OECD publishing

UNLOCKING CO-CREATION FOR GREEN INNOVATION

AN EXPLORATION OF THE DIVERSE CONTRIBUTIONS OF UNIVERSITIES

OECD SCIENCE, TECHNOLOGY AND INDUSTRY
POLICY PAPERS
December 2023 **No. 163**

OECD
BETTER POLICIES FOR BETTER LIVES

OECD Science, Technology and Industry Policy Papers

This document was approved and declassified by written procedure by the Committee for Scientific and Technological Policy (CSTP) on 28th November 2023 and prepared for publication by the OECD Secretariat.

Note to Delegations:

This document is also available on O.N.E under the reference code:

DSTI/STP/TIP(2023)12/FINAL

Unlocking co-creation for green innovation: An exploration of the diverse contributions of universities

Muthu De Silva, Caroline Paunov, Sandra Planes-Satorra and Patricia Peñalosa

In the context of the green transition, universities have much to offer in joint green innovation projects with business, government and citizens. As hubs of diverse expertise, universities are uniquely placed to build interdisciplinary teams and bridge gaps between society and industry. Their regional ties also enable them to engage with the local ecosystem. This paper draws from ten international case studies of university partnerships with industry and society in green mobility, green energy and green products, services and processes. The comparative evidence gathered from interviews with representatives from these initiatives examines universities' practices for green co-creation. Additionally, the paper outlines policy recommendations crucial to supporting these initiatives, essential for the global success of sustainable development efforts.

Keywords: Industry-science linkages, co-creation, universities, civil society, STI policy, innovation policy, innovation, green transition

JEL codes: O30, O36, O38

Acknowledgements

This report and associated case studies were produced by Muthu De Silva (Birkbeck, University of London) and Caroline Paunov, Sandra Planes-Satorra and Patricia Peñalosa from the OECD Directorate for Science, Technology and Innovation. The analysis was conducted as part of the 2021-22 project of the OECD Working Party on Innovation and Technology Policy on "Supporting co-creation for transitions: Exploring new tools and approaches". The analysis also contribute to the project "Improving the system of knowledge exchange and collaboration between universities and society in Italy" ("ITA.CON" project), carried out by the OECD to support the Italian Ministry of Universities and Research. The latter benefited from the financial support of the EU Technical Support Instrument (TSI) programme.

The authors would like to express their sincere gratitude to the following experts who participated in interviews conducted and/or shared secondary information to develop the case studies upon which this paper builds: Hilda Tellioglu and Magdalena Bürbaumer (Aspern.mobil.LAB and TU Wien, Austria), Mathias Mitteregger and Kathrin Raunig (AustriaTech), Walter Wasner (Austrian Federal Ministry for Climate Protection), Hugo Pereira and Tiago Toregão (GreenCoLab, Portugal), Paul Dickson and Lesley Lambert (Liverpool John Moores University, United Kingdom), Matthew Fulton (University of Liverpool, United Kingdom), Mauricio Camargo and Laurent Dupont (Université de Lorraine, France), Aila Maijanen (CLIC Innovation Ltd, Finland), Chunlin Xu (Åbo Akademi University, Finland), Tuomas Lehtinen (Business Finland), Stig P. Christensen, Christopher Donald Sorensen and Linda Fejerskov (GreenLab, Denmark), Martin Bourbonnais (Jonquière College, Canada), Igor Sauperl and Nicole Wermuth (LEC GmbH, Austria), Gerald Olde Monnikhof (ProRail, the Netherlands), Sander Mertens (The Hague University of Applied Science, the Netherlands), Robert A. Bezemer (TNO, the Netherlands), Dennis Whyte and Julianna Mullen (MIT Plasma Science and Fusion Center, USA), Tom Melville, Robert Stoner, Randall Field and Robert Armstrong (MIT Energy Initiative, USA), Bob Mumgaard (Commonwealth Fusion Systems).

The authors also extend their gratitude to all speakers and participants of two related workshops organised by the OECD Working Party on Innovation and Technology Policy (TIP), including "Enhancing universities' impact on sustainability: lessons from international best practices" (17 November 2022) and "What makes co-creation work for transitions?" (24-26 May 2023). We are also thankful to those that participated in the launch of this report, which took place during the TIP workshop "Aiming for the stars: Advancing key technology moonshots for green futures" on 5 December 2023. Comments received from case study representatives and from TIP and CSTP delegates and experts are gratefully acknowledged.

The authors would also like to thank Gry Osnes and Eliana Diodati for their excellent research assistance, Fernanda Zamora for designing the infographics and other communication materials to disseminate this report, Jovana Poznan for her editorial support, and Sylvain Fraccola for his support throughout the publication process.

Table of contents

Executive summary

Universities' roles in co-creation for the green transition

Universities have much to offer in joint green innovation projects with industry, research institutions, public authorities, and citizens.

Ten case studies of innovation partnerships from diverse OECD countries showcase unique roles universities play in advancing joint innovation in the domains of green mobility, green energy and the greening of products and processes.

Universities' roles in co-creation include:

- Providing multidisciplinary knowledge and expertise;
- Building the skills needed by industry for the development and deployment of green innovations, for instance through university-industry joint training programmes;
- Offering access to key infrastructures (e.g. laboratories, specialised equipment) and networks;
- Acting as trusted mediators between citizens, government and industry; and
- Anchoring innovation activities in regional ecosystems by leveraging close ties with local industries and communities

Four good practices for effective "green" co-creation practices

The ten case studies illustrate four best practices for "green" co-creation:

1. The green transition demands different practices compared to those that have accelerated climate change, calling for radical innovations and different ways of operating. This requires setting up mechanisms to quickly identify evolving industry needs and swiftly adjust to changing demands and unexpected developments.
2. Providing for public funding is necessary where private incentives for green innovation are weaker than what would be socially optimal. This includes addressing where pollution generated by production processes is not costed to firms at the right level. However, private funding matters where there is a business case. It is also important to ensure the long-term commitment of industry and the scalability of jointly developed solutions.
3. Collaboration initiatives can only succeed if regulatory constraints for "breakthrough" green innovation are simultaneously addressed. An effective approach consists in collaborating with regulatory agencies where innovative product are developed. Another involves setting up regulatory sandboxes – a limited form of regulatory waiver to test innovative products in a delimited space.
4. Involving citizens in co-creation activities matters critically to green transitions. Involvement enables tapping into new sources of (local) knowledge and ensuring that green solutions respond to citizens' needs and are more widely adopted. Communication campaigns also raise awareness about the role of local STI actors in advancing the green transition and stimulate behavioural changes to support it.

Policy considerations

For policy to best support the co-creation of green innovations, the following considerations are important:

- Considering differences across universities: Not all universities and their research groups should engage in the same ways in green co-creation efforts. The extent and nature of effective contributions differs across universities depending on key characteristics including location, size, nature and quality of expertise, focus on basic or applied research and relations with the local community.
- Ensuring researchers and universities have the right incentives: The well-known best practice principles for co-creation initiatives apply also to joint green innovation projects. This includes rewarding researchers for their engagement when it comes to promotions, internal resource allocation processes and awards. On the university side, institutional performance-based funding mechanisms can be used to stimulate and reward universities undertaking collaborative research contributing to the green transition.
- University neutrality is an asset for deliberating on directions of technological change: Ensuring that the green transition is fair and leads to shared prosperity and inclusive outcomes requires setting technological directions in ways that best serve society. Achieving neutral contributions based on expertise requires stable public funding to ensure academic pursuits remain unbiased and free from external influences.
- Balancing research freedom and targeted funding goals. A major question for policy emerges regarding the nature of research funding, from providing more targeted funding for green to supporting unrestricted research freedom. While advancing research and innovation to respond to the climate emergency demands increased directionality of STI policies, research freedom and investments in basic research across science fields should also be preserved.
- Integrating university co-creation support into the green STI policy mix by coordinating the use of diverse instruments, including as part of mission-oriented programmes. Such integration involves an expanded role for government beyond the provision of public funding, including that of lead user of green innovation solutions, network builder, or legitimiser of collaboration efforts.

Good practice when designing programmes to promote co-creation for the green transition are the following:

- Engaging prospective partners or beneficiaries in the design of co-creation programmes to ensure initiatives are aligned with local needs and leverage existing STI assets (e.g. networks and capabilities).
- Supporting more diverse multi-stakeholder, interdisciplinary and cross-sectoral collaboration to facilitate the development and diffusion of breakthrough innovations.
- Building new metrics and approaches to monitor and evaluate the impacts of co-creation programmes for green innovation.

