a shared digital ecosystem:

1. **Open standards** are publicly accessible agreements describing specific product, service, or system criteria. They ensure interoperability and compatibility between various technologies and platforms, allowing different devices, services, and

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applications to work together seamlessly. Open standards are developed and maintained through a collaborative and transparent process, often involving multiple stakeholders, including companies, organizations, and individual contributors (Simcoe, 2006).

Example: The C2PA (Coalition for Content Provenance and Authenticity) addresses online misinformation by establishing open that verify the origins and history of digital media, covering a broad spectrum of themes like climate change, healthcare, etc.

2. **Open source software & hardware:** Open-source software (OSS) refers to computer programs made available with their original source code, allowing anyone to modify, enhance and share software easily (Carter, 2023). Open-source hardware, such as solar panels, follows a similar philosophy, where the designs, software, and building instructions for physical objects are made publicly available so that anyone can study, modify, build, and distribute them.

Example: The Linux Foundation[8] oversees the development of Linux, an open-source operating system that forms the backbone of much of today's digital infrastructure, including the majority of the public cloud and numerous embedded systems worldwide. The Linux Foundation supports open-source projects such as the LF Energy[9] initiative focuses on using open-source collaboration to transform the energy sector, promoting

Open source and open AI are also increasingly gaining momentum, allowing for the creation and sharing AI models, their components, and datasets under open licenses. This approach fosters innovation and the emergence of new business models by enabling organizations and wider communities to tap into and extract value from these openly shared resources (Ferràs et al., 2023).

Example: Yara[9], a Norwegian company, has introduced a digital platform in the agricultural sector, blending weather data, AI and machine learning capabilities to generate actionable insights for enhancing agricultural productivity while adhering to

3. **Open Data:** By embracing open data, companies and institutions can venture beyond traditional boundaries, fostering the creation of value-added services through collaborative efforts. The practice of open data is making data freely available to everyone to use and republish with or without restrictions. Many private companies use this to build complementary products and services (Majchrzak et al., 2023).

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Public institutions such as the European Union or individual governments also publish demographics and data related to city analytics.

Example: For a range of sustainability goals, creating a means of analysing and using data from a combination of public, private, and commercial sources is essential. For instance, Enel X is a platform that specializes in energy supply and management services. For governments and municipalities, Enel X offers services such as smart public lighting, demand response programs, and energy efficiency solutions for public buildings. Enel X combines public domain data with proprietary data from its network of connected devices. These datasets are then processed into actionable insights, such as a set of indicators to foster the concept of a circular city. These indicators serve as a vital resource for municipalities to make informed decisions about urban planning, focusing on infrastructure, mobility, and public services.

Challenges of Digital technologies and Infrastructures

Data-sharing practices' challenges relate to data quality, reliability, standardization, privacy, and security. Also, companies need absorptive capacity to integrate new data insights and filter out non-viable ideas (West & Gallagher, 2006). Especially in private-public partnerships (e.g., Smart Cities), government and environmental legislations can help by driving sharing incentives and protecting vulnerable data.

Platform business models face technical as well as organizational challenges.

- **Platform architecture:**

  Successful orchestrators use a modular architecture for easy updates and replacements of modules as technologies or needs evolve. Platform functions and boundary assets such as APIs can be used to attract external actors. They need to be carefully coordinated to manage value creation and value capture while considering social and environmental impacts (Ritala, 2024).

- **Platform management**:

  When establishing a platform, orchestrators must attract and engage various stakeholders with platform functionalities, which becomes complex when entities like citizens, governments, and private companies collaborate. Orchestrators also face the "chicken-and-egg" problem, deciding which market side to attract first. Often, they may need to subsidize one side to initiate engagement. Additionally, a clear value proposition,

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governance structure, and policies are essential for sustainable growth, encompassing leadership roles, operational policies, and strategic frameworks (Ritala, 2024).

These challenges are inherent in all platforms, but they intensify significantly when addressing major issues like climate change, which require a comprehensive, long-term approach rather than simple, short-term economic solutions. Additionally, digital inequality is a growing concern (GIZ, 2023). As technological access varies widely among countries, adopting open models such as open data and open-source software and hardware can provide disadvantaged nations with essential, free resources.

The International Energy Agency forecasts that the energy consumption of data centers, AI, and cryptocurrencies will double by 2026. **Data centers** are notably driving up global carbon emissions, with their energy use approaching that of an entire country like Japan. To manage this significant increase in energy demand, it will be essential to implement updated regulations and invest in technological improvements focused on enhancing efficiency. Efforts to implement **Green Data centers** ensure their physical, electrical, and software systems are energy-efficient and minimize environmental waste (International Telecommunication Union, 2014).

COMMUNITY AND CROWD-BASED INNOVATION

Open innovation mechanisms are used for crowdsourcing thoughts, ideas, or implementations to showcase early-stage newly developed products or services or new applications for cutting-edge technologies. They are beneficial for co-creating value in groups that transcend the typical organizational boundary of research and development departments and allow collaboration with groups outside departments and even the organization.

Crowdsourcing

In Crowdsourcing, ideas are sourced from the "wisdom of crowds" through various strategies like contests and open calls, which can be particularly valuable in analyzing and addressing complex social issues. Recently, firms have increasingly engaged with external communities and crowds to enhance sustainable innovation. Both groups act like networks where people connect and share ideas, but they are more than just simple networks. ***Communities***, from informal groups to formal organizations, drive co-creation and innovation through shared goals and identities

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(Wellman et al., 2002). They include networks like trade consortia or virtual communities (O'Mahony & Lakhani, 2011; West & Lakhani, 2008). ***Crowds*** are diverse, often large groups of individuals, and contribute to projects based on self-selected interests or expertise. They can either be open and allow new members in, or closed, with fixed entering rules. This involves leveraging shared infrastructures such as platforms.

