FUTURE POTENTIALS OBSERVATORY

INNOVATION AND DESIGN HORIZONS

Forecasting New Innovation and Design Horizons

Working Paper

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Future Potentials Observatory

Forecasting New Innovation and Design Horizons – Working Paper

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Summary

Background and objectives

This working paper is based on the mission of the Future Potentials Observatory (FPO) which aims to investigate, analyze, and present the future potential of social entities, such as families, organizations, cities, countries, geopolitical frontiers, and innovation and design horizons in an East-West context, with a special focus on Hungary. These points represent thematically interconnected but separate research projects.

Within this research framework, three working papers focus on innovation and design horizons. The first working paper was focused on the theoretical foundations by a systematic meta-review, while the second working paper mapped the change drivers of innovation and design horizons by (1) the quantitative analysis of almost 1.000 articles and (2) supplementary qualitative analysis of highly cited research from pre-defined frontier countries (USA, China, India, Japan, South Korea, Israel). These works clarified the working definitions, reinforced the relevancy of the theoretical perspectives (transdisciplinarity, dynamic capabilities), and identified (a) the interplays of focal innovation areas[1] and (b) sustainable development as the main change drivers of innovation and design horizons.

The scope of this working paper is **forecasting innovation and design horizons based on the previous findings, emerging supplementary perspectives** (absorptive capacity, mapping recent influential research, artificial intelligence) and analyzing the role of **Hungary, the Carpathian basin and V4 countries**. This working paper defines forecastable horizons as **the limits of (our) academic knowledge and ideas which could increase future innovation and design performance** in the focal areas. Accordingly, this working paper does not aim to directly suggest operative, technical innovation and design activities to support by public policy or corporations, but instead, **clear strategic directions** in the focal innovation and design areas by synthesizing theoretical foundations, recent research themes and findings, moreover, V4 strategic frameworks and innovation opportunities. The main research question was the following:

> *What kind of strategic changes could facilitate innovation and design in Hungary, V4, and the Carpathian basin related to the policy, institutional, research, and corporate context? (within the focal innovation areas)*

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[1] Eco- and/or energy innovation (EEI), Technological (non-eco, non-energy) innovation and design (TI), Social and/or business model innovation and design (SBMI), Cultural and/or design innovation (CDI)

This working paper is partly based on the systematic literature review of the previous phase, but its depth and width were increased. It means that the working paper now elaborates on the potential models which could orient recommendations, moreover, involves UK and Australia as frontier countries based on the findings of the previous phase. The internal strategies, conditions, and capabilities of Hungary, V4 countries, and the Carpathian Basin are analyzed based on public statistical data and public policies and strategies, related to sustainable development and R&D&I.

Results

Influential models of frontier countries and supplementary perspectives

The literature review in this research phase identified and introduced **more than 30 theoretical models or important empirical findings** from highly cited research from frontier countries, the consideration of which could increase performance in the focal innovation and design areas. Accordingly, relevant findings are integrated into the policy, institutional, research, and corporate recommendations.

As the second working paper concluded that Hungary, V4, and the Carpathian basin could combine different approaches and access frontier research and knowledge from different geographical areas, the theory of absorptive capacity was also considered. Its main lesson is that **absorptive capacity and R&D performance are path-dependent**. Consequently, policymakers should support external learning in general and especially prioritize those innovation and design areas which are strategically important before the lack of early investments becomes a competitive disadvantage because of the more advanced R&D results of the competitors.

Besides, the working paper explored trending research in 2020-2022 concerning innovation and design interplays as a supplementary perspective. The results show that if EEI is relevant, Eastern countries dominate in terms of the number of highly cited research papers, while SBMI, TI, and CDI areas are more influenced by Western studies. The mapping also highlighted that sustainable development, which was the main change driver based on the literature of 2000-2022, is increasingly discussed in the recent literature (2020-2022) from the aspect of **circular economy**. Regarding the less frequent but relevant[2] author keywords, although artificial intelligence indeed appears in case of technological innovation, Big Data and smart solutions are mentioned more times and in more areas. It can be

[2] [2] Based on the direct connection to at least one of the innovation and design areas.

explained by the emergent nature of AI research, and the limited number of technological innovation research in the sample[3].

Nevertheless, AI research highlights that **sustainability can be the driver and also the outcome of AI adoption, moreover, AI solutions can support innovation and design management**. AI for sustainable development and innovation has been discussed from multiple perspectives, for example, concerning management education, or key consequences of AI deployment, such as product and process innovation, business model innovation and social innovation. Barriers, however, should be also considered (e.g., overreliance on historical data or cybersecurity risks).

Internal conditions, strategic frameworks, opportunities

The analysis based on the European Innovation Scoreboard shows that the countries of the Carpathian Basin belong to Moderate Innovators or Emerging Innovators, similar to the V4 countries. The highest ranking belongs to Slovenia, which partly belongs to the Carpathian Basin, and the Czechia, a V4 country. Hungary is a moderate innovator. In case of specific indicators, Hungary and the V4 countries together show a mixed picture: while the entrepreneurial potential is present (e.g., "Non-innovators with potential to innovate" index), synergies are not fully realized yet in terms of the technological, eco-innovative and design application performance (e.g., "Eco-innovation" and "Design applications" indices).

Besides the research and development strategies, climate or energy strategies were also thoroughly analyzed in case of V4 countries, from the aspect of the four innovation and design areas. The focus points included the present (strategic framework, capabilities) and the future (innovation goals, opportunities). Given the **many overlaps among the sustainability and R&D goals** (e.g., EEI: energy efficiency, nuclear energy; TI: digitalization and ICT; SBMI: aligning economic and environmental performance, productivity of SMEs, improving the quality of life; CDI: eco-design), **innovation and design-oriented cooperation of the V4 countries could be a promising policymaking direction**.

Recommendations

The summary of recommendations is presented in the following table. According to the fundamental approach of this research, recommendations outline **strategic change directions, which could lead to improved innovation and design performance in the focal areas**. In line with the main strategic change

[3] As detailed in the second working paper, the top-cited 250 articles were involved from every area.

drivers of innovation and design horizons, sustainable development and transdisciplinary approach underlie all the recommendations by the goal (e.g., building sustainable business models) or the realization (e.g., real-world problem-solving by stakeholder engagement or entrepreneurship).

Recommendations are detailed and explained in the last section of this working paper, including the list of potential partners for future international research in each innovation and design area.

Contributions and future research

The three working papers focusing on innovation and design horizons presented the theoretical foundations, mapped the strategic change drivers using a novel visualization tool, explored influential findings and models of frontier countries' research, combined the emerging academic knowledge with the in-depth analysis of V4 strategic frameworks, and finally, elaborated strategic recommendations for policymakers and decisionmakers in four innovation and design areas. The main contribution of this work is based on the **strictly followed systematic literature review methodology and the multifaceted innovation scope**, which enables to gather an in-depth understanding about the pathways and most influential models to increase innovation and design performance. Consequently, further research could narrow the scope to enable more operationalized findings, by focusing on only one innovation and design area (e.g., eco-innovation) and/or a certain sector (e.g., energy).

	V4 analyses		Recommendations based on the theoretical background, recent literature, mapping, and frontier countries' research			
	Strategic framework, capabilities (present)	**Innovation goals, opportunities (future)**	**Policy (with V4 focus)**	**Institutions**	**Research**	**Corporations**
EEI	**HU:** Need for changes in multiple dimensions of the energy sector; Sustainable economy development in the vision **CZ:** Primary focus on energy intensity **PL:** Environmentally and economically equally promising transformation goal; Need for sectoral transformation **SK:** Smart Specialization includes sustainability measures and advanced ICT technologies; R&D for sustainable development	**HU:** Clean energy use in numerous areas, involving nuclear capacities; Energy innovation for environmental and economic goals **CZ:** Energy efficiency, renewable and nuclear technologies **PL:** Energy efficiency in focus, partly by digital technologies; Low carbon economy development **SK:** RES, nuclear energy, and green innovation; Eco-innovation-related specialization areas (e.g., agriculture)	Eco-innovative technological ecosystem based on aligned energy strategies Primarily market-based instruments for improved environmental and financial performance of firms	Forming shared meanings for circular economy development Institutional support eco-(re)design, smart solutions, and technological diffusion	Absorbing eco- and energy innovation knowledge from the East	Developing sustainable business models and related organizational capabilities
TI	**HU:** Improving but still deficient basis for cutting-edge technology development **CZ:** Improving the currently insufficient basis to become an innovation leader **PL:** Productivity challenge **SK:** A need for a narrowed strategic scope	**HU:** Patent-based technological innovation in multiple sectors **CZ:** Digitalization, Smart Solutions; Life-long learning and specialization based on change in multiple levels **PL:** Healthcare, materials, ICT **SK:** Nanotechnology, Biotechnology, Industry 4.0	Focus on agriculture, healthcare, and ICT (inc. AI) Proactive regulation to balance market mechanisms and protect SMEs	Institutionalization of open innovation	AI research for innovation management and sustainable development, based on Western collaborations	Exploration by open innovation, developing core and supplementary innovation assets

Cont.