1 Introduction

In the pursuit of advancing the green transition and achieving the goals of the 2015 Paris Climate Agreement, universities have much to contribute through joint green innovation projects with industry, public authorities, and citizens. As hubs of diverse knowledge, universities are uniquely placed to build interdisciplinary teams. They are often entrusted by citizens, often serving as bridges between society and industry, and their regional ties enable them to engage with local ecosystems – a useful asset to develop tailored green solutions. However, the ways in which universities can best promote STI for green transitions and the necessary STI policy actions to facilitate them have been insufficiently analysed.

This paper explores how universities can enhance green innovation partnerships with industry and civil society and proposes policy options to support them. It draws from ten original case studies showcasing the various roles universities play in advancing joint innovation for green mobility, green energy, as well as green products, services and processes (Table 1.1). The case studies focus specifically on regional collaborations and innovative partnership approaches, such as living labs, which are localised areas for experimentation and user-centred collaborative innovation involving citizens.

The methodology used in this analysis consisted in developing ten case studies of green co-creation initiatives involving universities and other partners and exchanging on emerging policy themes with representatives from those initiatives and the wider policy community. To develop the case studies, in-depth interviews with initiative leaders were conducted based on a common template to enable comparisons. Synthesised notes describing each case in detail are presented in the companion document (OECD, 2023[1]). Policy themes were then discussed and refined at two international workshops on "Enhancing universities' impact on sustainability: lessons from international best practices" (virtual, 17 November 2022) and "What makes co-creation work for transitions?" (Paris, 24-26 May 2023).

This report builds on work on knowledge transfer and co-creation activities conducted by the OECD Working Party on Innovation and Technology Policy (TIP), which explored good practices for innovation partnerships (Kreiling and Paunov, 2021[2]), including a policy analysis of 30 case studies on COVID-19-related co-creation initiatives (de Silva et al., 2022[3]; de Silva et al., 2022[4]).

The remainder of the paper is structured as follows. Section 2 describes key features of the cases. Section 3 discusses good practices from these initiatives to specifically support green innovation. Section 4 concludes by discussing additional considerations for STI policy makers.

Table 1.1. Overview of 10 selected case studies

No.	Initiative name	Country	Short description
Green mobility			
1	**aspern.mobil LAB**	Austria	Initiated by Vienna University of Technology, aspern.mobil LAB offers a space for universities, companies, citizens, and the government to participate in joint innovation for a green and inclusive local mobility system in Vienna.
2	**HyMethShip**	International	This international consortium of 13 partners involving universities, research centres and industry partners aimed at jointly developing a hydrogen-fueled combustion solution to reduce emissions of ships.
Green energy			
3	**Centre TERRE**	Canada	Created by the Jonquière College and his automation Center (CPA), the Centre TERRE co-creates renewables and automated energy solutions jointly with SMEs, universities and other partners to respond to the needs of businesses and citizens located in remote areas that are not served by the national electricity grid.
4	**GreenLab**	Denmark	Green industrial park and a national research and development facility aimed at accelerating innovation in the field of green energy generation, storage and sharing. It provides testing the ground for green energy solutions co-created by industry, academia and government.
5	**NEWRAIL project**	Netherlands	Initiated by ProRail, this co-creation project involves TNO, the Hague University of Applied Sciences and local authorities to develop a new solution to install solar panels on existing noise barriers along railway lines.
6	**MIT Plasma Science and Fusion Center (PSFC) and Commonwealth Fusion Systems (CFS) Fusion Technology project***	United States	This partnership between the MIT Plasma Science and Fusion Center (PSFC) and the spin-out Commonwealth Fusion Systems (CFS) aims at developing advanced superconducting magnets for fusion technology devices aimed at generating carbon-free electricity.
Green products, services and processes			
7	**SUSBINCO**	Finland	Co-creation project involving 18 partners (incl. businesses and public research institutions) to develop innovations to substitute fossil-based binders and coatings (i.e. materials used in various industries and applications to provide adhesion, protection and desired properties to surfaces) with bio-based solutions to use in packaging, paints, adhesives, sealants, and abrasives.
8	**Lorraine Smart Cities Living Lab**	France	Located in the Université de Lorraine, the living lab collaborates with local authorities/municipalities, companies, citizens and incubators to co-create user-centered solutions related to the green transition. For example, the lab has co-created new objects based on plastic waste.
9	**GreenCoLab**	Portugal	Initiated by the Centre of Marine Sciences and other five founding partners with the objective of bringing together researchers and businesses to drive innovation in the field of algae biotechnology (i.e. the application of biotechnological techniques to use algae for the production of valuable products or for environmental purposes).
10	**Low Carbon Eco-Innovatory (LCEI)**	United Kingdom	Initiated by Liverpool John Moores University, University of Liverpool and Lancaster University to co-create jointly with regional SMEs for the development of a wide variety of goods, processes and services that are environmentally-friendly (e.g. alternative packaging from naturally degradable materials such as starch, vegetable oil and seaweed).

Notes: Case study details can be found in document (OECD, 2023[1]).
* For brevity, this initiative is referred to as "MIT-led fusion technology initiative" throughout the document.

2 University collaborations in green innovation

This section describes the ten cases of university green innovation partnerships, also referred to here as co-creation initiatives.

2.1. What are the initiatives' goals?

The initiatives focus on advancing green innovation through co-creation in three different fields: green mobility, green energy and green products, services and processes (see an overview in Table 1.1).

In the field of green mobility, two selected initiatives focus respectively on urban mobility and maritime shipping:

- Austria's aspern.mobil LAB offers a space for universities, companies, citizens and the government to develop sustainable urban mobility solutions (e.g. shared mobility as a service, first/last mile logistics) and investigate their associated spatial, economic, ecological and social added value. With a testing ground in the Seestadt district of Vienna, the initiative aims to create a blueprint for urban mobility transformation that can be applied in other locations (Case 1).
- The international Hydrogen-Methanol Ship Propulsion System project (HyMethShip) focuses on developing technologies for green hydrogen-fuelled combustion solutions to reduce ship emissions (Case 2).

In the field of green energy, four cases focus on carbon-free energy generation, storage and diffusion:

- The MIT Plasma Science and Fusion Centre (PSFC) and the Commonwealth Fusion Systems (CFS) in the United States work on early stages of technology development in the field of fusion technology to generate carbon-free energy (Case 6).
- In Denmark, GreenLab is a green industrial park and R&D facility, focusing on accelerating innovation in green energy generation, storage, and sharing, as well as facilitating the commercialisation of new green energy solutions. Products of the GreenLab include systems for thermal storage in rocks, to share surplus energy between companies in the industrial park, as well as hydrogen, ammonia, methanol, proteins, and methane for use in transport, agriculture, materials, food and energy industries (Case 4).
- In Canada, the Centre TERRE works on facilitating the deployment of green energy solutions in remote areas without access to the national electricity grid (Case 3).
- The NEWRAIL project in the Netherlands deploys innovative approaches to installing solar panels on existing noise barriers along railway lines. The purpose is to harness solar energy while minimising any disruptions or inconveniences associated with these installations (Case 5).

The remaining four cases focus on the development of a diversity of green products, services, and processes:

- In Finland, SUSBINCO conducts research on bio-based solutions to replace fossil-based binders and coatings used in a wide range of industries and applications, including packaging, paints, adhesives, sealants, and abrasives (Case 7).
- The GreenCoLab in Portugal focuses on promoting industry-research collaborations that utilise biotechnological techniques to harness the potential of algae feedstocks for the production of goods such as food, textiles, nutraceuticals, cosmeceuticals, and agricultural products (e.g. biopesticides), and addressing environmental challenges related to water treatment, nutrient recycling and CO_2 mitigation (Case 9).
- In the United Kingdom, the Low Carbon Eco-Innovatory supports collaborations between universities and regional SMEs in developing a wide variety of environmentally-friendly goods, processes and services, including alternative packaging from naturally degradable materials such as starch, vegetable oil and seaweed (Case 10).
- Finally, the Lorraine Smart Cities Living Lab in France facilitates co-creation between government, companies, citizens and incubators to create user driven solutions related to the green transition. The lab also gives citizens access to equipment such as laser cutting, 3D printers and digital milling machines. Using these tools and with the support of researchers, citizens have for instance created new objects made of plastic waste (Case 8).
- The 10 initiatives can be grouped according to whether they support: (1) early-stage research and technology development, or (2) applied green innovation projects that respond to businesses challenges or challenges directly faced by citizens (Table 2.1).