Crowdsourcing offers mutual benefits: Participants may gain new skills, satisfaction, or rewards while project initiators advance in solving specific issues. Emphasizing cooperation and creativity, crowdsourcing facilitates global collaboration, often leading to superior outcomes compared to individual efforts (Braham, 2013; Chesbrough & DiMinin, 2014).

Crowdsourcing involves four main elements: An institution, company, or NGO with a problem or task; a group of people that has the motivation to contribute to the task; an outcome that benefits the task-solving seekers (i.e., the organization) and the solvers (i.e., the community); and an (online) platform where the organization and the community can communicate, interact and solve tasks (Braham, 2013)

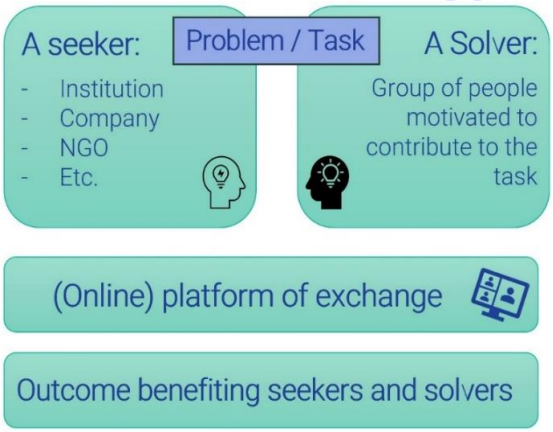

Figure 5: *Crowdsourcing framework* (Source: own representation based on Brabham, 2013)

Crowdsourcing varies in practice and is defined by the methods through which the organizers want to gather knowledge and how that knowledge is produced, either individually or collectively.

Microtasking, for instance, involves simple and repetitive tasks such *as categorizing data, translating and classifying data*, which help gather collective information on simple tasks, with the main goal to be scale effective and time efficient (Brabham, 2013; Blohm et al. 2018). For instance, Zooniverse[7] is a platform for citizen science projects where volunteers participate in

[7] https://www.zooniverse.org/

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research across various fields, including environmental sciences. Projects on Zooniverse often involve microtasks like classifying data and identifying animal species in camera trap images, which helps biodiversity research and conservation efforts.

Open collaboration brings together diverse groups for joint problem-solving in ideation, open-source software, and various community-driven projects. Social and public actors increasingly use crowdsourcing as open collaboration, showcasing how public engagement aids data collection and policy shaping. This strategy marks a shift from traditional contract-based solutions to a more open and collaborative approach, transforming governments' delivery of societal value (Blohm et al. 2018). For example, OpenStreetMap (OSM)[8] is a collaborative project that creates a free, editable map of the world to which millions of users contribute to. OSM supports sustainability efforts by providing critical geographical data for disaster response, urban planning, and conservation projects. Its open nature allows anyone to contribute and use the data.

Broadcast search platforms seek diverse external solutions for complex problems that benefit R&D challenges. Here, solutions are sought to solve scientific, creative, and analytical problems. By leveraging the knowledge of crowds, organizations can outsource innovation activities that were originally performed internally to a large community or crowd. The company can control the involvement and input of solvers and include them at different stages of the innovation process, for instance, at the research or ideation phase of a product development process or both (Brabham, 2013; Blohm et al., 2018).

Example: Enel developed the Open Innovability platform through which it shares technological and environmental challenges with a diverse audience to develop a new sustainable project or technology.

- ➔ Enel first draws from a broad spectrum of market insights, collaborations with academia, industry partners, and its own internal knowledge-sharing culture.
- ➔ It then identifies key themes and invites a global community of thinkers, including online users, business partners, and educational organizations, to propose inventive solutions.

The platform has successfully engaged over 500,000 contributors from over 100 countries, amassing more than 7,000 proposed solutions that range from individual ideas to research projects. Depending on the specific challenge, viable solutions can lead to various forms of collaboration like partnerships, acquisitions, or exclusive agreements, integrating these innovations into Enel's operations and aligning with its long-term goals. The company also has innovation hubs and labs globally, which enables them to scale the ideas further.

[8] https://www.openstreetmap.org/#map=6/42.088/12.564

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Open innovation contests & competitions

Sustainability promoted through open innovation can take different forms, such as open innovation contests. The crowd is invited to compete by submitting solutions to a posed challenge. Competitions typically have a competitive element, whereas some innovation contests clients are driven by connecting it to social goods or positioning them as environmentally oriented events with positive social values. For instance, the combination of open innovation practices fostering environmental sustainability goals can be seen in 'sustainathons', sustainability-oriented hackathons.

Hackathons are contests in which diverse sets of public and private stakeholders get to collaborate. These competitions can either take place online or in person and are usually short in time, typically lasting around two to three days, but can also call for longer or repeated interactions between the hackathon community (Bertello et al. 2022; Attalah et al. 2023). This leads to a coupled approach to open innovation, as there is a repeated exchange and progress monitoring between the solution seeker and the solution providers. Participation can also vary between being open to the public or concerning specific communities or small groups of people, where the best ideas and solutions are rewarded with monetary or non-monetary rewards. These events can be seen as initiatives that foster multi-actor collaboration and, at the same time, promote sustainability.