	Strategic framework, capabilities (present)	Innovation goals, opportunities (future)	Policy	Institutions	Research	Corporations
SBMI	**HU:** Aligning environmental and economic goals; New and valuable connections within the innovation system, but not in case of social innovation **CZ:** Difficulties in reducing import dependencies; Advanced digitization but a concept is needed **PL:** Improving market and social conditions; Aging society **SK:** Existing programs to generate economic and social benefits; Retaining and attracting talents	**HU:** Technological innovation combined with business model innovation and social innovation; Focus on SME productivity and new societal needs through innovation **CZ:** Knowledge, quality life, healthcare, security; Overarching digitalization and start-up focused strategies and programs **PL:** Quality of life, healthcare, and air quality improvement through stakeholder involvement; Improving social activation and capital **SK:** Using technological advancements for economic growth and employment; Institutional changes to enable socio-economic progress	Transition management for sustainable development	Supporting social innovators and SME-sized business model innovators to avoid strategic concealment Holistic innovation in cities	Circular economy research on policy level, sustainable business model research on corporate level	Social innovation by substantial organization changes or new ventures Sustainable business model innovation following technological, organizational, social archetypes
CDI	**HU:** Existing R&D institution which involves also cultural aspects; "Invented and Made in Hungary" principle **CZ:** Eco-design in public procurement; Unexploited opportunities in cooperation **PL:** Civilization gap; Digital technologies for cultural participation **SK:** Design innovation potential for circularity; Past achievements in product and game design	**HU:** Design innovation for zero waste; Exploiting emerging global opportunities, partly by design innovation **CZ:** Researching social and cultural challenges; Developing an entrepreneurial culture **PL:** Increasing scientific impact; Considering cultural heritage in a digital age **SK:** Environmental design as a strategic measure; Creative industry as perspective area	Cultural drift toward eco-culture and AI-supported sustainable business models	Moderate and balanced incentives for exploitative and explorative routines Analyzing social needs, monitoring social dynamics	Exploring the cultural and design aspects of sustainable development	Design innovation based on versatile value categories, supported by marketing integration

Summary of the V4 analyses and strategic change directions for policy, institutions, research, and corporations in the focal innovation and design areas

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1. Introduction

This working paper is based on the mission of the Future Potentials Observatory (FPO) which aims to investigate, analyze, and present

a) the future potential of social entities, such as families, organizations, cities, countries,
b) geopolitical frontiers, and
c) innovation and design horizons

in an East-West context, with a special focus on Hungary. These points represent thematically interconnected but separate research projects.

Within this research framework, three working papers focus on innovation and design horizons. The phases of the research process are the following:

1. ***Historical/Economic aspects of innovation and design horizons in East-West context research***
   This was the topic of the first working paper which highlighted the key characteristics of historical and economic aspects of innovation and design horizons in the East-West context, based on a systematic literature (meta-)review.
2. ***Innovation and Design Horizons Map research***
   Associating key drivers of innovation and design horizons to key historical and economic characteristics in the East-West context, creating a map of these drivers across geopolitical, industry and policy dimensions.
3. **Forecasting new Innovation and Design Horizons *(the scope of this working paper)***
   Forecasting new innovation and design trends based on the innovation and design horizons map, as well as additional relevant international scientific literature. Highlighting the role of Hungary, the Carpathian basin and V4 countries.

The main goal of the Innovation and Design Horizons research and its three phases is to provide insightful decision-making material for policymakers by which they can contribute to previously defined areas[4] of fundamental human goods.

[4] Peace and safety, attachment, care, and balance (Szántó, et al., 2020)

1.1. The background of this working paper

1.1.1. Future potentials, strategic management, and innovation

In this research, the relevant innovation and design areas were defined according to the key pillars of the future-potential-related strategic fields (Szántó, 2018):

- Ecological – (geo)political changes: Eco- and/or energy innovation and design (EEI)
- Technological changes: Technological (non-eco, non-energy) innovation and design (TI)
- Socio-economic changes: Social and/or business model innovation and design (SBMI)
- Cultural – spiritual: Cultural and/or design innovation (CDI).

These strategic fields have been also the fundamental pillars for the antecedent concept of the future potentials index, i.e., social futuring. In a broader context, compared to traditional social sciences which mostly consider individual self-interests as a starting base, social futuring *"starts by only considering a collection of individuals who have a common plan and then studies how that collective group achieves a broader outcome as defined by their plan"* (Szántó, et al., 2019, p. 122). Compared to similar concepts, such as resilience, future orientation, and future proofing, social futuring is unique by

1. approaching change as a process and an opportunity with a reactive, active, or proactive attitude
2. being fundamentally based on a vision (as a condition)
3. being interpretable at social, cultural, and instrumental levels
4. concerning strategic actions. (Aczél, 2018)

Nevertheless, the future potential concept steps further as *"the holistic concept of future potential (FP) expresses the readiness of social entities (e.g. countries, cities, organizations, groups) in terms of their ability to preserve a good life for their members in a unity of order (constitutedness) through the strategic management of future change"* (Szántó, et al., 2023, p. 8).

Regarding the literature on the above-mentioned strategic management, there is a broad consensus that in a rapidly changing environment, the ability to innovate and adapt is a critical precondition for organizational survival, and managing strategic changes and innovation are interrelated activities (March, 1991; Teece, 2007; Csedő & Zavarkó, 2019). This statement has become even more relevant in the recent era of rapid changes, for example:

1. environmental changes and fight against climate change, which impacts organizations through green transformation (Magyari, et al., 2022; Guimarães, et al., 2018), inter-organizational networks and knowledge networks (Csedő & Zavarkó, 2020; Csedő, et al., 2021), and also (eco-)innovation (Carrillo-Hermosilla, et al., 2010; Csedő, et al., 2023) and (sustainability) change management (Csedő, 2023; Lozano, et al., 2015).
2. technological changes, e.g., digital transformation and Industry 4.0 as key topics in the previous decade, which influences the future of work (Kudyba, et al., 2020), followed by AI which accelerates further digital transformation (Holmström, 2022)
3. socio-economic changes in several sectors, e.g., in healthcare or finance, because of the opportunities of digitalization (Sára, et al., 2013; Csedő, et al., 2019) or challenges, such as the COVID-19 which also impacted firms' performance (Shen, et al., 2020)
4. cultural changes, which, for example, are argued to be necessary for sustainable development (Brooks, et al., 2018).

The above-mentioned ecological, technological, socio-economic, and cultural challenges mean pressure for strategic adaptation and are discussed from the perspective of innovation management, including the above-mentioned sectors, such as healthcare (Pörzse, 2008; Pörzse, 2011) or energy (Csedő, et al., 2019; Sharif, et al., 2023). Consequently, focusing on these change areas is relevant from the aspects of future potentials and innovation management as well.

1.1.2. Lessons from the previous research phases

In the first phase of the research, the theoretical foundations were elaborated from two aspects:

1. Selecting and validating the theoretical approaches to govern future strategic changes;
2. Selecting focal innovation and design areas and analyzing their theoretical background.

Regarding the first point, two approaches were elaborated and validated: transdisciplinary research and development, and the dynamic capabilities framework. The transdisciplinary approach could fundamentally support institutional policymaking based on (1) an outside-in approach (e.g., finding and solving real-world problems), (2) a bottom-up change direction (e.g., emphasizing stakeholder involvement), (3) finding operative or micro-level problems and solutions (e.g., concrete social and scientific problems). In contrast, the dynamic capabilities framework is more relevant for corporate decision-making, as it comes with (1) an inside-out approach (e.g., building and using valuable capabilities), (2) a top-down change direction (e.g.., the role of leadership in sensing changes and reallocating resources), (3) finding strategic or macro-level problems or solutions (e.g., the threat of environmental misfit).