Table 2.1. Classification of selected co-creation initiatives

No.	Initiative name	Early-stage research and technology development	Applied green innovation projects	
			Responding to business challenges	Responding to challenges faced by citizens
1	aspern.mobil LAB, Austria			X
2	HyMethShip, International		X	
3	Centre TERRE, Canada		X	X
4	GreenLab, Denmark	X	X	
5	NEWRAIL project, The Netherlands		X	
6	MIT-led fusion technology initiative, United States	X		
7	SUSBINCO, Finland	X	X	
8	Lorraine Smart Cities Living Lab, France		X	X
9	GreenCoLab, Portugal	X	X	
10	Low Carbon Eco-Innovatory, United Kingdom		X	

Several initiatives were set up as part of a specific policy programme. Examples include the GreenCoLab, created following the launch in 2017 of Portugal's collaborative laboratories (CoLABs) initiative by the Ministry of Science, aimed at creating interface institutions between academia and industry in sectors of strategic importance; and the aspern.mobil LAB, created under the umbrella of the Austrian Mobility Labs programme of the Austrian Ministry of Climate Action.

Others were created as bottom-up initiatives. Public support (e.g. funding from regional, national or EU programmes) has been instrumental in enabling them, but their specific set up and characteristics were not precisely shaped by specific policy programmes. Examples include the Lorraine Smart Cities Living Lab in France, the Centre TERRE in Canada and the Low Carbon Eco-Innovatory in the United Kingdom, which were initiated by academics and progressively expanded their activities and sources of funding. Another example is GreenLab in Denmark, founded by a public-private investment group, as a non-profit company with own financing.

Another differentiating aspect relates to the sources of funding, discussed in more depth in section 3.1. Most initiatives rely on government funding and involve industry co-funding. Sources of funding also tend to evolve over time. For example, two of the initiatives are currently mainly privately funded (GreenLab in Denmark and the MIT-led fusion technology initiative in the United States), but critically build on initial public investments.

2.2. Who engages in the initiatives?

Universities, public research institutions, business, and citizens

Engagement of universities, government, business, and citizens differs across the initiatives and their projects (Table 2.2). Universities and businesses (incl. large firms and/or SMEs) are engaged in all initiatives, and public research organisations are involved in seven of them. Three initiatives also involve business associations.

Table 2.2. Key partners involved in the 10 selected co-creation initiatives

No.	Initiative name	University	Public research org.	Private Sector			Government / public authority (excl. funding roles)	Citizens as partners	Other
				Large firm	SME	Business association			
1	aspern.mobil LAB, Austria	X		X			X	X	
2	HyMethShip, International	X	X	X	X	X			Regulatory body
3	Centre TERRE, Canada	X	X		X	X		X	Colleges
4	GreenLab, Denmark	X	X	X	X		X		Regulatory body, national energy provider
5	NEWRAIL project, The Netherlands	X	X				X	X (consultation)	Local energy cooperative
6	MIT-led fusion technology initiative, United States	X		X	X				
7	SUSBINCO, Finland	X	X	X	X				Intermediary
8	Lorraine Smart Cities Living Lab, France	X	X	X	X		X	X	Incubator
9	GreenCoLab, Portugal	X	X	X	X		X		
10	Low Carbon Eco-Innovatory, United Kingdom	X			X	X	X		

Note: When involvement of citizens is limited to participation in awareness raising or communication activities, citizens are not considered partners of co-creation initiatives.

Citizens are directly involved as co-creation partners in activities of three of those initiatives (aspern.mobil LAB, Lorraine Smart Cities Living Lab and Centre TERRE). In the case of NEWRAIL in the Netherlands, consultation with local residents is an imperative for the local deployment of new solutions developed by the project. Most of the other initiatives also connect with citizens through communication and awareness raising activities. Approaches used to engage citizens are discussed in section 3.2.

Some of the co-creation projects are led by universities (e.g. aspern.mobil LAB in Austria, Centre TERRE in Canada, and Low Carbon Eco-Innovatory in the United Kingdom), while others are led by industry (e.g. GreenLab in Denmark) or other actors such as public authorities (e.g. NEWRAIL in the Netherlands).

The role of government and public authorities

Governments and public authorities at different levels, from national to local, also engage in several of those initiatives, with roles that go beyond that of funding providers. Building on the classification of Borrás and Edler (2020[5]), these include the roles of:

- initiator and collaborator, when they identify opportunities early-on and participate in co-steering developments in order to better meet the requirements in continuously changing environments (e.g. the Skive Municipality in Denmark is at the origins of the vision of the GreenLab industrial park, which was later supported by private funding);
- network builder, when they help connect different partners (e.g. the Austrian Ministry of Climate Action connected the research and industry actors in Austria's mobility sector during the process of creation of the Austrian Mobility Labs);
- lead-user, when they promote innovation by acting as lead users of specific solutions to public needs (e.g. ProRail – the Dutch state-owned rail infrastructure company – initiated, co-designed and is expected to be the lead user of the new solutions developed as part of the NEWRAIL project);
- facilitator, for instance when adjusting regulations to support innovation (e.g. the Danish Energy Agency created a regulatory sandbox to support experimentation in the GreenLab industrial park, as described in section 3.1 below).

The role of networks and intermediaries

The projects often built on pre-existing networks. Partners had in many cases already developed trust and a good understanding of each other's strengths (and possibly weaknesses), facilitating the task of quickly creating new teams and setting up new projects. Examples from the cases include the following:

- The GreenCoLab in Portugal was initiated by a research group within the Centre of Marine Sciences that had long-standing relationships of working with different companies of the algae sector in the context of European and national research projects. This facilitated the agreement and rapid scaling-up of activities, and reduced risks of competing interests among them.
- In the case of the international HyMethShip project, the Large Engines Competence Centre (LEC) in Austria, which was the project initiator and had significant experience coordinating large-scale projects, used its existing networks within the industrial and research community to identify potential partners.

Intermediary organisations (including technology transfer offices embedded within universities and public research organisations, and a wide range of independent intermediation service providers) play critical roles in connecting partners when these have no previous linkages. For example:

- The Low Carbon Eco-Innovatory (LCEI) in the United Kingdom has engaged in co-creation activities with SMEs who are referred to them by a range of trusted intermediaries that offer business support in the Liverpool City Region. The collaboration has facilitated the set-up of projects with diverse committed SMEs. The LCEI team also provides partner SMEs with the services of experienced industry liaison officers to manage research-industry collaborations.
- In Finland, the coordinating organisation of the SUSBINCO project, CLIC Innovation Ltd, is an intermediary – which defines itself as an "open innovation cluster" – involved in ecosystem building in the field of forest-based circular bioeconomy, energy systems and circular economy. Based on a public-private-partnership model, they are well placed to bring together complementary partners for co-creation projects developed under SUSBINCO to address specific challenges faced by industry.
- The GreenLab in Denmark also functions as an intermediary. It provides companies, public entities, researchers, and utility providers that aim to develop a new technology or business idea with access to expertise, physical facilities, an ecosystem and co-investment opportunities. In this way, GreenLab contributes to the development of a green cluster in the municipality of Skive in Denmark.

2.3. Universities' distinctive contributions

The unique roles played by universities in co-creation projects aimed at addressing green-transition related challenges include the following:

First, providing diverse disciplinary expertise and knowledge needed to address green transition challenges. Technology-based solutions to the complex challenges posed by the green transition critically rely on research and innovation capacities at the frontier of knowledge. They often also emerge from new combinations of diverse knowledge and the collaboration of experts from various fields. To the extent that cross-disciplinarity is nurtured, universities, with their different faculties and departments spanning social sciences to STEM disciplines, can be a highly valuable partner for businesses seeking to tap into the potential of multidisciplinary perspectives to develop innovative solutions (OECD, 2020[6]). Examples from the cases include the following:

- MIT-led fusion energy co-creation initiative, United States: Fusion energy development requires the collaboration of researchers in multiple disciplines that are present in the Massachusetts Institute of Technology (MIT), including plasma physics, material science, electrical engineering, magnetism, manufacturing and mechanical engineering, as well as non-STEM fields such as finance, safety, licensing and market analysis.
- GreenLab, Denmark: Projects involve researchers from the four main technical universities in Denmark with expertise in the fields of thermal heat, water systems, electrolysis, power systems and information technology.
- Centre TERRE, Canada: Projects conducted by the Centre benefit from expertise of researchers from the Jonquière College and collaborating universities in the fields of engineering, renewable energy, sustainable development and social sciences.

Second, building skills needed by industry for green innovation. By working closely with industry on green transition challenges, universities can develop joint training programmes to provide skills most needed by industry. Such programmes improve the employability of new graduates in sectors "of the future" and allow for addressing skills gaps in the labour market that could slow down the adoption of new technologies. Examples from the cases include the following:

- GreenCoLab, Portugal: It collaborates with universities to offer MSc, PhD and postdoc opportunities that involve three supervisors: from the university, the GreenCoLab and the company.
- Low Carbon Eco-Innovatory, United Kingdom: It offers opportunities for industry-led PhDs and jointly supervised master projects and internships.