> **Sustainathons** or sustainability-oriented hackathons, are a way innovation contests promote sustainability. Sustainathon challenges are often organized by universities, and they may form part of a university course.[9]

Example: The Sustainathon challenge at Institute for Entrepreneurship and Innovation Science (ENI) and ARENA2036 in Stuttgart, Germany, addressed the impacts of global warming on the environment, society, and the economy. It was an interdisciplinary hackathon open to university students and researchers from all fields. Teams had two days to develop innovative solutions for presented challenges. Participating students earned certificates and university credits, and could even enrol in the hackathon as a course through ENI at the University of Stuttgart. Organized by a network of university-affiliated organizations including ENI, IVS, CampusHochi, Green Office, and ARENA2036 e.V., the challenge provided coaching, mentoring, and input sessions. Attractive prizes were awarded to the top three teams, with judging based on predefined sustainability criteria. Developing truly sustainable solutions posed a significant challenge for participants.

[9] See for other examples: https://www.mtuk.ee/uritused/sustain-a-thon, or the Action for Climate Empowerment (ACE)* Hackathon in 2022 by the UN Climate Change UNFCCC secretariat https://unfccc.int/topics/education-youth/ace-hub/action-for-climate-empowerment-hackathon

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Challenges to community and crowd-based innovation

Significant challenges in crowdsourcing and competitions relate to *ensuring the participation and management* of a diverse and skilled pool of contributors, who often have different value propositions and goals, especially when considering public and private actors. However, engaging such individuals, crowds, and communities can be difficult due *to unclear problems and objectives, wrong task allocations to the appropriate participants, and incentives for participation*.

Additionally, filtering good ideas from bad ideas can be difficult and time-consuming. Translating the innovative ideas generated through these platforms into actionable and practical solutions presents another challenge. Many crowdsourced ideas or hackathon projects may be conceptually strong but lack feasibility or alignment with the organization's strategic goals.

Governance in crowdsourcing sets clear objectives by organizing roles, rules, and responsibilities, guiding task allocation and communication to meet the project's goals through various ways:

1. ***Defining the challenge***: Challenge definition involves the orchestrator laying out tasks clearly for participants, and creating manageable subtasks that leverage the platform's modularity (Afuah & Tucci, 2012; Blohm et al., 2018). A clear value proposition is needed for innovation competitions such as hackathons or sustainathons, which can be defined by the orchestrator or co-defined by all participants (Ritala et al., 2022). Value is mainly derived from intellectual and knowledge resources for 'joint value creation,' where social value arises from mutually supportive contributions (Bridoux & Stoelhorst, 2016). The organizer must balance individual interests to maximize this collective value.
2. ***Addressing the right community or crowd***: Participation can be encouraged by offering payments or rewards, recognition, and the opportunity to contribute to meaningful causes. Incentives can be tailored to specific groups (Leimeister et al. 2009; Malone et al. 2010; Blohm et al. 2018).
3. ***Quality control and regulations***: Orchestrators ensure quality through manual checks or AI-powered software, filtering solutions against set criteria. Peer reviews also contribute to assessing contributions (Blohm et al. 2018). Regulations, including NDAs and authentication, maintain legal compliance and integrity, with clear guidelines for participation and rewards (Enkel et al. 2009).
4. ***What happens after?*** After a crowdsourcing event or competition, orchestrators may engage previous participants by offering additional opportunities for growth or collaboration, thus encouraging ongoing contributions and building valuable co-creation partnerships. This ongoing engagement fosters a community of regular contributors (Attalah et al., 2023).

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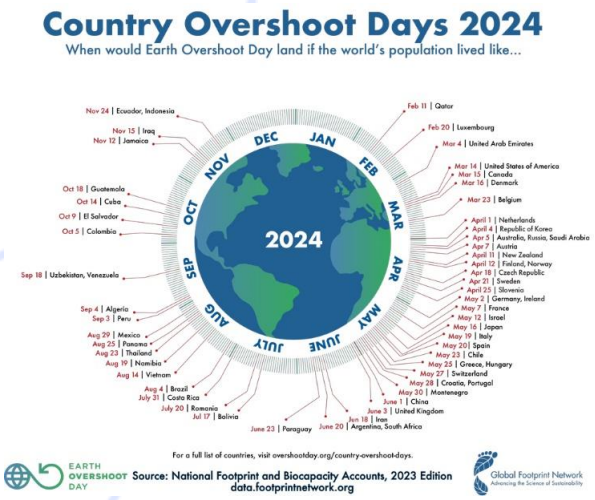
MEASURING OI AND SUSTAINABILITY

As corporate performance is nowadays not only measured by business metrics but also by climate and sustainability measurements, leaders must understand these complex issues and act to overcome them. For example, leaders need to understand environmental emissions within their firm and outside of it, try to develop and scale low-emissions technologies, and collaborate across internal boundaries and industries in a 'distributed innovation process' (Zobel et al., 2023). Setting clear goals and standards for measuring sustainability are important drivers to achieving the SDGs, as is the inclusion of open science, for example, by using the 'Open Innovation in Science (OIS) Research Framework' (Beck et al., 2022).

Measuring and using metrics reveal our behavior and preferences, shaping how we see the world and changing the institutions we build. As we are faced with more diverse and complex phenomena such as environmental pollution, public health implications, or resulting inequalities, a large variety of factors need to be assessed. In practice, organizations often blur measures and targets (Islam & Greenwood, 2021).

The societal transformations needed to head towards 'climate positive futures' are shaped by accelerated climate change, loss of biodiversity, and resource depletion (Mention et al., 2023). Measurement systems such as the Earth Overshoot Day, indicating the day when humanity's resource demand exceeds its biocapacity, is an illustrative example of measuring humankind's ecological footprint. The planetary boundaries framework represents another important example of the visualization of environmental changes.