In the first phase of the research, the literature review of the most-cited review articles from these areas (i.e., the meta-review)

1. clarified the working definitions;
2. reinforced that both theoretical perspectives are relevant in these innovation and design areas;
3. suggested there could be interlays among these areas.

The second phase of the research reinforced this assumption based on original research articles from pre-defined frontier countries (USA, China, India, Japan, South Korea, Israel), and identified these interplays as an important change driver of innovation and design horizons. Besides, the quantitative analysis of almost 1.000 articles suggested that the other main change driver of innovation and design horizons is sustainable development.

The relevance of the innovation interplays gives an additional layer to the transdisciplinary theoretical perspective: it is not only a validated governance approach, but also indicates the need for combining the knowledge streams from different innovation and design areas. Also, not only from different functional areas but geographical areas as well. It is because the mapping results suggested that Western and Eastern research are – in a relative sense – different regarding their sustainable development approach (West: enabler; East: command & control), and the topics in which they are the most influential (West: social and/or business model innovation and design; East: eco- and energy innovation and design).

1.1.3. Emerging research perspectives

Based on the above, the following perspectives must be considered in this working paper:

1. **Innovation and design area-specific insights:**
   a. As the number of articles from Hungary, V4 countries, and the Carpathian basin was underrepresented in the sample of the quantitative research, a deeper analysis of the change or governance models from frontier countries' highly cited research should be also explored. However, the group of frontier countries might be extended. It is because, (1) the UK and (2) Australia might be considered frontier countries as well,

owing to (1) the large volume of highly cited papers and (2) its significant growth from 2000-2011 to 2012-2022 in focal innovation and design areas.

b. To contextualize literature findings, internal conditions, capabilities, and resources of Hungary, V4 countries, and the Carpathian Basin must be explored. For this, public EU data about innovation performance and national strategies for sustainable development and R&D are analyzed.

2. **Supplementary perspectives:**
   a. Results so far suggested that cross-functional interplays of innovation and design areas and sustainable development seem to be the main strategic change drivers of the past 20 years. This could be supplemented by a specific insight into the most cited research from *2020-2022*.
   b. Given the unique resource of Hungary, V4, and the Carpathian basin of being in a central geographical position which can enable the combination of different approaches and accessing frontier research and knowledge, the theory of *absorptive capacity* should be also considered.
   c. Without the aim of predicting the future *subjects* of innovation and design, artificial intelligence (AI) is considered an additional perspective which might affect innovation and design *management* in the future.

1.2. Scope of this working paper

1.2.1. Objectives, scope, and objectives out of scope

Based on the title of this working paper, first, it must be defined what type of innovation and design horizons can be forecasted. Obviously, we do not aim to predict the future in terms of upcoming innovations and designs. Instead, this working paper aims to provide recommendations about strategic directions for policymakers and decision-makers to increase their performance in the focal innovation and design areas.

So, the question is how one can define forecastable horizons in innovation and design. In an abstract sense, horizons are *"the limit of [one's] desires, knowledge, or interests"* (Oxford Advanced American Dictionary, 2011) or *"the limit of [one's] ideas, knowledge, and experience"* (Cambridge Advanced Learner's Dictionary & Thesaurus, 2003).

In line with these descriptions and the previously elaborated theoretical (strategic management-based) perspectives, this working paper defines forecastable horizons as the limits of (our) academic knowledge and ideas which could increase future innovation and design performance in the focal areas.

Accordingly, this working paper does not aim to directly suggest operative, technical innovation and design activities to support by public policy or corporations, but instead, clear strategic directions in the focal innovation and design areas by synthetizing theoretical foundations and recent research. Furthermore, this working paper also does not aim to provide an exhaustive analysis of innovation and design activities of Hungary, V4 countries or the Carpathian basin, but instead, it aims to reflect on the applicability of the influential theories based on national strategies, resources, and opportunities.

Finally, in line with the previous phases, given the practical purpose of the working paper (supporting future policymaking on institutional and corporate levels), it (still) does not aim to be value-neutral regarding the fundamental goals (contributing to human goods), nor the research approach (future potentials and governing strategic change in the future), nor the list of frontier countries. Instead, this work uses scientifically established theoretical concepts and methodologies to support practical goals and reflects on its own assumptions, in line with the requirements of qualitative research.

1.2.2. Research questions of this working paper

Based on these objectives, there are three main questions (MQ) of this working paper:

Main question (MQ): What kind of strategic changes could facilitate innovation and design in Hungary, V4, and the Carpathian basin related to the policy, institutional, research, and corporate context?

Sub-questions (SQs, see Table 1):

SQ1: What policy, institutional, research, and corporate actions could facilitate eco- and/or energy innovation and design in Hungary, V4, and the Carpathian basin?
SQ2: What policy, institutional, research, and corporate actions could facilitate technological innovation and design in Hungary, V4, and the Carpathian basin?
SQ3: What policy, institutional, research, and corporate actions could facilitate social and/or business model innovation and design in Hungary, V4, and the Carpathian basin?
SQ4: What policy, institutional, research, and corporate actions could facilitate cultural and/or design innovation in Hungary, V4, and the Carpathian basin?

Approach		Research questions and sub-questions (SQ)			#
History and current economic development	Fundamental external factors	What similarities and differences could be identified regarding the dominant	ecological and energy	innovation and design research?	1
			technological		2
			social and business model		3
			cultural		4
	Mapping & Internal factors (change drivers)	What are the unique resources and opportunities for	ecological and energy	innovation and design activities?	5
			technological		6
			social and business model		7
			cultural		8
Recommen-dations	Governance actions	What policy, institutional, research, and corporate actions could facilitate	ecological and energy	innovation and design?	9
			technological		10
			social and business model		11
			cultural		12

Table 1. Research sub-questions of the project and this research phase

Source: authors

2. Methodology

This working paper is partly based on the systematic literature review of the previous phase, where highly cited original research articles were selected which were written by authors of frontier countries' research institutions (China, India, Israel, Japan, South Korea, and the USA). Nevertheless, this analysis goes further from two perspectives:

1. Depth of the analysis: The previous working paper focused on the interplays of innovation and design areas, and the drivers of strategic change, while now, the emphasis is on the potential models which could orient policy recommendations and corporate decision-making. This goal requires a more in-depth analysis of the selected articles.
2. Width of the analysis: The previous working paper concluded the list of frontier countries could be extended by the UK and Australia due to their dominance or increasing presence in the focal innovation and design research areas. Their involvement also helps to balance the East-West context[5].

Besides, there is a separate part in the working paper, which analyses the internal strategies, conditions, and capabilities of Hungary, V4 countries, and the Carpathian Basin. This part is built on

a) public statistical data which is related to the Carpathian Basin
b) public policies and strategies of the V4 countries, related to sustainable development and R&D&I.

The scope of the analyses involves the following fundamental aspects:

1. Theoretical routes toward governing strategic change (transdisciplinary research and development, dynamic capabilities)
2. The main trend of the past and the current innovation and design horizons[6]: Sustainable development (where relevant)
3. The main trend of the future innovation and design horizons: The potential of artificial intelligence on shaping innovation and design (as a supplementary viewpoint).

[5] There were initially more frontier countries listed from the East: China, South Korea, Japan, India.
[6] Based on the conclusion of the previous working paper

3. Shaping innovation and design horizons – Influential findings and models from frontier countries' research

In the following, frontier countries' relevant and highly cited research papers are summarized from the perspective of the practical implications.

3.1. Ecological and/or energy innovation

3.1.1. Australia

Lee and Min (2015) from Australia analyzed the data of Japanese firms while exploring the role of green R&D investment for EI. Their study is highly important regarding the incentives to invest in EI, as they find that

1. there is a negative relationship between green R&D investment and carbon emissions
2. there is a ***positive relationship between green R&D and the firms' financial performance***.

3.1.2. China

Xie et al. (2019) aimed to explore the relationship between green technology innovation and the financial performance of Chinese manufacturing firms. The authors interpreted green technology innovation as a term which involved green process innovation and green product innovation and found that both types can improve financial performance. Nevertheless, there are two mediating effects behind this causality:

1. Green process innovation supports the development of green product innovation, and green product innovation can turn green process innovation into financial value (i.e., revenue)
2. Green image of a company can help to increase financial performance based on green product innovation. (Xie, et al., 2019)

Table 2 summarizes the results of their study. It highlights that green process innovation and green product innovation are complementary, and both should be applied for competitive advantage. Moreover, ***the authors did not find evidence that green subsidies moderated the effect between green product innovation and financial performance***, which suggests that large manufacturing firms should build their green technology innovation on internal initiatives instead of external factors. (Xie, et al., 2019)

From a strategic change perspective, these findings suggest that green technology innovation must generate changes in the business model (e.g., operations, value proposition, segments) to increase financial performance.