Third, providing key research infrastructures and networks. Universities typically host state-of-the-art labs, specialised equipment and other research tools (e.g. supercomputers) that are critical to advance in cutting-edge research areas but often expensive to set up and maintain. They also benefit from the concentration of experts (academics, researchers) in multiple disciplinary fields, who are in turn part of formal and informal networks at the regional, national and often international levels. For businesses, engaging in co-creation projects with universities is a cost-effective way of tapping into such resources. Examples from the cases include the following:

- aspern.mobil LAB, Austria: Companies engaging in the initiative value having access to the Vienna University of Technology's infrastructure, data and networks. For instance, the initiative allows them to test their mobility solutions with local communities in Vienna and other cities, leveraging the universities' connections with similar labs in other countries.
- GreenCoLab, Portugal: Partners benefit from access to infrastructure and research capabilities offered by the University of Algarve, where the CoLAB is based. GreenCoLab's capabilities include algae experimental testing from laboratory to industrial scale, biochemical analysis and molecular biology services for algae, biorefinery of algae biomass into ingredients, prototyping of algae-based products and data analysis (i.e. modelling, bioinformatics, life cycle analysis and techno-economic analysis).
- MIT-led fusion technology initiative, United States: It enables partners to gain access to advanced research facilities, experimental equipment, and cutting-edge technology to accelerate developments of high-temperature superconducting magnets for fusion devices.

Fourth, building trust and acting as mediators between citizens, government and industry. In a context of spread of mis- and disinformation, polarisation of political debates (also in relation to the climate change emergency) and citizens' rising concerns about business use of their personal data, such trusted mediators become ever more important. Universities are also geared towards activities with significant social impact but limited scope for profit generation, which would therefore not be addressed by market players. Universities having access to a range of funding sources, they are well placed to support such projects, contributing to make green transitions more inclusive. Examples from the cases include the following:

- aspern.mobil LAB, Austria: The involvement of the Vienna University of Technology served to establish trust and engage citizens in its activities, which is critical to obtain first-hand insights about citizen mobility patterns, needs and concerns.
- NEWRAIL, the Netherlands: Universities played a key role in approaching citizens through a range of meetings and surveys that allowed gathering valuable insights about the views of the local community regarding the installation of solar panels on noise barriers, which greatly facilitated negotiations with them.
- Centre TERRE, Canada: It provides technical and R&D support combine with specialized training for the development of efficiency, automated process, and green energy solutions in locations that are not served by the national electricity grid.

Fifth, anchoring activities in regional ecosystems. Universities are often closely tied to their regional economies and communities. This regional presence allows them to be more aware of the needs and challenges faced by those communities and develop solutions that are tailored to those needs. They can

also become poles of attraction and retention of talent in the region. Examples from the cases include the following:

- Low Carbon Eco-Innovatory, United Kingdom: Led by Liverpool John Moores University (LJMU) in collaboration with University of Liverpool and Lancaster University, LCEI engages with local SMEs to co-develop low carbon products, process and services and help create a low carbon economy in the Liverpool City region. The universities work closely with a range of regional business support intermediaries (e.g. chambers of commerce) to identify best suited regional business partners with potential for successful collaborations.
- CoLABs, Portugal: They focus on sectors of strategic importance for regional economies, such as agri-food, urban sustainability, ocean, tourism, health and forestry, with high potential for generating positive spill-over effects in terms of regional economic growth and job creation in sectors “of the future”.

3 Specificities of green co-creation

This section discusses specific co-creation practices that support green innovation, involving industry and engaging citizens in the process.

There are many other practices relevant to all co-creation initiatives that similarly matter, such as setting up partnerships, managing differences in incentives, operating in multidisciplinary teams, or managing the intellectual property resulting from co-creation. These have been extensively discussed in previous TIP work in this area (Kreiling and Paunov, 2021[2]; de Silva et al., 2022[4]). The following section extends this work by discussing specific co-creation practices for green innovation.

3.1. Enabling conditions

Identifying emerging industry needs

The green transition demands different practices from those that have accelerated climate change, requiring consequently innovations that are radical and different ways of operating. Identifying the specific industry needs and adjusting to new demands and unexpected developments, including the following:

- The SUSBINCO initiative in Finland focuses on co-creation projects that align with the Strategic Research and Innovation Agenda (SRIA) for forest-based circular bioeconomy developed in 2020 by a wide range of stakeholders representing business and research. The selection of projects starts by industry stakeholders raising specific challenges that align with the SRIA (CLIC Innovation, 2020[7]). Later, in pitching events, university researchers propose projects to tackle challenges. Businesses then select and collaborate on chosen projects, co-funding and working with the researchers.
- The GreenLab in Denmark has university and industry partners jointly develop project proposals. These undergo swift evaluation by a dedicated panel of experts. Approved projects are then given resources and support to develop their project for commercialisation further for initially a one-year period with the possibility of further funded, if needed.

Public funding

The support for university collaborations for the green transition requires public and public funding. Public funding is the dominant funding source of the 10 case studies, which also include different levels of industry co-funding (Table 3.1).

Table 3.1. Who is the main funder of the initiative?

No.	Initiative name	**Mainly public funding** (with industry co-funding)	**Mainly private funding**	Explanation
1	aspern.mobil LAB, Austria	X		50% funding by the Austrian Ministry of Climate Action (BMK), 35% co-financing by TU Wien, 10% co-financing by the urban development joint-venture Wien 3420 AG, 5% co-financed by other partners.
2	HyMethShip, International	X		EU Horizon 2020 funding with 30% co-funding from industry partners.
3	Centre TERRE, Canada	X		Basic grant from the National Natural Science and Engineering Research Council in Canada to cover daily operations for 5 years. The Centre has also raised more than 20 different types of funding for projects.
4	GreenLab, Denmark		X	Initially GreenLab was initially funded by equity financing from a local municipal fund (1/3), a local development fund (1/3), and a regional energy company (1/3). The GreenLab has since established a project funding model based on funding from the Danish Energy Agency (DEA), EU Horizon 2020 as well as private equity funding.
5	NEWRAIL project, The Netherlands	X		Government funding with university providing 20% match funding for the portion of the subsidy allocated to them.
6	MIT-led fusion technology initiative, United States		X	Initially publicly funded when the technology was developed at the university. Once spun-out from the university, mainly privately funded through equity and membership-based funding.
7	SUSBINCO, Finland	X		Government (Business Finland) offers co-funding for projects, covering typically 40-50% of the costs of business and 70% of the costs of universities.
8	Lorraine Smart Cities Living Lab, France	X		Between 60-70% of the cost is covered by different sources of public funding (national and EU funding). Private-sector funding is provided for different projects.
9	GreenCoLab, Portugal	X		Initially mainly publicly funded to establish the team and support its operations, and expected to move towards a 1/3 funding model (i.e. 33% government, 33% competitive funding; 33% products/services/IP/partners).
10	Low Carbon Eco-Innovatory, United Kingdom	X		Mainly funded by the European Regional Development Fund (ERDF). until 2023. Since 2023 funded by the UK's Shared Prosperity Fund, administered by the Liverpool City Region Combined Authority.

Private funding is valuable as it is an important mechanism to ensure industry is committed to the success of the initiatives and to enable the future uptake and scaling of jointly developed solutions. Only two initiatives have to date secured mainly private funding:

- The GreenLab in Denmark operates with public and private resources. The GreenLab initially received USD 11 million in equity financing from a municipal fund (1/3), a local development fund (1/3) and a regional energy company (1/3), to establish the industrial park. The GreenLab has since established a project funding model based on funding from public sources (the Danish Energy Agency (DEA) and EU Horizon 2020 programme) as well as private equity funding from local industrial partners and farmers of about USD 205.2 million (EUR 187 million) [as of November 2023].
- The public-private funding arrangement has allowed GreenLab to initiate two of the world's first large-scale Power-to-X (PtX) projects, where green energy from the wind and sun is converted into other forms of energy and then stored for use as sustainable fuels for heavy transport and process industries.

- The MIT-led fusion technology initiative was initially fully publicly funded. The initiative then became primarily funded by industry, combining annual membership fees to the MIT Plasma Science and Fusion Center (PSFC) provided by the consortium of industry members as well as equity-based investments.

Several other initiatives that were set up on fully public funding are provisioning for private funding to complement:

- The CoLABS in Portugal receive a base funding from the government to initially set up their teams and operations and are expected to move to a 1/3 funding model (i.e. 33% funding from government; 33% from competitive funding from EU and national calls for research and innovation projects; and 33% revenue from the commercialisation of products and services developed by the CoLAB, as well as IP and partners' contributions).
- The international HyMethShip project received initial funding from the EU to develop a prototype of a new technology. The project partners are now looking for investors to fund the process of manufacturing and commercialisation of the prototype.