For firms, measuring sustainability refers to assessing and attributing environmental, social, and economic aspects of products, services, or organizations. Indicators and indicator systems are used to measure and compare aspects of sustainability

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The growing emphasis on *accurately measuring emissions within sustainability frameworks* involves accounting for direct emissions from organizations, indirect emissions from energy and resource usage within the immediate collaborative environment of companies (including suppliers and the general value chain), and emissions from the broader ecosystem that the organization influences (Zobel et al., 2023).

The measurement of these outputs is a critical step forward. Tools and assessments provided by public services aim to incentivize companies to measure and disclose their activities effectively. However, the **responsibility** for these emissions and the **accountability** for meeting sustainability targets still need clear definition, management, and either sanctions or rewards from regulatory entities. Companies are encouraged to adopt greener practices by integrating sustainability criteria into procurement policies or by offering incentives for lower-carbon products and processes. Combining regulatory pressure, financial incentives, and market-based mechanisms such as carbon pricing and subsidies for clean technology can effectively stimulate the reduction of emissions. Enhanced reporting requirements in company *sustainable reports* and *corporate social responsibility reports* also play a crucial role in increasing transparency and pushing companies towards more sustainable practices.

However, the metrics reported can often be ambiguous (Freiberg et al., 2021). The challenges related to measuring sustainability, such as carbon emissions, lie in the heterogeneous metrics of reporting companies. Managing this complexity requires precise measurement and disclosure to stakeholders, enhancing credibility and transparency. Here, OI can improve the quality and credibility of measurements and reports by exchanging and sharing data, knowledge, and best practices, thus working toward a standardized measurement system (Zobel et al., 2023). This approach raises questions about the distribution of responsibilities and benefits, particularly when new low-emission technologies are developed and shared.

OI can contribute to emission reduction efforts by facilitating the sharing of knowledge and solutions across organizational boundaries. Here, clear agreements on who is responsible for what (e.g., financial responsibility) are essential to enhance the effectiveness of OI in sustainability initiatives (Zobel et al., 2023).

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Example: The Science Based Targets initiative (SBTi) is a collaboration among the Carbon Disclosure Project (CDP), UN Global Compact, World Resources Institute (WRI), and the World Wide Fund for Nature (WWF). SBTi provides a structured framework for businesses globally to set scientifically aligned emission reduction targets. It guides companies through a five-step process to systematically measure and minimize their environmental impact. The steps include committing to a target and intentions, developing it according to SBTi criteria, submitting it for validation, communicating the target with its stakeholders and wider ecosystem, and regularly reporting on emissions and progress. However, the reporting and measurements in these types of coalitions also need a certain control (see controversy in infor box p.46)

Measuring sustainable economic activities

To advance climate and energy sustainability goals, it is essential to allocate resources toward sustainable projects and initiatives. Consequently, a collective understanding of 'sustainable economic activities'[10] has been established. Sustainable finance tools play a crucial role in enhancing market transparency. The EU Taxonomy Regulation provides a clear definition of environmentally sustainable economic activities, enabling both financial and non-financial entities to adopt a consistent framework.

[10] https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

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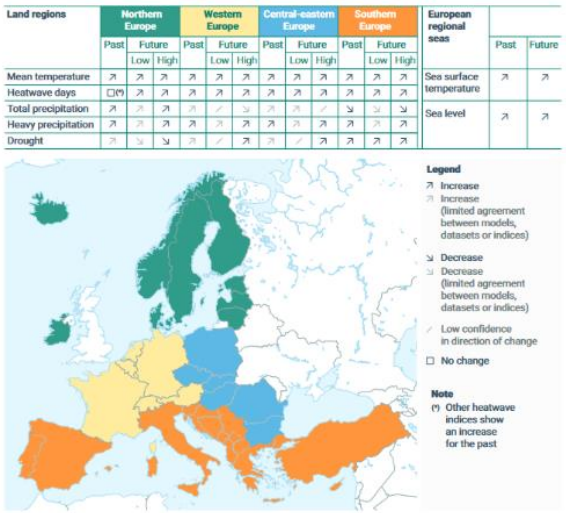
Example: The EU's sustainable finance framework enhances market transparency and guides economic activities toward the goals of the European Green Deal. The EU Taxonomy Regulation sets criteria for environmentally sustainable economic activities, covering environmental objectives beyond climate change. These activities must meet conditions including avoiding significant harm to defined environmental objectives, not adversely affecting climate change mitigation, adaptation, or biodiversity, making substantial environmental contributions, complying with minimum social safeguards, and promoting pollution prevention and a circular economy. By establishing these criteria, the EU Taxonomy fosters sustainable investment, boosts investor confidence, combats greenwashing, promotes climate-friendly practices, and reduces market fragmentation. It specifies technical screening criteria for each environmental objective to determine if activities qualify as environmentally sustainable.

Assessment of current and future European climate change impacts and risks

On the European level, the recently launched **European Climate Risk Assessment (EUCRA)**[11] by the European Environment Agency provides a comprehensive assessment of current and future climate change impacts and risks. The focus is on the environment, economy, and wider society, with a particular focus on complex climate risks and social justice implications.



Europe as the world's fastest-warming continent faces severe climate risks, for example, human-induced temperature rise. Climate events combined with environmental and social risk factors, are major challenges and act as risk multipliers, increasing risks and crises.