	Does it increase financial performance?	Why / How?	Strategic change perspective
Green process innovation	Yes	Facilitates green product innovation	Production activities could be reconfigured
Green product innovation	Yes	Helps to commercialize green process innovation	Market-side of the business model, especially targeted segments and the value proposition might be modified
Green image	Yes	Increases customer awareness, influences purchasing decisions, increases demand for green products	New marketing and communications approach could be needed
Green subsidies	No	Environmental policies can change periodically	Focus on internal drivers, initiatives, project ideas

Table 2. Green technology innovation and financial performance

Source: authors, based on Xie, et al., 2019

Economic performance was also a key topic in the study of Cai and Li (2018), who focused, however, on the drivers of eco-innovation. The authors developed a conceptual model with external and internal factors, presented in Figure 1. The authors highlighted that (1) technological capabilities and (2) environmental organizational capabilities (e.g., programs and practices to reduce environmental impact) were both relevant internal drivers, and competitive pressure and customer demand are both relevant external market drivers. ***Regarding, external policy-based change drivers, market-based instruments were found to be more effective than command and control***. Finally, eco-innovation can indirectly increase economic performance, through better environmental performance, which suggests that *"environmental performance and improving economic performance are not a zero-sum game"* (Cai & Li, 2018, p. 116).

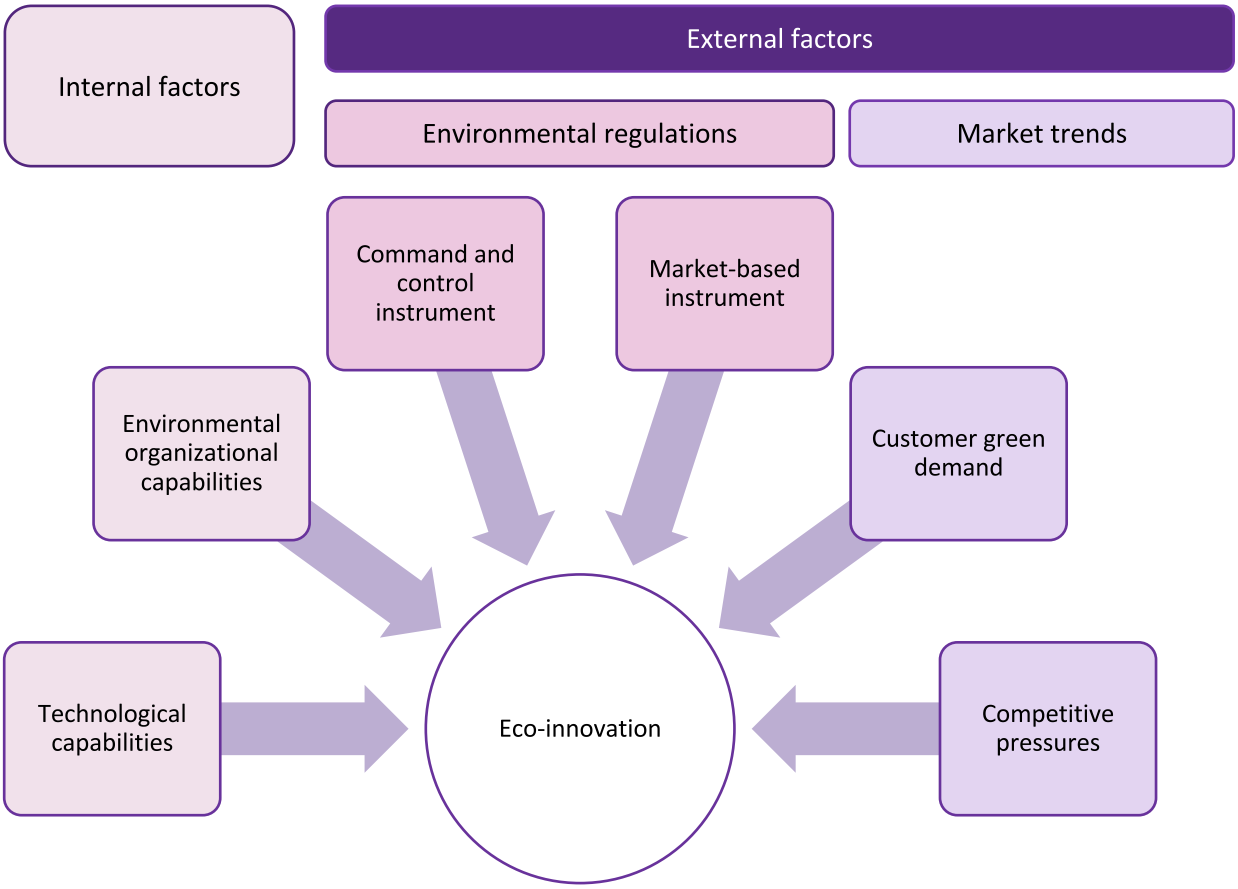


Figure 1. Drivers of eco-innovation, categorized

Source: authors, based on Cai & Li, 2018

3.1.3. India

Haldar and Sethi (2022) argued that climate change mitigation efforts should always consider the carbon footprint of the ICT sector, because of the broad use of ICT applications. Accordingly, the authors focused on the effects of ICT on the environment in emerging countries, and identified that the following factors could reduce carbon dioxide emissions:

1) increasing internet use,
2) renewable energy consumption and trade,
3) interaction between innovation and internet use,
4) renewable energy, innovation, trade, and financial development in relation to increased mobile use.

The authors highlight that only growth-related research, development, and innovation can increase carbon dioxide emissions based on their empirical data, e.g., because of the "rebound-effect" when ***customers' energy demand becomes larger when the energy efficiency increases. To avoid this phenomenon, policymakers (in emerging economies) should support "green" and "smart" innovation technologies*** (e.g., Internet of Things). (Haldar & Sethi, 2022)

3.1.4. Israel

No highly cited research articles are found in the area of eco- or energy innovation, written or co-written by institution(s) from Israel.

3.1.5. Japan

A collaboration of Japanese and Indonesian research institutes focused on the relationship between environmental performance and financial performance, based on data from Indonesian firms. Nishitani et al. (2017) found that firms that reduce greenhouse gas (GHG) emissions were more likely to increase their profit, but this was explained more by reducing production costs than increasing sales. The results of their study also suggested that ***environmental innovation performance is quite low when firms must implement environmental management involuntarily***, and that is why policy incentives might be valuable to create environmental innovations at least to improve productivity (i.e., reduce GHG emissions, as a profit growing path), and increasing sales secondly. (Nishitani, et al., 2017)

3.1.6. South Korea

Concerning eco-innovation, eco-design is a key activity which aims to eliminate *"the possible environmental impacts of a product through the incorporation of environmental attributes at the product design stage"* (Hur, et al., 2005, p. 229). Hur et al. (2005), however, argued that designers are challenged by the complex and time-consuming methods which would allow them to evaluate environmental characteristics. Consequently, the authors introduced and compared two promising methods in the context of electrical and electronic equipment (EEE). The first is the simplified life cycle assessment (SLCA) method. The simplification in case of SLCA can mean the reduction of scope for data needs or substituting actual data gathering with an existing database. On the other hand, the environmentally responsible product assessment (ERPA) matrix is a more complex method, where one dimension is the life cycle stage, while the other is the environmental concerns. From an innovation perspective, the different methods rather complement each other with different information, and SLCA could be more useful for developing a new product, while ERPA has greater potential to improve an existing one to lower its environmental impacts (Table 3). The underlying idea of these results suggests that ***not only new product development should be encouraged (i.e., eco-design) for eco-***

innovation but also the environmental-friendly improvement of existing systems (i.e., eco-redesign). (Hur, et al., 2005)

Goal	New product development	Existing product improvement
Eco-innovation content	Large	Limited
Approach	Eco-design	Eco-redesign
Preferred environmental assessment method	Simplified life cycle assessment (SLCA)	Environmentally responsible product assessment (ERPA)
Main methodological steps	Gathering actual data, substituting by database, or excluding certain stages. Potential stages: 1. **Pre-manufacturing:** • Resource acquisition and materials production (Level -3), • Sub-components manufacturing (Level -2) • Components manufacturing (Level -1) 2. **Manufacturing** (Level 0) 3. **Distribution and use** (Level 1) 4. **End-of life:** • Components recycling (Level 2) • Materials disposal (Level 3)	Creating a matrix based on (1) life cycle stage and (2) environmental concerns. Procedure: 1. **Environmental performance scoring** based on relevant issue identification 2. **Double weighting** factors: life cycle stages and environmental concerns 3. **Environmental responsibility calculation** based on score (1.) and weighting factor (2.) 4. **Priority for improvement** based on the result

Table 3. Environmental assessment methods for eco-innovation and eco-(re)design

Source: authors, based on Hur, et al., 2005

3.1.7. UK

Kesidou and Demirel (2012) focused on UK firms to explore the drivers of EI, which are discussed traditionally from two perspectives:

1. environmental economics, which emphasizes environmental regulations

2. innovation management, which highlights other determinants of EI, such as organizational capabilities as one of the supply-side factors and customer or social requirements on CSR as one of the demand-side factors.