Moreover, since green innovation differs from other types of innovations in that they contribute to global public goods (e.g. mitigating the effects of climate change, protecting the environment) or reduce negative externalities of economic activities (e.g. pollution) that are not priced by the market, firms tend to underinvest in them than would be socially optimal. The Low Carbon Eco-Innovatory (LCEI) in the United Kingdom supports SMEs that often have limited budgets or lack the internal capacities to undertake innovation activities. These capital grants provided to SMEs help them to implement new low carbon technologies. Ensuring that those actors continue to have access to such technical support could not be guaranteed without public support.

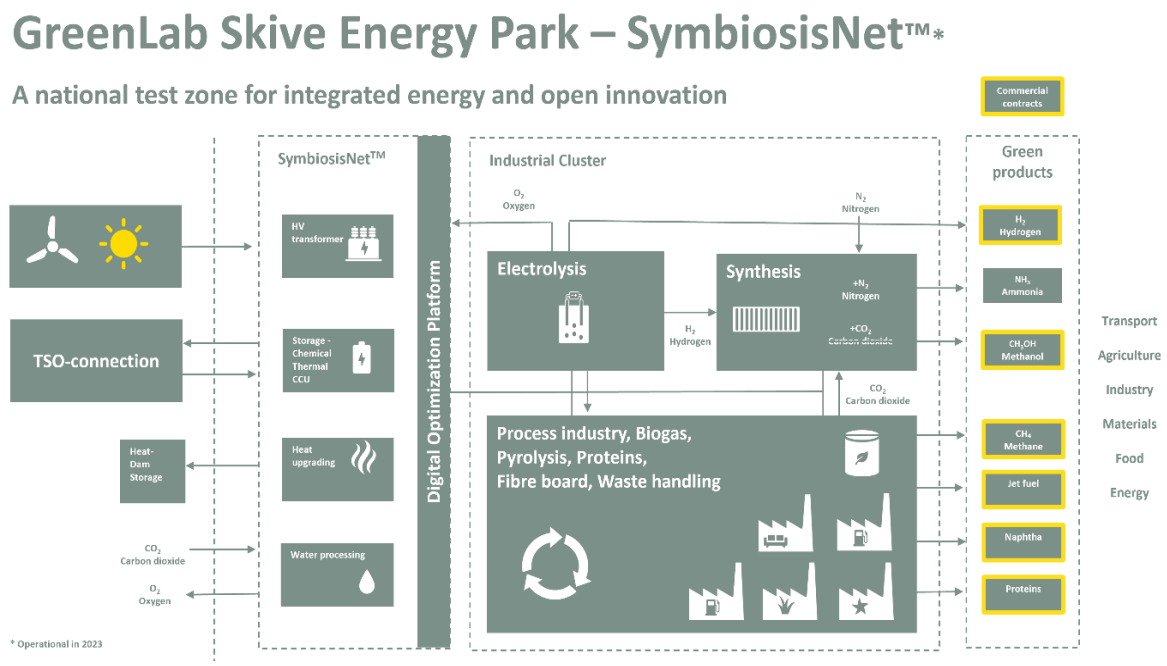
What is more, significant investments in infrastructure are often necessary for the large-scale implementation of green innovations, as illustrated by the deployment of charging stations for the diffusion of electric vehicles. An example is the Centre TERRE in Canada initiative, which provides technical support for the development of green energy solutions in remote areas not served by the national energy network. Public financing is consequently vital.

Addressing regulatory constraints for green innovation

Radical "green" innovations may face regulatory uncertainties. Effective approaches to address them include the following:

- Embedding regulatory verification through product development stages to identify non-compliances issues upfront. The international consortium of the HyMethShip project included a regulatory body as partner to ensure the new propulsion system for vessels comply with technical and safety standards in the process, rather than conducting safety checks required to obtain its operating certification only at the end of the process.
- Regulatory sandboxes – a limited form of regulatory waiver or flexibility to test innovative products in a delimited space – are another option to deal with regulatory issues (OECD, 2019[8]; Attrey, Lesher and Lomax, 2020[9]). This is the case of the Green Lab, which is an official regulatory test zone. Its smart grid infrastructure (called SymbiosisNet, see Figure 3.1) is consequently exempted from electricity regulations. Universities and industry partners are consequently in position to find the technology solutions to generate green energy from industrial processes, store and share it, with potential for solutions to be replicated and scaled in other contexts (GreenLab, 2021[10]).

Figure 3.1. GreenLab's smart grid solution to share energy



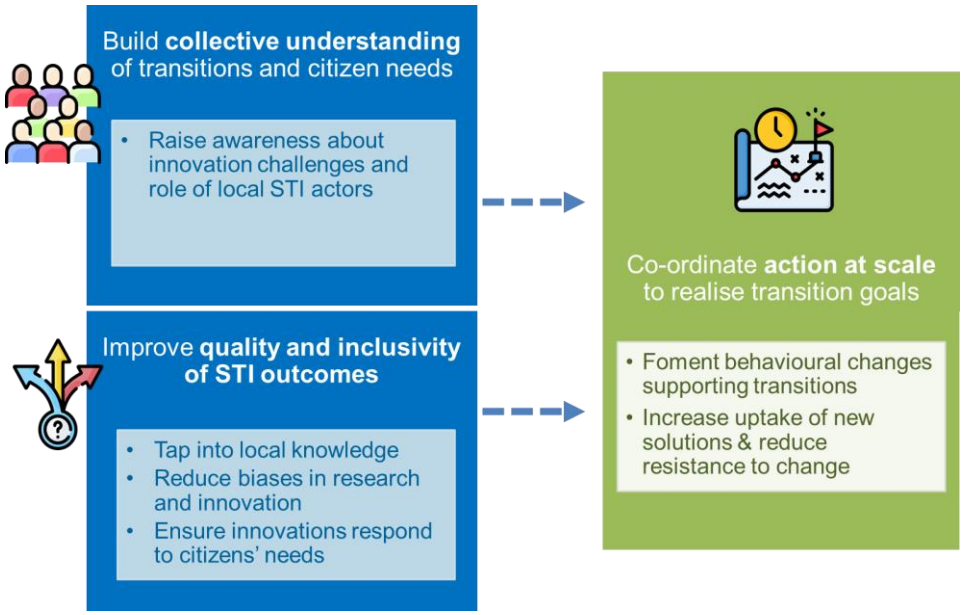
Source: Presentation by Christopher Sorensen (CEO, GreenLab) "Green & Circular Energy Park – Technology Enabler– National Research Facility" at the METI-OECD workshop

Note: The figure describes GreenLab's SymbiosisNet system, which acts as an intelligent energy and data network, allowing companies in the park to share surplus energy. The boxes on the left represent the energy sources that power the SymbiosisNet system and what they release in the process: energy from the wind and sun is fed into SymbiosisNet and connected to a high-voltage (HV) transformer, which raises the electrical voltage for the local private network administered by GreenLab; a transmission system operator (TSO) is connected to GreenLab SymbiosisNet,, which includes thermal storage (TCS), battery and PtX systems and captures excess thermal energy and stores it as chemical compounds; and the heat released from the PtX process may be stored in the thermal dam and/or released to district heating. The box on the centre-right represents the activities in the industrial cluster that are powered with the energy generated by the SymbiosisNet system: these include electrolysis and synthesis of compounds to produce biogas, pyrolysis, proteins, fibre board and waste handling. The excess energy from each activity is used as a source for other activities or stored back in the digital optimisation platform. Finally, the box in the right summarises GreenLab commercial contracts and products (yellow rectangles): hydrogen, ammonia, methanol, methane, jet fuel, naphtha and proteins to supply the transport, agriculture, materials, food and energy sectors.

3.2. Engaging citizens in co-creation

Most of the cases explored involve citizens, either engaging them directly in co-creation efforts or connecting with them through a range of communication and consultation activities (Paunov and Planes-Satorra, 2023[11]). This is important for the green transition for several reasons (Figure 3.2):

Figure 3.2. Why is it important to engage citizens in co-creation?



Source: Adapted from Arnold et al. (2023[12]).

Raise awareness and understanding needs

Some initiatives organise awareness rising and information campaigns, often targeting citizens in the local area. These can help increase social awareness about specific research and innovation challenges related to the green transition and about what science and innovation actors in their region do to respond to them. Feeling closer to such initiatives can help increase general interest in STI (including among young students) and stimulate behavioural changes in support of the green transition.