[11] https://www.eea.europa.eu/publications/european-climate-risk-assessment

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Effective policies and actions at European and national levels can significantly reduce climate risks. However, societal preparedness remains low due to policy implementation, which is lagging behind the increasing levels of risk (European Environment Agency, 2024). As climate risks are owned by both the EU and its Member States, cooperation for coordinated action across governance levels is needed.

Measuring environmental and health risks

In 2008, the World Health Organization (WHO) Global Commission on Social Determinants of Health called for action on the social determinants of health, aiming to "close the gap in a generation." In 2011, the Rio Political Declaration on Social Determinants of Health, which recommended interventions by governments and international organizations, was signed by 125 countries. To determine health inequalities, an initial step is to monitor relevant topics and indicators. However, this can be challenging, and research needs to identify health inequalities indicators[12]. Various indicators and topics exist across different countries and organizations, although certain commonalities persist. Evaluating health indicators is crucial to understanding health inequality research and identifying pathways for improvement (Albert-Ballestar & García-Altés, 2021).

Measuring environmental pollution is essential to assessing environmental risks related to health risks. Assessments of environmental risks and inequalities can support strategic policymaking. Reducing health inequalities requires identifying and characterizing exposure inequalities considering social factors. The World Health Organization (WHO) emphasizes this approach to help prioritize preventive actions to enhance population health.

Example: A tool to measure health risks related to environmental pollution exposure is the AirQ+ tool by the World Health Organization WHO to quantify the health effects of air pollution. The impact of air pollution on public health is quantified for policy discussions by AirQ+, the WHO's software tool for the quantification of health effects related to air pollution. The health effects attributable to specific air pollutants are assessed and changes in health effects due to future air pollution levels are predicted.

[12] These indicators can be grouped into topics. Some of the most frequently encountered topics are life expectancy, infant mortality, obesity and overweight (BMI), mortality rate, regular smokers/tobacco consumption, self-perceived health, unemployment, mental well-being, cardiovascular disease/hypertension, socioeconomic status (SES)/material deprivation (Albert-Ballestar & García-Altés, 2021).

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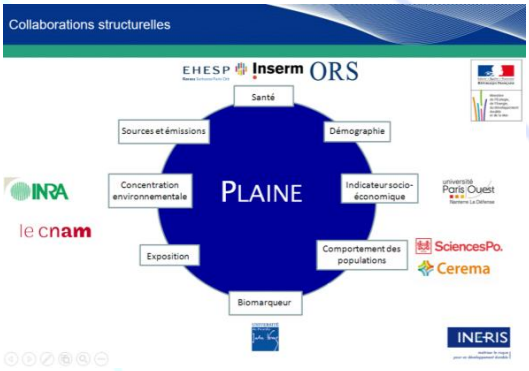

Example: Plaine platform is an action developed by the French National Institute for Industrial Environment and Risks INERIS plays a crucial role in representing geographical environmental inequalities. The expert on industrial and environmental risk management developed the PLAINE platform to address the challenge of analyzing environmental inequalities by aggregating diverse data from various sources. These data include pollutant concentrations, health information, and social practices. By integrating these dimensions of exposure to environmental pollutants, Plaine assists decision-makers in identifying and prioritizing actions to reduce environmental inequalities.

Environmental risks and social inequalities

Health inequalities are a worldwide issue in Europe, with inequalities in different regions. In the European national health systems, national health plans ensure citizens have equal access to public health services. However, the COVID-19 pandemic revealed health inequalities in Europe, which the EU addresses together with its member states (Blasco-Palau et al., 2023).

- **Social inequality** refers to differences in access to valuable resources (e.g., income, education, or cultural capital) among individuals or social groups.
- **Spatial or territorial inequalities** relate to places lacking the same services and economic opportunities as others, such as rural areas where the local population may not have equal access to digital services compared to urban areas.
- **Environmental inequalities** [13] combine the social, territorial, and environmental dimensions. Exposure to environmental risks or pollution does not automatically lead to environmental inequality. However, environmental inequalities often mainly affect disadvantaged populations and poor areas. The creators of such damages often do not bear the cost.

[13] See: https://www.encyclopedie-environnement.org/en/society/environmental-inequalities/

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In urban areas and big cities, pollution acts as a *health risk factor*. Also, former industrial zones and agricultural areas experience high exposure to specific pollutants and social disadvantages such as unemployment and poverty rates.

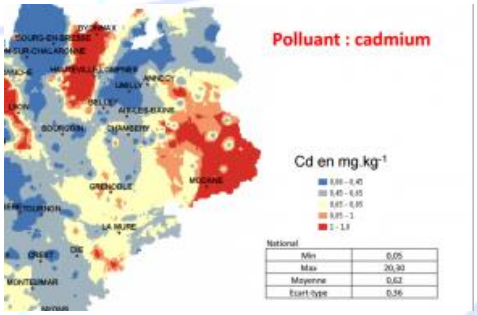
The example of the research done in France (see INERIS example below) shows, that the limited availability of data constrains the analysis of environmental risks and health. There is a *lack of epidemiological data* on the geographic distribution of diseases that are potentially induced by specific pollutants. Rather than being able to measure direct health risks, data scarcity led to the use of established or suspected risk factors for diseases. *Highly diverse pollution data* that varies significantly across different territories and types of pollutants restrict analysis in a more detailed way. Some pollutant levels are *not monitored continuously over time*. Thus, documentation often covers only basic compliance with regulatory analysis standards[14] (Fosse et al., 2022).

Do environmental and social inequalities overlap?

The analysis of linkages and potential overlaps between environmental and social inequalities (Fosse et al., 2022) shows the difficulties presented by the heterogeneity of data for an analysis of environmental inequality and the combination with epidemiological data.