The authors find that while demand factors, including centralized green procurements or related plans from the government, could be beneficial to boost EI, ***policies must***

1. ***support the organizational capability building***, e.g., through innovation platforms,
2. and introduce ***strict regulatory frameworks*** as well for decarbonization. (Kesidou & Demirel, 2012)

To find the proper policy interventions, not only the drivers but the barriers should be also recognized. Accordingly, de Jesus and Mendonça (2018) argued that soft and hard barriers and drivers must be differentiated:

1. Harder factors
    a. Technical drivers, e.g., availability of technologies
    b. Technical barriers, e.g., the lag between design and diffusion
    c. Economic/Financial/Market drivers, e.g., resource costs increase
    d. Economic/Financial/Market barriers, e.g., large capital requirements
2. Softer factors
    a. Institutional/Regulatory drivers, e.g., waste management directives
    b. Institutional/Regulatory barriers, e.g., misaligned incentives
    c. Social/Cultural drivers, e.g., social awareness
    d. Social/Cultural barriers, e.g., rigid business routines.

According to the authors, the drivers of the ***EI-based transition toward the circular economy belong rather to the softer factors, while hard barriers hamper the transition process***. (de Jesus & Mendonça, 2018)

3.1.8. USA

McCauley and Stephens (2012) focused on green energy clusters which are usually seen as a tool to balance economic viability and sustainability energy transition. The authors conducted qualitative research in Massachusetts and demonstrated that green energy ***cluster initiatives indeed can drive change within the energy regimes***. From a policy perspective, while supporting TI is crucial, ***cluster strategy could facilitate system-level change*** by TI and social learning. Figure 2 shows the potential cluster members and their effect. (McCauley & Stephens, 2012)

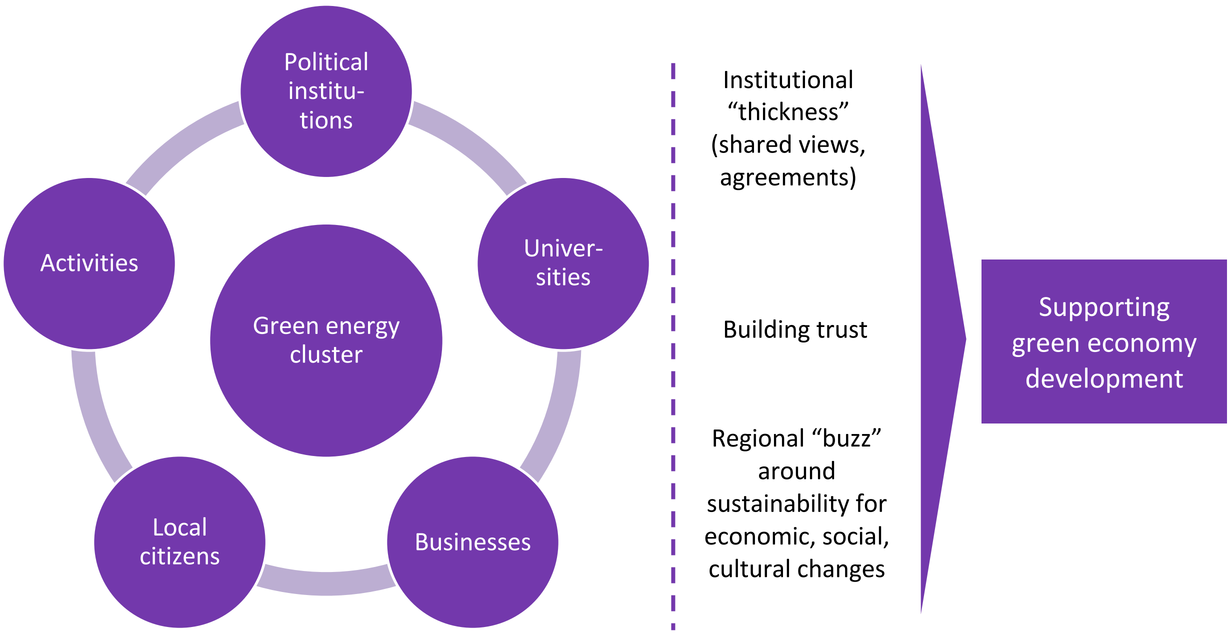


Figure 2. The role of green clusters in green economy development

Source: authors, based on McCauley & Stephens, 2012

Also, regarding energy innovation, Gaddy et al. (2017) analyzed cleantech-focused investments of venture capital funds between 2006 and 2011. The authors identified that early-stage cleantech companies, especially those which focused on new materials, chemicals and processes were underperforming compared to, for example, the software companies. Nevertheless, as there is a vast need for cleantech innovations to mitigate climate change, the authors suggest that the public sector must accelerate cleantech innovations and their commercialization in the following ways:

- Increasing support to startups and private investors, which means an alternative to venture capital funding
- Funding small business innovation programs and the expansion of provide and non-profit cleantech incubators and accelerators
- Establishing new programs for energy research institutes and providing resources
- Encouraging corporations to participate in the cleantech innovation process
- Incentivizing partnerships, including corporations, startups, incubators, to accelerate technology transfer

- Supporting entrepreneurship in national laboratories or research institutions. (Gaddy, et al., 2017)

In sum, ***sustainability-oriented change by energy innovation would require "patient capital", institutional support, and broad collaborations***, because the nature of the energy sector and green transformation (e.g., complexity, rigidity) challenges the rapid commercialization of cleantech solutions.

3.2. Technological (non-eco, non-energy) innovation

3.2.1. Australia

Murmann and Frenken (2006) introduced a systematic framework to analyze technology cycles, dominant designs, and industrial change. The authors argue that ***technological innovation cycles involve four phases*** from an evolutionary perspective, and a cycle happens at different levels of an industry, which must be interpreted as a hierarchy (Figure 3).

Hierarchical levels	Levels	Phases of every level
Highest (less cycles)	System	1. Technological discontinuity, i.e., ***variation*** 2. Era of ferment, i.e., ***substitution and competition*** 3. Dominant design, i.e., ***selection*** 4. Era of incremental change, i.e., ***retention and elaboration***.
	First-order subsystem	
	Second-order subsystem	
Lowest (more cycles)	Basic component	

Figure 3. Technological innovation levels and cycles

Source: authors, based on Murmann & Frenken, 2006

3.2.2. China

The export performance of Chinese firms was explored by Guan and Ma (2003), from the aspect of innovative capability. The authors argue that higher productivity and firm size are found to be beneficial for export competitiveness. Moreover, export growth is mainly based on innovation capability, the dimensions of which can be categorized as "core innovation assets" and "supplementary innovation assets". Table 4 details this categorization. ***Supplementary innovation assets are found to be crucial for maintained international competitiveness, as core innovation assets alone are not enough for maintained export growth***. (Guan & Ma, 2003)

Despite the literature search protocol (i.e., non-eco, non-energy), highly cited TI papers seem to be sometimes related to environmental performance. Accordingly, Ahmad et al. (2020) focused on the impact of economic growth, natural resources, and TIs on the ecological footprint in emerging economies. Based on their study, economic growth and ecological footprint are associated according to an inverted U-shape, and *"unsustainable extraction and consumption of natural resources have reached an all-time high in emerging economies"* (p. 8). Thus, regulations to stop this process are inevitable. As TIs can decrease ecological footprint, policymakers must find ways by which natural resources can be used efficiently and sustainably, even with the ***introduction of new measures and taxes to discourage fossil fuel consumption, incite the reduction of carbon emissions, and promote environmentally friendly technologies***. (Ahmad, et al., 2020)

Figure 4 presents the causalities behind the increasing ecological footprint and the potential role of TIs.