In Denmark, the GreenLab offers tours and educational activities for different groups, ranging from school children to city council members and industrial leaders interested in replicating similar green and circular industrial cluster models. It also participates in the local festival "Skivemødet", where they present research projects, innovation challenges, and discussions about green competencies of the industrial park. Some of the GreenLab communication and awareness raising activities specifically target neighbours, including an annual "Open House", and a newsletter and SMS service to inform neighbours about the latest projects. This has raised local interest and support for the initiative, creating a sense of "ownership" of the initiative among locals.

In France, the Lorraine Smart Cities Living Lab also organises several communication activities, such as establishing informational stands at the Nancy Trade Fair to increase citizen awareness about the Lab's activities and opportunities to engage in them. Similarly, the GreenCoLab in Portugal organises public events where people can try algae-based food products prepared by chefs, showcasing the potential uses and nutritional benefits of algae.

Several initiatives also look for citizen inputs to better define priorities to be set. For instance, Centre TERRE in Canada engages directly with citizens to better understand their needs, practices and constraints regarding energy use, to subsequently develop tailored green energy solutions jointly with them. Citizens provide regular feedback throughout the process, and the Centre accompanies them in identifying the behavioural changes needed to make the most of new solutions.

The buy-in from citizens becomes even more important when projects have a direct impact on specific communities or local areas. In the Netherlands, the first phase of the NEWRAIL project faced significant opposition from citizens in the local area where noise barriers were planned to be installed. This implied significant delays in the project deployment. An alternative location was found, and the project organised information and discussion sessions with residents, enabling them to voice their views and concerns. The needed adjustments were introduced to the project in order to finally reach a high level of acceptance of the local community.

Engage citizens and tap into diverse expertise

Aspern.mobil LAB in Austria and the Lorraine Smart Cities Living Lab in France involve citizens in co-creation activities to gather ideas and insights about needs and collect local data relevant to research. They use a variety of tools for local businesses and citizens to work together closely to develop green mobility solutions, as outlined in Table 3.2. Findings from those projects are made publicly available and accessible so that citizens can witness the tangible impact of their engagement, increasing trust in the initiative and willingness to continue engaging in the future (Table 3.2).

Table 3.2. Examples of citizen engagement activities undertaken by aspern.mobil LAB and the Lorraine Smart Cities Living Lab

Initiative name	Example	Description
aspern.mobil LAB, Austria	Seestadt Design Game	The game board, a representation of Seestadt Aspern, encourages players to communicate and learn from each other to decide on setting scenarios, answer research questions and find mobility solutions. The goal of the game is to explore micro-mobility and sharing transportation options in Aspern, but it could be adapted to other topics and scenarios.
	Do-it-yourself Lab hours	Lab hours (and space) offered to citizens and other stakeholders to develop their own products and services with the support of lab researchers
	Sensor box	Sensors are developed by lab staff and citizens of aspern Seestadt to collect data on noise pollution and temperature, which is combined with GPS coordinates. Citizens can carry and install this mobile box in different settings for a 2-week test period. Environmental data collected is transmitted to the university for analysis and to inform future research. Sensor boxes also help raise citizens' awareness about the quality of their environment, making them more willing to take actions towards sustainability.
	Research Mat	Mobile carpet with a scale image of aspern Seestadt, which creates a space for exchange and joint learning between citizens and the research community. Residents and project partners (incl. business, public administration and researchers) have used the mat to explore daily routes, points of interest, transport routes, hot spots and cold spots in the neighborhood. It is also used to locate areas facing specific mobility challenges and jointly devise potential solutions.
	Pop-up Lab	Temporary labs set up in public spaces to encourage interactions with citizens. These labs provide access to the Seestadt Design Game and the Research Mat. The pop-up lab is accessible to everyone, and members of AML are available to answer questions, and facilitate discussions with citizens. The goal is to encourage citizens to reflect on their mobility practices and actively participate in discussions related to urban mobility and transportation solutions.
Lorraine Smart Cities Living Lab, France	Open Citizen Labs (in the Annual Nancy Trade Fair)	Stand in the Annual Nancy Trade Fair open to all (incl. students, researchers, teachers, and startups) to, experience virtual reality and explore 3D technologies to create new products.
	Lorraine Fab Living Lab (LF2L) platform	Collaborative innovation lab that provides tools that make it possible to co-create, prototype and test products and services between citizens, businesses and researchers. For example, it organized workshops brought together start-ups, researchers, engineers and citizens to transform plastic into new objects.
	48h innovation makers	Open innovation challenge where students (from high school to PhD level, from France and abroad) are given 2 days to provide innovative solutions to specific industry-related challenges.
	Co-designing solutions for efficient energy use	The lab engaged with electricity companies and citizens to co-design potential uses of smart meters and organised interactions and discussions about the tool's utility and desirability to support more efficient electricity consumption in France.

4 Policy considerations

This section discusses four policy considerations that emerge from the analysis.

4.1. Incentivising and supporting diverse university contributions to the green transition

Incentives for universities to support the green transition should reward these efforts. While universities can contribute in many ways to green innovation partnerships as outlined in section 2, the extent and nature of contributions differs across universities. Several university characteristics shape their potential to contribute to co-creation (Table 4.1).

Table 4.1. University co-creation assets and factors influencing their contributions

Unique characteristics of universities as co-creation partners	Factors influencing universities' capacity to engage in co-creation
• Providers of leading-edge and diverse disciplinary knowledge • Capacity to build new skills needed by industry • Access to key research infrastructures and networks • Trusted actor guided by public interest • Anchored in regional ecosystems	• Location • Size • Connections to local, national & international STI ecosystems • Academic disciplines represented • Nature of research activities (basic vs applied) • Access to intermediary support services (e.g.TTOs) • Resources available for social impact activities

Requirements for universities to contribute to green innovation and support transitions need to be considered as part of the full set of universities' roles. Not every university and all its research groups should be expected to engage in the same ways in green co-creation efforts. The impacts of such an engagement on core teaching, research tasks and other industry and societal engagement activities need to be considered.

As discussed in an extensive literature, the incentives systems of researchers (as individuals) and universities (as institutions) must acknowledge and reward better contributions beyond research and teaching, so that collaboration (or social impact) activities are not neglected (Table 4.2). To provide an example of such practice, in the United Kingdom, the Knowledge Exchange Framework (KEF) allocates government funding based on impacts. As a result, universities have incorporated impact generation as a criterion for academic promotions and engaged in projects such as the Low Carbon Eco-Innovatory initiative (LCEI) discussed here.

Investing in support for universities engaging in green co-creation efforts is also important for their success. Research and teaching capabilities are critical ingredients but insufficient since collaborations require

extensive project management capacities and skills. Citizen engagement processes are also complex and require expertise in organising those consultations if they are to provide diverse citizen inputs to ongoing processes (Table 4.2).

Table 4.2. Public policy actions to Improve the incentives of universities to engage in co-creation for the green transition

Improving researchers' incentives systems	
Why?	*How?*
University researchers are in most cases still rewarded mainly in terms of academic excellence, as measured by the quality of scientific publications.	Reform researchers' reward system so that knowledge transfer, collaboration and engagement activities are considered. Recognise impact and engagement activities in performance reviews and remunerations, and use them as criteria for promotions, internal resource allocation processes and awards. Provide support to researchers engaging in such processes, including project support and resources, training opportunities to strengthen skills for co-creation (e.g. as part of PhD programmes). Offer training to researchers and PhDs on engaging in co-creation. Share good practices within and across universities on successful co-creation engagements to increase their visibility.
Improving universities' institutional incentives	
Why?	How?
University (institutional) strategies increasingly refer to green transition objectives, but do not necessarily put in place mechanisms to stimulate them. While universities are considered key actors for the green transition in national STI and university strategies, institutional funding mechanisms do not always sufficiently encourage engagement and impact generation activities.	Reward universities for undertaking collaborative research that contribute to the green transition. For example, use institutional performance-based funding mechanisms linked to universities' contributions to national, regional and/or local green transition goals (e.g. contributions to missions set at national level). Provide additional funding streams to help universities strengthen institutional capacities to support researcher engagement in co-creation and engagement with citizens. Incorporate the green transition among core university missions to increase the visibility of universities' role in this area. Provide public sector support beyond funding for co-creation, e.g. by offering convening, negotiation and networking power to support partnerships.

The type of support provided can be in the form of dedicated institutions, partnerships with external institutions and direct financial support for projects. The mixed experience universities have had with technology-transfer offices (TTOs) to support industry-science linkages shows that creating institutions is not a guarantee for success. These institutions cannot deliver on their full potential without sufficient resources to recruit and retain specialised staff. A prerequisite for TTOs to be effective is for incentives to be in place.