INERIS

maîtriser le risque pour un développement durable



Example: The analysis by INERIS of the overlap between environmental and social inequalities looked at air, soil, and water pollution, and geo-localized information on illnesses from data in local registries. This proved difficult as illnesses often result from multiple different factors. The analysis found for instance, that poor communities often face more polluted soils and showed how environmental inequality results from a combination of exposure to pollution and social inequality in specific territorial areas. Assessing the intersection of environmental and social inequalities presents challenges due to the lack of epidemiological data on illnesses caused by specific pollutants, varying pollution data, and temporal considerations in analysing pollutant effects in urban, industrial, and agricultural areas.

[14] Such as, e.g. the presence or absence, or exceeding detection thresholds of pollution levels.

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Citizens have the right to a clean environment, and public and private organizations will continue to be confronted with claims regarding environmental and health effects on the population and resulting inequalities.

More complete, long-term data is needed to generate more valuable insights into environmental inequalities. Open innovation mechanisms can be used to address the challenges of heterogeneity, uncertainty, and lack of data.

Environmental justice refers to the actions taken by disadvantaged populations to oppose industrial or governmental decisions and practices that lead to environmental and health hazards, sometimes dramatically (INERIS, 2014). The environmental justice movement is seen as a democratic struggle with significant implications for socio-economic development. It can be combined with open innovation mechanisms to foster bottom-up understanding and initiatives to reduce environmental and social inequalities.

ACCOUNTABILITY

In a globalized world where complex challenges need to be solved, addressing questions of accountability is crucial. Accountable governance is essential to create legitimacy, foster collaboration, and enhance governance effectiveness. Accountability is complex in institutional settings with organizational overlap. Overlapping memberships of organizations can result in different legal and normative standards across multi-lateral organizations, which may interfere with each other's operational activities. Thus, accountability is often not just attributed to a single organization but must instead be attributed as a collective property of multiple institutions.

Understanding accountability in global multi-stakeholder governance settings needs to be dynamic, forward-looking, interactive, and future-oriented. It should allow joint standard-setting, the prevention of harm, and widening participation. Accountability needs a holistic approach that includes overlapping organizational standards and activities in the wider context (Eilstrup-Sangiovanni & Hofmann, 2024).

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Example: Delivering the European Green Deal highlights accountability for EU Member States regarding climate targets. According to the European Climate Law, the EU has pledged to decrease its net greenhouse gas emissions by a minimum of 55% by 2030. The goal is to make the EU the first climate-neutral continent by 2050.[15] 'Fit for 55' legislation aims for all sectors to achieve this goal and guides the EU economy towards the defined and legally binding climate targets.[16]

Firm accountability

If we start first at the firm-level, accountability involves holding companies responsible for their impact on the environment and ensuring they take proactive measures to minimize harm and promote sustainability in their operations. While this often involves adhering to business standards (typically set externally), complying with national and international regulations, and various reporting requirements, there are several less explicit ways in which environmental accountability manifests in the firm. These include:

- **Transparency** – firms can practice transparency at all levels, including disclosing impacts, practices, and decision-making to all necessary stakeholders. Managing the tension between information and communication overload is challenging, which may take practice.
- **Corporate culture and leadership** - promoting a culture of environmental responsibility from top management to employees fosters a sense of accountability throughout the organization. This includes exhibiting transparent behaviors i.e., being honest about what you are doing and how. Culture and norms play a huge role here. Firms may want to challenge these at times to promote accountability.

[15] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

[16] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal/fit-55-delivering-proposals_en

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➔ **Mobilization of goals** – Internally, top management and employees need to make efforts towards the company's sustainability goals, even in everyday practices. This might require some sensemaking work within the company for everyone to understand how their everyday actions influence the larger goals and targets. Workplace sustainability empowerment has been found to positively affect job satisfaction and commitment (Harrach, Geiger, & Schrader, 2020).

In recent controversy, employees at UN-backed Science-Based Targets initiative (SBTi) have called for their CEO to resign over controversial plans which they fear will enable greenwashing (Greenfield & Harvey, 2024). The organization certifies whether a company is on track to help limit global heating to under 1.5C, often emphasizing the importance of significant greenhouse gas emissions cuts. On 9 April 2024, the SBTi board of trustees released plans to allow carbon credits in their net zero standard by permitting companies to use them to offset emissions from their supply chains. Advocates for carbon markets argues that this provides much more incentive for companies to take responsibility of scope 3 emissions and helps to fund climate change mitigation and adaptation. Meanwhile, those against carbon markets say there is no room for offsetting anymore, pointing out that scientific studies have shown these schemes often do little to limit global heating. *This highlights the very contested reality of how we achieve transition and accountability of this, as well as the importance of transparency in decision-making.*

Cross-Organizational accountability

Good governance features organizational accountability. However, such accountability may not be easily assigned or distributed in international multi-stakeholder settings such as international organizations with overlapping functions, memberships, and authority claims. Multilateral collaborations between global sets of actors such as intergovernmental organizations (IGOs), international organizations, non-governmental organizations (NGOs), or transnational corporations are confronted with different criteria and mechanisms for accountability and overlap of organizational accountability. Accountability in global governance spaces thus focuses less on the state level but on new collaborative forms of governance. In a densely institutionalized world, accountability needs to be seen as a prospective process rather than a retrospective one focused on fixed standards and legal obligations. Thus, the focus must be on participatory, pluralistic, and deliberative forms of accountability emphasizing standards-setting and responsiveness through competition, collective deliberation, and learning (Eilstrup-Sangiovanni & Hofmann, 2024).