Based on these findings, TI can enable economic growth without increasing its ecological footprint, but – besides the ***aligned development scope***, e.g., for energy efficiency or lower emissions – policymakers must support, and corporate decision-makers must invest in core innovation assets (e.g., R&D and manufacturing capabilities) and supplementary innovation assets (e.g., learning and organizational capabilities).

Category	Capability	Examples for operational components
Core innovation assets	Research and development	Linking R&D to strategy and tech-competence Cross-functional screening of R&D plans Competent team leader Facilitated communication among experts Advanced designing methods
	Manufacturing	Involving in product development Advanced manufacturing technology Production regulations and system Total quality management Adjustable production process according to new design
	Marketing	Long-term customer relationships Market monitoring Understanding sub-divided market Selecting and testing innovative ideas Improving brand name
Supplementary innovation assets	Learning	Monitoring trends Reengineering ability Learning from experiences and failings Transforming knowledge into R&D guidelines Investing in learning
	Organization	Flexible structure for new projects Overlap between R&D, marketing, and manufacturing Autonomy of low managers Benchmark system Interconnection of functional departments
	Resource exploitation	Predicting new technology trends Using external technologies Attaching importance to HR HR training Steady capital supplement
	Strategy planning	Support from top management Entrepreneur spirit Enduring risk Adjusting innovation strategy based on competition Connecting technological and business strategy

Table 4. Categories and examples of innovation capabilities

Source: authors, based on Guan & Ma, 2003

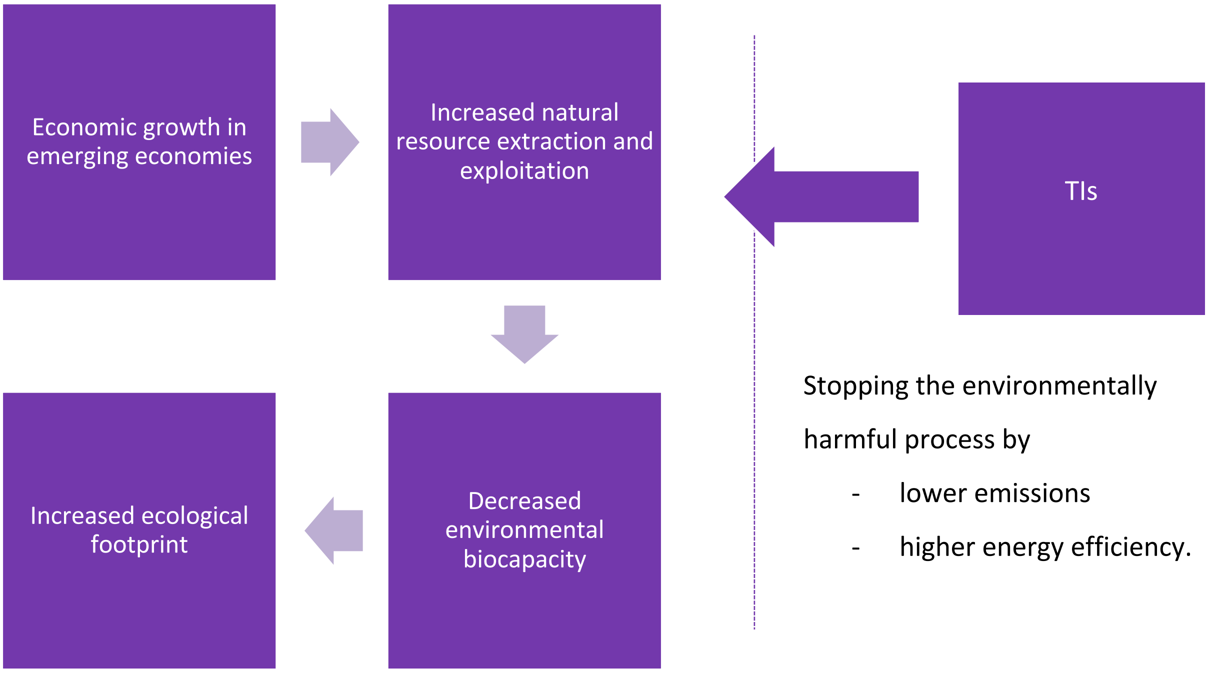


Figure 4. Economic growth and ecological footprint in emerging economies, and the role of TIs

Source: authors, based on (Ahmad, et al., 2020)

3.2.3. India

Gupta and Barua (2016) argued that micro, small, and medium enterprises are key for the economic growth of developing economies, and that is why understanding the enablers of their TI is crucial. The authors identified several potential enablers based on the literature review, of which the following are the most important:

- ***Project resources and capabilities***, i.e., people with appropriate skills and knowledge, material resources, organizational systems, and processes
- ***Technical know-how of entrepreneurs***, i.e., procedures and production-related knowledge
- ***Government policies***, i.e., facilitating technological development by a supportive context, quality standards, incubation centers, and knowledge sharing platforms. (Gupta & Barua, 2016)

The potential enables were divided into four categories by the authors. Figure 5, however, also shows that there are potential overlaps in these categories, e.g., according to organizational capabilities, industrial network resources, and other external resources.

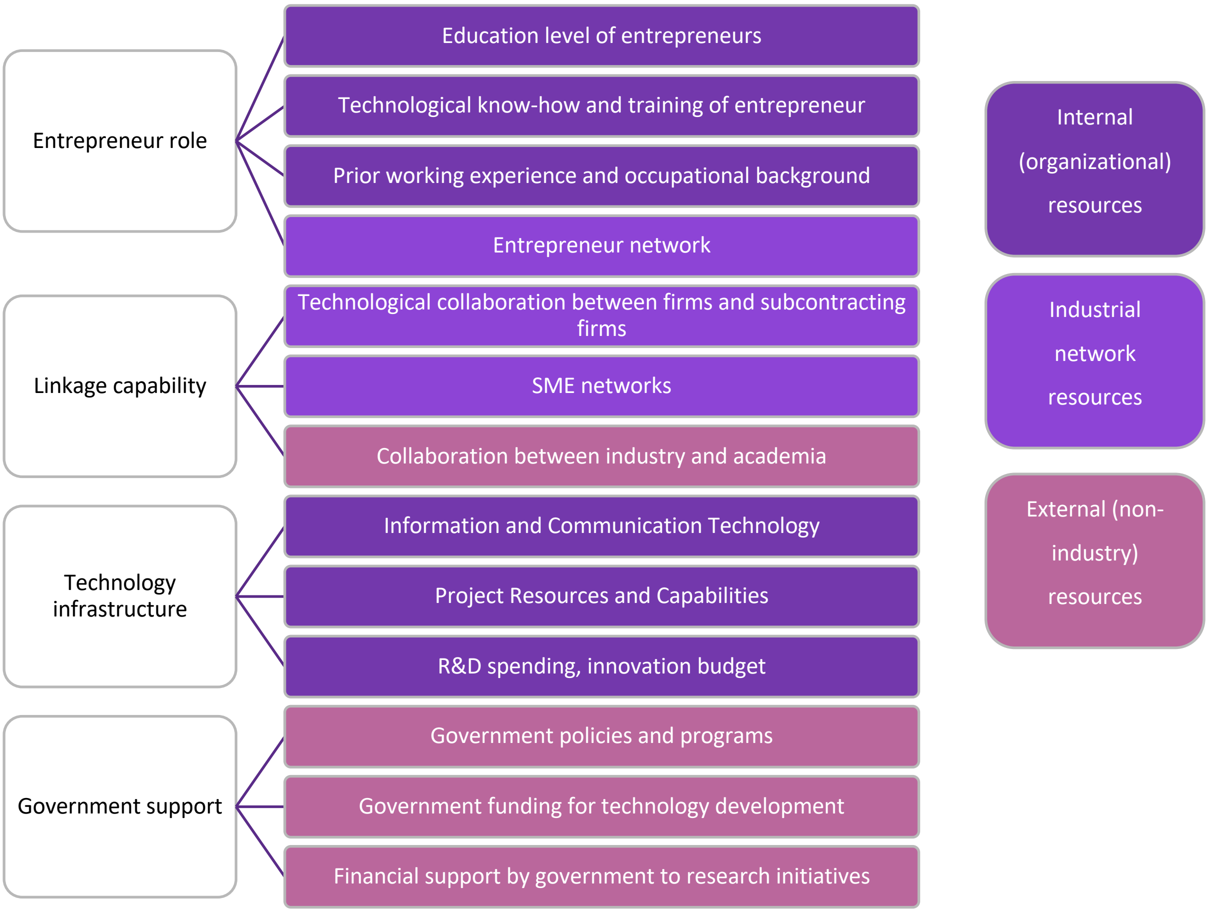


Figure 5. Enablers of TI according to different categorization perspectives

Source: authors, based on Gupta & Barua, 2016

3.2.4. Israel

The application of real-time sensors was analyzed in the agricultural sector by the collaboration of research institutions in Israel, Italy, and the USA. Halachmi et al. (2018) argued that agriculture needs more automation and TI to meet increasing demand, especially for animal products (e.g., meat, milk, eggs). The authors highlight that sensors can provide an early warning for farmers to treat individual animals even before serious medical problems, thus ***precision livestock farming (PLF) technologies could drive a "smart animal agriculture".*** (Halachmi, et al., 2018)