If the range of co-creation activities in which a university engages is limited, obtaining specific external support when needed may be more effective. This can for instance be in the form of dedicated training opportunities for researchers engaging in co-creation, or access to external expert support to organise citizen engagement activities. The mutualisation of intermediation services (e.g. TTOs) across different universities is another option that would enable reaching an optimal scale and offering more specialised services to universities that might otherwise not be able to develop their own support services. The 14 Technology Transfer and Acceleration Companies (SATT) in France, set as part of the Investments for the Future Programme (PIA), are examples of entities conceived as local/regional intermediaries to support universities and research centres connect with the private sector (OECD, 2021[13]).

4.2. Supporting universities' core assets and contributions to green innovation

Safeguard universities' neutrality

University neutrality is an asset for deliberating on directions of technological change. Different technology avenues have different impacts on societies and economies (Johnson and Acemoglu, 2023[14]). Ensuring that the green transition is fair and leads to shared prosperity and inclusive outcomes requires setting technological directions in ways that best serve society. Given universities' wide expertise across disciplinary fields, they are well placed to play a key role in identifying and pushing forward the technological avenues that ensure societies move towards desirable futures.

Neutrality is also a core asset for universities to support engagement, connecting society with science and policymaking in green transition processes. As discussed in section 3.3, university efforts to engage citizens in co-creation initiatives serve a diversity of objectives, including enhancing societal awareness and interest in sustainability issues, ensuring innovation responds to citizens' needs and increasing chances of successful uptake. A diversity of tools can be used by universities to enhance citizen participation in research and innovation activities contributing to the green transition, including citizen science projects in which citizens collect data to be used for research purposes, hackathons, living labs, fablabs and serious games (Paunov and Planes-Satorra, 2023[11]).

Achieving neutral contributions based on expertise requires stable public funding to maintain such expertise. Financial independence from private interests allows universities to maintain the integrity and impartiality of their work. This in turn ensures that they continue to be perceived as trusted entities by citizens. This does not imply that industry should not provide funding to support universities' research and innovation activities (see discussion in section 3.2). Rather, it is about guaranteeing that they have sufficient financial autonomy to ensure academic pursuits remain unbiased and free from external influences.

Adopt challenge-based green research programmes

Advancing research and innovation to respond to the climate emergency demands increased directionality of STI policies (Arnold et al., 2023[12]). The launch of challenge-based or mission-oriented research funding opportunities open to academics (often in collaboration with other actors) and targeting specific green challenges also contributes to steering university research agendas towards green-related topics. Performance contracts setting specific targets for universities, often binding a share of their block funding allocation to the achievement of such targets, have gained in importance as a way of rewarding impact activities and influence the direction of university research agendas. Some countries have long-standing tradition in using performance indicators in the form of allocating research funding (Borowiecki and Paunov, 2018[15]).

While setting directions and clear goals is essential to advance on the green transition, research freedom and investments in basic research across science fields should be preserved. Ground-breaking innovations often build on decades of public investments in basic research, as illustrated by the invention of the Internet or the development of mRNA vaccines for COVID-19. Moreover, challenge-based or mission-oriented research should also leave sufficient autonomy for researchers to choose among diverse technology avenues to achieve the set objectives, in order to allow for the development of "unexpected" technology solutions.

Supporting universities' green innovation activities where there is no market case should be considered. Some technologies with potential to contribute to the green transition are in very early stages of development, requiring significant levels of investments and risk- taking. The private sector may be less willing to engage in such endeavours if expected return on investment is very uncertain. Moreover, where

"greening" production is resulting in pollution that does not represent a direct cost to industry, then incentives to engage in costly efforts to reduce pollution will be lower. In addition, not all green innovation activities have potential for revenue generation, for instance when they target disadvantaged groups or a small number of citizens or firms. The Centre TERRE in Canada, which supports the deployment of small-scale green energy solutions in remote areas, is a case in point. Initiatives that target those with lower capacity to adopt and benefit from new technologies, or that risk being left behind, are important to support inclusive transitions.

Engage universities in STI policy making

The engagement of universities in STI policy making for the green transition should be more actively promoted. Universities can critically contribute to advancing the green transition not only through their research and collaboration activities, but also by providing their expertise, technical knowledge and inputs during policymaking processes, especially in the context of stakeholder consultations to develop shared visions and set policy directions, for instance in the process of design of mission-oriented programmes (Arnold et al., 2023[12]). Such engagement enables more informed policy choices. Ensuring that a broad range of institutions and academics are represented in such consultation processes is essential to capture the diversity that exists within university systems, mitigate possible biases, and improve the quality of outcomes.

Universities can also play a critical role in facilitating processes of consultation and citizen engagement in STI policymaking – a core priority in a context of transitions. Their role could consist in helping to identify community needs or consult about different policy alternatives affecting groups differently. Academics in local universities can be well placed to play the role of intermediaries between government and citizens, helping to effectively connect to communities that feel more distant from government. Such figures may benefit from higher levels of trust from citizens than government and can help bridge possible barriers to engagement (Paunov and Planes-Satorra, 2023[11]).

Other areas that remain critical to enhance the capacity of universities to effectively engage in co-creation activities, although not specific about the green transition, include:

- *Access to professional intermediary support services.* Allocating sufficient and stable institutional resources to the activities of technology transfer offices (TTOs) within universities ensures that researchers can devote their time to research and innovation activities instead of other more administrative and technology management activities (e.g. IP management). Providing TTO professionals with training and clear career paths can also promote the attraction of retention of highly qualified personnel.
- *Investments in research, testing and demonstration infrastructures.* The development of breakthrough innovations often builds on researchers and innovators having access to leading-edge scientific and technical infrastructures (e.g. supercomputers, biomedical imaging, fusion laboratories, oceanographic research vessels). Facilitating access to university researchers and their partners to state-of-the-art demonstration and testing facilities and actively encouraging researchers to pursue innovative lines of research and collaborate across disciplines is critical to stimulate creativity. For example, GreenLab in Denmark provides an integrated energy and industry infrastructure which researchers can use to test, scale, and validate their innovations within a real-world setting.

4.3. Coordinating policy efforts for the green transition

Integrate university co-creation support as part of the green STI policy mix

STI policy can support the green transition in multiple ways, going beyond supporting co-creation for green innovation. A range of traditional STI policy instruments have been used to promote green innovation, including R&D grants, tax incentives, public procurement of green innovations, and measures to build the technical skills and capabilities needed to advance green research and innovation but also to deploy the resulting technologies. For instance, vocational training in specific green technology fields, supported by programmes such as the EU-funded Greenovet initiative, can be critical to enable the diffusion of green technologies such as solar panels or windmills.

Ensuring the coordination and alignment among those instruments is of paramount importance to maximise their impacts by reinforcing the effects of each other. The most important development to implement directionality in STI policy has been the implementation of mission-oriented policies (MOIPs), which are co-ordinated packages of policy and regulatory measures tailored specifically to mobilise STI to address well-defined objectives related to a societal challenge, in a defined timeframe (Larrue, 2021[16]; OECD, 2023[17]).

This ambitious agenda also implies that governments take up a range of new roles that go beyond that of identifying and correcting market and system failures limiting the development and deployment of knowledge, technology and innovation, often through the provision of funding. As reflected in Section 2.2, in the case of the co-creation cases studied, government roles go well beyond that of providers of funding. Roles such as those of lead-users of innovation, facilitators of experimentation, and network builders become essential. Other roles may include that of legitimiser of co-creation projects by directly using the data or outputs produced, as well as of co-creator in some projects that could leverage unique knowledge and skills of the government (de Silva et al., 2022[4]). This also implies that new capacities need to be developed within the government to optimally fulfil those roles.

Enhance coordination across policy areas to support initiatives' success

Co-creation initiatives alone, and even more broadly STI policies for green, will not be sufficient to transition towards green economies and societies. For government to be able to have an impact on the directionality of technological change to support the green transition, it is important to coordinate such policy action, both horizontally across different areas of government (e.g. between STI, environment, labour, fiscal and social policies) and vertically across multiple-levels of government (from the local to the regional, national and transnational levels).

Co-creation programmes targeting green innovation have an important sectoral dimension (e.g. targeting innovation in the energy sector, mobility, housing, etc). It is therefore important that they are set in coordination with those other parts of government (e.g. through joint programming, a process of internal consultation, or as part of the agenda of higher-level councils or committees in charge of the overall steering of green transition policies across government), so that policies can benefit from expertise and insights from those different policy fields.

Alignment is also critical to reinforce the effects of such policy actions – and avoid contradictions. For instance, providing financial support to fossil fuel consumption undermines the economic incentives for firms to engage in co-creation with universities for green innovation.