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Interoperability facilitation strengthens accountability between different stakeholder organizations and beneficiaries and helps promote and assign accountability in multilateral settings. For instance, the multilingual open knowledge organization system AGROVOC[17] covers all interest areas of FAO, and the multilingual thesaurus is a Linked Open Data set about agriculture. It coordinates a controlled multilingual vocabulary, facilitating cross-domain access and visibility of data open for public use. It builds bridges between datasets and facilitates homogeneous data classification, reuse, and interoperability.

Example: AGROVOC - The open multilingual knowledge organization system AGROVOC is a Linked Open Data set in the field of agriculture and has recently been enriched by expert communities. These experts curate specific topics within AGROVOC, contributing specialist knowledge and enhancing its accessibility. Through semantic technologies, their research gains visibility and becomes more accessible. Currently, AGROVOC comprises five schemes, namely Land Governance (LandVoc); Aquatic Sciences and Fisheries Abstracts (ASFA); Legislative and Policy Concepts (FAOLEX); FAO Indigenous Peoples, a sub-vocabulary with a focus on concepts related to Indigenous Peoples; and One CGIAR addressing the interoperability between food and agricultural information systems.

State accountability

States need to take climate action; they must be able to create policies for climate risk mitigation. The need to mitigate climate risks suggests the urgent need to move away from fossil fuels. However, the transition is complicated. Open innovation can help to build trust and increase public engagement by involving citizens in decision-making processes. By sharing information and involving the public in policy-making, governments can demonstrate transparency and accountability, ultimately building stronger relationships with citizens.

State environmental action can be limited thus, intergovernmental organizations can support the promotion of the interests of developing countries. For instance, the United Nations Conference on Trade and Development (UNCTAD) focuses on development through trade and international economic cooperation and promotes the interests of developing countries in world trade. Yet its

[17] https://www.fao.org/agrovoc/index.php/

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treaty-based Investor-State Dispute Settlement (ISDS)[18] regime is often seen as a barrier to climate action. It is a set of rules that allows foreign investors to sue countries for actions affecting their investments. It provides legal recourse for foreign investors impacted by state actions, but its effectiveness remains a subject of debate and reform. The ISDS allows companies invested in fossil fuels to challenge climate policies based on investment treaties (UNCTAD, 2022). Climate change measures are discussed to be carved out in ISDS to align investment treaties with environmental agreements. Past investor-state dispute settlement cases related to climate action involve measures or sectors directly relevant to environmental protection. For example, 192 cases against various State actions were initiated by investors in the fossil fuel sector, and 80 ISDS cases in the last decade were seen in the renewable energy sector.[19] Concerns continue to exist about ISDS being used to challenge climate policies, as past cases were related to environmental protection measures (Schaugg et al., 2024).

Scaling

While novel innovations are often introduced to the market by start-ups, the scaling of sustainable business may also involve a range of strategic actions undertaken by established companies that support the introduction and scaling of sustainable technologies by their suppliers or collaborators. A recent study by Bor et al. (2024) on the food packaging industry suggests that established firms can support the scaling of sustainability innovation in five different ways:

1. **Signposting:** Companies openly communicate their sustainability targets and needs, which signals to the entire industry, especially suppliers, the urgent demand for sustainable innovations.
2. **Demanding:** By adjusting purchasing specifications and choosing suppliers who meet these new sustainability criteria, companies exert direct pressure on the supply chain to innovate sustainably.
3. **Incubating:** Companies provide resources and opportunities for testing and piloting innovative packaging solutions by niche players, helping to bring these innovations to market.

[18] ISDS is a legal mechanism enabling investors to bring a claim against a host state that is a party to the treaty. Dispute settlement is otherwise a state-to-state process. See: https://www.dfat.gov.au/trade/investment/investor-state-dispute-settlement

[19] https://investmentpolicy.unctad.org/publications/1270/treaty-based-investor-state-dispute-settlement-cases-and-climate-action

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4. **Orchestrating:** Companies actively coordinate R&D efforts across the value chain to co-develop sustainable solutions.
5. **Integrating:** Some companies go as far as integrating the innovation supply chain into their operations by developing or acquiring capabilities in areas outside their core business area, often through establishing dedicated R&D centers.

These actions are indicative of a shift from the traditional role of private companies in sustainability, where they not only adapt to external sustainability pressures but also actively shape the supply chain and market conditions to favor sustainable practices. Moreover, the interactions between different socio-technical systems highlighted in the study (e.g., food production and packaging) show how pressures in one system can catalyze changes across related industries, thereby scaling up the adoption of sustainable technologies. These companies' strategic use of demand-pull innovation serves as a critical mechanism in accelerating the transition toward sustainable packaging solutions.

Scaling of sustainable business models

Multi-lateral collaboration across sectors and industries is often important as achieving sustainability goals requires alignment with other businesses, government bodies, and research institutions. By participating in or initiating open innovation platforms, companies engage with various stakeholders to leverage external knowledge, technologies, and innovations that can be adapted to their sustainability goals.

Digital technologies allow faster scaling of business models. For instance, the **DLT Climate Hackathon** aims to utilize HBAR to enhance climate accountability. Participants need to develop digital approaches that enhance climate data measurement, reporting, and verification. Such initiatives can promote the effectiveness of climate project methodologies, ESG reporting, and sustainable finance. By enabling solvers, it also contributes to the scaling of their initiative.