3.2.5. Japan

An international research project, including researchers from Japanese, Chinese, and Norwegian institutions, analyzed the role of TI and knowledge spillover on energy efficiency. Sun et al. (2021) explored how TI in a certain country affects the energy efficiency of neighboring countries. First, the authors argued that international knowledge spillover could be highly important in tackling energy and environmental problems as TIs are usually generated in just a few regions or countries. From a theoretical perspective, the authors conclude that

- ***the smaller the geographic distance, the higher the probability of the knowledge spillover***
- ***knowledge spillover (in relation to TI) indeed improves energy efficiency***.

From a practical perspective, the technological gap between countries was highlighted, as *"US and Japan alone accounting for about 60% of these technologies"*. (Sun, et al., 2021, p. 9)

Based on these findings, sustainability-related strategic change within the energy system could be driven by

- facilitating international cooperation and developing knowledge-sharing platforms (from a policy perspective),
- developing absorptive capacity, focusing on international markets (from a corporate perspective).

3.2.6. South Korea

Despite the affiliation, one of the most cited works from a South Korean institution was focusing on China and its carbon dioxide emissions. Liu and Bae (2018) analyzed the linkage among carbon dioxide emissions, energy intensity, GDP, industrialization and urbanization over the period from 1970 to 2015. Their key results are presented in Table 5. CO_2 emissions might be increased because of all the individual factors. The authors suggest policy implications:

1. Green and sustainable urbanization which increases economic growth without environmental harm, by using more renewable energy toward solar lighting, heating systems or transportation;
2. Reforming heavy and chemical industries (which are the main contributors to CO_2 emission) by environmental technologies and administrative means;
3. Improving energy efficiency and TI focusing on reducing energy waste, renewable energy use, accelerated by scientific and international research and development;
4. Increasing the share of renewable energy by infrastructure investment and cost-reduction initiatives. (Liu & Bae, 2018)

In sum, the authors suggest a ***central intervention in China to drive strategic changes toward maintained economic growth and decreased environmental harm***. From a corporate adaptation perspective, energy efficiency and renewable energy use are found to be key directions of TI in urban and industrial contexts.

1% augments of…	Result in CO_2 emissions	Definition of the variable	Suggestions for policymaking
Energy intensity	+ 1,1%	Energy intensity: Energy use in kg of oil equivalent relative to GDP	• Increasing renewable energy use • Improving energy efficiency • TI
GDP	+ 0,6 %	-	
Industrialization	+ 0,3 %	Industrialization: Share of industrial value added in GDP	• Strategically adjusting and optimizing industrial structure
Urbanization	+ 1,0%	Urbanization: Share of urban population in total population	• Encouraging green and sustainable urbanization

Table 5. The impact of urbanization and industrialization on carbon dioxide emissions in China

Source: authors, based on Liu & Bae, 2018

3.2.7. UK

In line with the insights of the second working paper, the most cited TI study from the UK focuses on healthcare. Greenhalgh et al. (2017) aimed to develop a pragmatic framework which helps to predict and analyze the ***nonadoption, abandonment, and scale-up challenges of programs with new health and social care technologies***. Their study explored varied challenges in seven domains:

1. the condition or illness,
2. the technology,
3. the value proposition,
4. the adopter system,
5. the organization(s),
6. the wider (institutional and societal) context,
7. the interaction and mutual adaptation between all these domains over time. (Greenhalgh, et al., 2017)

3.2.8. USA

In case of the TI-focused articles which were written by scientists of USA-located institutions, two of the most-cited ones are related to concrete challenges, i.e., ***healthcare (Heidenreich, et al., 2013) and nanotechnology in water management*** (Qu, et al., 2013). This phenomenon is unexpected based on the findings of the first phase which showed that most-cited Western review papers are more focused on how to generate TIs for business success, and less focused on concrete technologies (in contrast to the most-cited Eastern review papers). Nevertheless, it suggests a degree of Western thought leadership regarding the practical contexts of TI. The above-mentioned dominance of general TI studies, however, is present in case of original research as well.

Ahuja (2000) argued that there are usually two overarching reasons behind interfirm linkages. First, *inducement* can cover strategic or resource needs (e.g., companies need to learn new skills). Second, *opportunities* are based on the position in the prior network structure. In this context, the author explored three types of capital which played a crucial role regarding inducements and opportunities for collaboration:

1. Technical capital, i.e., capability to produce new technologies, products, or processes;
2. Commercial capital, i.e., complementary assets which are required to commercialize new solutions and generate profits from them;
3. Social capital, i.e., prior relations in the inter-organizational networks which come with information and status benefits.

These capital stocks can be accumulated and the firms which own high levels of technical, commercial, and social capital are in a more advantageous position than others. Moreover, resources are found to be highly influential regarding the formation of interfirm linkages (i.e., changes in the inter-organizational network), which is mainly characterized by the exchange of those resources which are not obtainable on the market. (Ahuja, 2000)

These findings have relevance from the perspective of public policy-making and corporate decision-making as well, as detailed in Table 6.

	Phenomenon	Conclusion in theory	Implication in practice
Public policy	Companies which are strong in technological capabilities, collaboration history and commercial assets can obtain partners more easily	Restrictive or liberal anti-trust policies do not affect market leaders and smaller firms similarly	***Industries with high network externalities, e.g., software, can become anticompetitive without restrictive regulation***
Managerial decisions	A firm is unwilling to collaborate with another firm if it should share its valuable, *"supernormal profit generating"* (p. 338) resource in exchange for only a factor that can be obtained on the market	There is an *"interfirm linkage market"* where potential partners are evaluated based on the volume/existence of non-tradable factors (unique resources) and the contribution for competitive advantage	***Managers should provide access to a key resource for another firm only if they can get also a valuable resource in exchange, or alternatively, if only a tradable asset is available, it should be undervalued as a contribution during the collaboration***

Table 6. Policy-making and decision-making implications of collaboration-forming dynamics

Source: authors, based on Ahuja, 2000

Understanding this role of social, commercial, and technical capital might be useful to turn previously identified theoretical opportunities into practical actions[7], i.e., establishing innovation eco-systems for eco-innovation (Mirabella, et al., 2014) or managing interfirm dynamics in the paradigm of open innovation (West & Bogers, 2014).

Reaching back to another influential thought of Western TI, Benner and Tuschman (2002) explored empirical evidence about the exploitative role of process management which was later discussed in a highly cited review[8] article as well (Benner & Tushman, 2003). Based on their longitudinal study in the paint and photography industries, emphasis on process management has resulted in increased exploitation and exploitative innovations (which are based on existing knowledge), but this efficiency focus might threaten exploration and long-term adaptation. One of their concluding arguments seems to be still relevant and advises caution for decision-makers:

[7] Identified in the first working paper
[8] As presented in the first working paper

"Even as organizations are exhorted to innovate in times of rapid technological change, process management activities focused on mapping, incrementally improving, and adhering to organizational processes have been widely adopted. These activities aimed at refining and stabilizing processes may be in conflict with exploratory innovation required for adaptation as environments change." (Benner & Tuschman, 2002, p. 702)

Accordingly, in the current era of rapid technological changes (e.g., artificial intelligence), moreover, social and geopolitical changes (e.g., pandemics, war), ***too much emphasis on process management might be counter-productive*** where disruptive, breakthrough or radical innovations would be needed or beneficial.