Coordination is also needed to ensure that the framework conditions are in place to support green innovation. This includes investments in infrastructures needed for joint science-industry collaboration (e.g. joint research labs and demonstration facilities) and to enable the large-scale deployment of new solutions (e.g. investments in the network of charging stations is necessary if electric vehicles are to replace internal

combustion engine ones). The potential for scaling of new technologies may also have limitations if regulations pose barriers or if regulatory holes affect some new technology areas.

Support the diffusion of successful approaches

Successful collaborations are even more valuable if they leverage networks to improve and diffusion successful practice nationally. While individual experiences will have specificities, there will be lessons to be shared with other initiatives to improve their performance. The active engagement of government in the Austrian Mobility Labs has facilitated synergies between these labs and the development of competencies on a broader scale. To provide an example, the Cooperation and Exchange Platform of Mobility Labs Austria has organised 3-4 meetings a year to facilitate exchanges of knowledge and best-practices across Austrian Mobility Labs.

Moreover, for these bottom-up initiatives to have larger-scale impacts, it is vital to increase the visibility of those efforts and create opportunities for strengthening ties between the university and policymaking communities, so that lessons learned through those exchanges can feed into the policy process and inform future co-creation policies for green transitions.

The successful experiences of living labs are an example of local partnerships with a much wider scaling dynamic. For instance, the Lorraine Smart Cities Living Lab in France is a member of the European Network of Living Labs (ENoLL), which brings together more than 420 Living Labs from different countries. Through the Climate Labs initiative, LSCLL also collaborates with universities in Mexico, Brazil, and Colombia to improve applied research in climate mitigation through the design and implementation of innovation labs.

4.4. Good practice for co-creation policy support

The following considerations are relevant for governments planning to design new or reform existing programmes to foster co-creation for the green transition.

First, engaging prospective future partners, users or beneficiaries of initiatives in the very design of innovative co-creation programmes to enhance their success. Stakeholders – which may include representatives of the academic community, industry, local government and civil society – can help shape initiatives that better respond to local needs, leverage existing assets in the STI system (e.g. existing networks and capabilities) and account for specific barriers actors may face to engage in co-creation. Engaging stakeholders in the design of programmes also promotes transparency, builds trust, and fosters a sense of ownership among participants. For instance, the Austrian government collaborated with stakeholders for nearly a year to define the prerequisites for Austrian Mobility Labs in the mobility sector before launching the funding call to establish them. This inclusive approach facilitated knowledge sharing and synergy generation among the six Mobility Labs established in the country.

Second, supporting more diverse and intensive collaborations both for the development and the diffusion of new solutions. With many technological solutions still missing as regards achieving environmentally friendly modes of energy generation, industrial production and mobility, breakthrough innovations become essential. Breakthroughs often result from combining different fields of researchers (novelty generation potential) and also from the application of existing technologies to new areas, as illustrated by the use of drones originally developed in warfare for crop management in agriculture. Programmes that support multi-stakeholder, cross-disciplinary and cross-sectoral collaborations for the green transition, as well as the development of academic spin-offs and start-ups, can critically contribute to accelerating the development of such breakthrough solutions. The densification of such collaboration networks would also enhance

systems' resilience. As experienced during the COVID-19 pandemic, existing networks facilitated the quick mobilisation of partners to jointly respond to urgent challenges.

Third, building new metrics, monitoring programmes and enhancing their flexibility to adapt to rapidly changing contexts. New metrics and approaches are needed to monitor and evaluate the impacts of university co-creation programmes for green innovation. Impacts of such activities may be materialised in the longer term, and go beyond that of productivity growth or employment creation to also have positive impacts on multiple dimensions of wellbeing (e.g. health, safety).

Regular iteration with beneficiaries and involvement of independent advisors in monitoring and evaluation processes also supports effective monitoring. For instance, the Knowledge Exchange Framework (KEF) in the United Kingdom was reviewed based on feedback from the sector and users gathered after the first results launched in 2021, which allowed refining the methodology and dashboard designs. In Portugal, each CoLAB counts with two international independent mentors that have a double role as advisors (as they support CoLABs' processes of strategic planning) and evaluators (as they conduct annual assessments of their progress).

Fourth, encouraging the implementation of citizen engagement and communication activities as part of partnerships. While not all co-creation activities are suited to engage citizens, it is relevant to bear in mind when this could be beneficial, and when it may be worth to consider engaging in communication activities more widely to increase awareness and avoid opposition from citizens. For example, the GreenLab in Denmark engages in educational initiatives, organises "open house" days and offers a newsletter and SMS service for neighbours, while the Lorraine Smart Cities Living Lab participates in local trade fairs.

Through activities that involve the public, initiatives can increase citizen awareness, interest, and understanding of those innovation efforts. This in turn can contribute to combat the spread of misinformation and disinformation related to technology development and the climate emergency. Such activities could also be integrated into broader government communication activities on science and the green transition, such as science festivals, exhibits in public spaces and documentaries, to reach larger audiences. Experimentation with new approaches such as gamification can help engaging broader audiences beyond those already interested in those topics.

References

Arnold, E. et al. (2023), "Navigating green and digital transitions: Five imperatives for effective STI policy", *OECD Science, Technology and Industry Policy Papers*, No. 162, OECD Publishing, Paris, https://doi.org/10.1787/dffb0747-en. [12]

Attrey, A., M. Lesher and C. Lomax (2020), "The role of sandboxes in promoting flexibility and innovation in the digital age", *OECD Going Digital Toolkit Notes*, No. 2, OECD Publishing, Paris, https://doi.org/10.1787/cdf5ed45-en. [9]

Borowiecki, M. and C. Paunov (2018), "How is research policy across the OECD organised?: Insights from a new policy database", *OECD Science, Technology and Industry Policy Papers*, No. 55, OECD Publishing, Paris, https://doi.org/10.1787/235c9806-en. [15]

Borrás, S. and J. Edler (2020), "The roles of the state in the governance of socio-technical systems' transformation", *Research Policy*, Vol. 49/5, p. 103971, https://doi.org/10.1016/j.respol.2020.103971. [5]

CLIC Innovation (2020), *Strategic Research and Innovation Agenda for the Forest-Based Circular Bioeconomy*, https://clicinnovation.fi/bioeconomy-sria/ (accessed on 2023). [7]

de Silva, M. et al. (2022), "Co-creation during COVID-19: 30 comparative international case studies", *OECD Science, Technology and Industry Policy Papers*, No. 135, OECD Publishing, Paris, https://doi.org/10.1787/08f79edd-en. [3]

de Silva, M. et al. (2022), "How did COVID-19 shape co-creation?: Insights and policy lessons from international initiatives", *OECD Science, Technology and Industry Policy Papers*, No. 134, OECD Publishing, Paris, https://doi.org/10.1787/e11c5274-en. [4]

GreenLab (2021), *Historic test zone designation paves the way for the use of 100% green power*, https://www.greenlab.dk/knowledge/test-zone-designation-paves-the-way-for-the-use-of-green-power/. [10]

Johnson, S. and D. Acemoglu (2023), *Power and Progress: Our Thousand-Year Struggle Over Technology and Prosperity*, PublicAffairs. [14]

Kreiling, L. and C. Paunov (2021), "Knowledge co-creation in the 21st century: A cross-country experience-based policy report", *OECD Science, Technology and Industry Policy Papers*, No. 115, OECD Publishing, Paris, https://doi.org/10.1787/c067606f-en. [2]

Larrue, P. (2021), "The design and implementation of mission-oriented innovation policies: A new systemic policy approach to address societal challenges", *OECD Science, Technology* [16]

and Industry Policy Papers, No. 100, OECD Publishing, Paris, https://doi.org/10.1787/3f6c76a4-en.

OECD (2023), "Co-creation for green innovation: 10 international case studies". [1]

OECD (2023), *OECD Science, Technology and Innovation Outlook 2023: Enabling Transitions in Times of Disruption*, OECD Publishing, Paris, https://doi.org/10.1787/0b55736e-en. [17]

OECD (2021), "Improving knowledge transfer and collaboration between science and business in Spain"*, OECD Science, Technology and Industry Policy Papers*, No. 122, OECD Publishing, Paris, https://doi.org/10.1787/4d787b35-en. [13]

OECD (2020), "Addressing societal challenges using transdisciplinary research", *OECD Science, Technology and Industry Policy Papers,* No. 88, OECD Publishing, Paris, https://doi.org/10.1787/0ca0ca45-en. [6]

OECD (2019), *Digital Innovation: Seizing Policy Opportunities*, OECD Publishing, Paris, https://doi.org/10.1787/a298dc87-en. [8]

Paunov, C. and S. Planes-Satorra (2023), "Engaging citizens in innovation policy: Why, when and how?"*, OECD Science, Technology and Industry Policy Papers*, No. 149, OECD Publishing, Paris, https://doi.org/10.1787/ba068fa6-en. [11]