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Example: With its new brand 'phiyond', the company Adelphi supports other firms in their transformation towards sustainable business. Adelphi shares its previous insights from research and consulting and contributes to the scaling of sustainable solutions. In collaboration with companies Adelphi creates ambitious climate strategies that involve initiating decarbonization, establishing science-based reduction targets, aligning with initiatives such as the Science Based Targets Initiative (SBTi), and developing transition plans toward decarbonization. The 'phiyond' project advances sustainable business, as Adelphi actively assists other companies in their journey toward sustainable business practices. By sharing valuable insights gained from research and consulting, Adelphi contributes to the broader adoption of sustainable solutions. Crafting strategic approaches for other firms to play a meaningful role in climate protection and adaptation leads to a positive impact, ultimately scaling sustainable business models.

Multi-stakeholder alliances promote SDGs through the Digital Public Goods status

Multi-stakeholder initiatives such as the Digital Public Goods Alliance (DPGA) facilitate the discovery, development, and use of Digital Public Goods (DPGs) and aim to accelerate the achievement of the Sustainable Development Goals (SDGs). International organizations such as the Food and Agriculture Organization of the United Nations (FAO) are committed to developing sustainable agrifood systems using digital solutions to promote and achieve the SDGs, using a DPG-first approach (see 'State of the Digital Public Goods Ecosystem 2023'[20]).

AGROVOC was awarded the Digital Public Good status[21] , which supports monitoring progress on the SDGs by covering all domains relevant to them. It highlights the relevance of the SDGs and recognizes that AGROVOC plays a crucial role in indexing data and resources across repositories and institutions. AGROVOC includes a dedicated SDG concept and individual sub-concepts for each SDG, complete with official definitions. Its protocols and formats are accessible and comply with open standards. The Digital Public Good status recognizes adherence to openness and standard compliance since the DPG status is a valuable digital resource in advancing sustainable agrifood systems and contributing to the SDGs.

[20] https://digitalpublicgoods.net/DPG-Ecosystem-2023.pdf
[21] https://www.fao.org/agrovoc/news/agrovoc-now-certified-digital-public-good

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Example: As the world's largest humanitarian organization, the United Nations World Food Programme (WFP), saves lives during emergencies and uses food assistance to create a path toward peace, stability, and prosperity for individuals recovering from conflict, disasters, and climate change impacts. The WFP Innovation Accelerator tests novel solutions and expands promising innovations to combat hunger, leveraging its legacy of innovation. The WFP Innovation Accelerator has received recognition for its efforts. Its Scale-Up Enablement Programme facilitates the rapid expansion of high-impact innovations by providing customized strategic planning, fundraising, communication, knowledge management, and mentorship support. Through this program, the organization aims to disrupt hunger by enhancing livelihoods across multiple countries.

WFP World Food Programme

INNOVATION ACCELERATOR

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BEST PRACTICE AND CONCLUSION

Increasingly collaborative structures illustrate the cooperative efforts needed to address grand challenges like climate change and environmental sustainability.

Most OI mechanisms involved in cross-organizational collaborations to tackle the SDG framework involve sharing ideas, data and knowledge, developing and adopting technologies collaboratively, and orchestrating multilateral interdependencies (Zobel et al., 2023). Best practices to address grand challenges through open innovation have evolved to include:

1. Collaborative networks and ecosystems:

Establishing and nurturing collaborative networks and ecosystems, such as public-private partnerships and ecosystem structures, can facilitate knowledge sharing, resource pooling, and collective problem-solving. These inter-organizational arrangements are pivotal in accelerating the development and adoption of sustainable solutions by leveraging the strengths of multiple stakeholders.

2. Digital technologies

Digital technologies boost sustainable practices by optimizing resource use, minimizing waste, and enhancing transparency in supply chains, and can help measure operational impacts.

→ Open Source and Open Data Movements advocate for open standards, software, hardware, and data practices. These initiatives can democratize technology access, spur sustainable innovation practices.

3. Community and crowdsourcing

Utilizing crowdsourcing and community engagement strategies allows organizations to tap into the collective intelligence of a broader audience. This approach not only enriches the innovation process with diverse perspectives but also promotes inclusivity and community involvement in addressing sustainability challenges.

Conclusion

The implementation of open innovation (OI) for sustainability has proven to be a multifaceted strategy that requires a robust framework to ensure effectiveness. Organizations can enhance their innovative capabilities and sustainability outcomes by adopting best practices such as developing collaborative networks, integrating advanced digital technologies, and promoting open source and data movements. Moreover, the strategic use of service design in managing these ecosystems and actively engaging communities through crowdsourcing can foster a more inclusive and comprehensive approach to sustainability. These practices collectively contribute to achieving the Sustainable Development Goals (SDGs), addressing critical global challenges like climate change, and fostering a sustainable future.

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To ensure the effectiveness of open innovation in sustainability, organizations must prioritize establishing clear metrics and KPIs aligned with global standards like the SDGs, incorporating sustainable finance tools such as the EU Taxonomy Regulation to enhance market transparency, and implementing robust governance structures for managing collaborative networks. Additionally, maintaining data quality and integrity, ensuring accountability through regular reporting and independent audits, and building scalable and adaptive measurement systems are critical. These practices not only help track and report on sustainability progress but also ensure that innovations are genuinely contributing to environmental and social objectives, thereby maintaining transparency and building trust among all stakeholders.

Through these multi-stakeholder engagements and the strategic use of technology, the future of sustainable open innovation looks promising, highlighting that tackling the climate crisis necessitates OI in the private sector and active engagement from the public sector (Zobel et al. 2023). The continued evolution of these practices and the scaling of their impact are essential for meeting the urgent needs of our time, ensuring environmental stewardship, social equity, and economic viability for future generations.

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