3.3. Social and/or business model innovation

3.3.1. Australia

Almost 15 years ago, Pol and Ville (2009) focused on the question of whether social innovation is only a buzzword or an enduring term. While social innovation remained an important topic, their approach to developing desirable social innovations might be still relevant. The authors differentiate social innovations from business innovations which generate consumer products, and *"often bring improvements to human welfare by widening the range of goods and services available to us"* (p. 882). In contrast, *"a desirable social innovation is one that in fact ('in fact' meaning 'there is convincing evidence') improves the macro-quality of life or extends life expectancy"* (p. 882). From a policy perspective, the authors argue that ***governments can incite and support social innovators, e.g., through prizes, as pure social innovations generate only public goods, for which private markets are unlikely to show significant interest***. (Pol & Ville, 2009)

3.3.2. China

Focusing on Chinese firms, Guo et al. (2016) found empirical evidence for the positive relationship between ***exploratory orientation and BMI, while opportunity recognition and entrepreneurial bricolage can support this process***. The interrelations of these key terms and their definitions are presented in Table 7.

Framework	Term	Role	Definition
Orientation	Exploratory orientation	Antecedent of BMI	Strategic orientation towards experimenting with new alternatives and developing new ways of doing business (p. 534)
Action	Opportunity recognition	Mediating role between exploratory orientation and BMI	Identifying opportunities, finding changes in market demands and customer preferences, avoiding intense competition, and achieving superior performance (p. 534, 538)
	Entrepreneurial bricolage		Active engagement with problems or opportunities, and applying combinations of resources at hand (cheap or free) for new purposes to solve problems and seize opportunities; creating something from nothing (p. 538)
Outcome	BMI	A key for sustained competitive advantage	Identify potential opportunities and coordinating resources to capture those opportunities (p. 534); it is a process of experimentation (p. 536)

Table 7. Orientation-action-outcome framework for business model innovation

Source: authors, based on Guo, et al., 2016

However, business models and social innovations could be also interrelated, as presented by Wu et al (2020) in the context of barrier-free transportation. The collaborative research of Chinese and Taiwanese institutions illustrated how a ***social business model can be aimed to satisfy the transport needs of the elderly and disabled people, supported by ICT integration***. The authors argue finding self-maintained operations by new business models is important for non-profit organizations, but new technology-based solutions, such as mobile-based services and ICT must be used for integrating service providers (e.g., operating a mobile information platform) and government resources. (Wu, et al., 2020)

3.3.3. India

Based on the collaboration of an Indian and a Croatian research institute, Šlaus & Jacobs (2011) focused on the human capital, and mainly the role of education in ensuring sustainability. The authors argue that education affects every aspect of human existence, from fertility rates to social innovation or patterns of consumption, and these factors affect sustainable development. According to the authors, *„the continuous evolution of human consciousness is the ultimate determinant of sustainability"* (p. 147), and that is why the development of human capacities and human welfare must be the central elements of sustainable development strategies*. **In the context of social innovation, working against***

inequality could be a main driver, as it could reduce economic development and inhibit entrepreneurship, however, a higher quality of consciousness could increase creativity and capacity for invention and innovation. (Šlaus & Jacobs, 2011)

3.3.4. Israel

No highly cited research articles are found in the area of social or business model innovation, written or co-written by institution(s) from Israel.

3.3.5. Japan

No highly cited research articles are found in the area of social or business model innovation, written or co-written by institution(s) from Japan.

3.3.6. South Korea

Urban policy for sustainability transitions can be not only relevant in case of energy efficiency and eco-innovation but in social innovations as well. According to Wolfram (2018), cities are crucial places of socio-technical transitions toward sustainability, because these can be incubators and catalysts of social, economic, and environmental change – besides their inherent relevance in the urbanized world. Based on the case study of Seoul, the author identified four key areas where urban policy could play an important role in accelerating grassroots transitions (Table 8). (Wolfram, 2018)

Pathways	Main elements
Urban empowerment capacities	• Developing methods for anticipation, socio-political feedback and learning • Ensuring inclusiveness, legitimacy, effectiveness • Avoiding creating new divides
Embedded holistic innovation	• Inducing changes in individual behavior, social behavior and/or structure, and technology • Maximizing synergies for economic, social, and ecological benefits
Novel community-oriented governance modes	• New urban governance arrangement for welfare, inclusion, education, and care • Involving organizations and individuals from different sectors (e.g., local public, civil society) • Sharing knowledge, concerns, expectations
Urban niche/regime interactions	• Urban institutional thickness building with trust between grassroots innovators and regime actors • Legitimation of new practices, enabling linking policy, cognitive changes (e.g., using new words for reframing phenomena), and knowledge transfer

Table 8. Social innovation pathways of urban policy for sustainable transitions

Source: authors, based on Wolfram, 2018

3.3.7. UK

One of the key terms of the social innovation-related discussions is social entrepreneurship. Focusing on this, Dacin et al. (2011) offered five avenues for research, which have practical significance as well:

1. ***Institutions*** and social movements, e.g., managing the institutional conflict of for-profit and nonprofit logic, creating new institutions and transforming existing ones through social innovation
2. ***Networks***, e.g., building and leveraging networks through which they follow their social mission and implement strategies
3. ***Culture***, e.g., rituals through which social value creation is evaluated and celebrated
4. ***Identity and image***, e.g., the brands of social entrepreneurs and social entrepreneurial communities and their impacts on social interactions
5. ***Cognition***, e.g., specific knowledge structure and information-processing capacities which enable social entrepreneurship and innovation.

3.3.8. USA

Casadesus-Masanell and Zhu (2012) reached back to Schumpeter who differentiated five types of innovation in 1934 and argued that (1) new products and (2) new methods of production were mainly in the scope of the literature for several decades, while (3) new sources of supply and (4) exploitation of new markets had got less attention. Most importantly, (5) new ways to organize business were also often overlooked which the authors identify as the same as business model innovation (BMI). The authors highlight that there are competitive effects which should be considered before revealing a BMI (Figure 6). From a social and policy perspective, it is important ***entrants might hide ideas related to the implementation of BMI (strategic concealment). It is because of the power of the incumbents who might easily copy the model with other competitive advantages based on the existing resources. This strategic concealment does not help improve social welfare***, and even though intellectual property regulation could involve BMI ideas, its realization in practice would be challenging. (Casadesus-Masanell & Zhu, 2012)

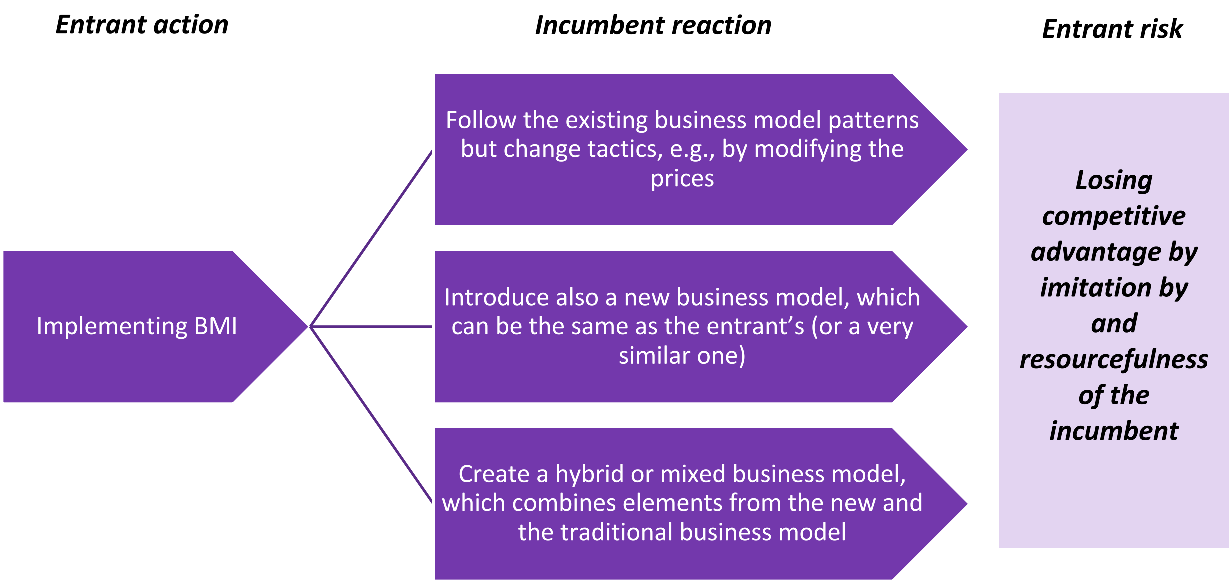


Figure 6. Dynamics of competitive imitation in case of business model innovation

Source: authors, based on Casadesus-Masanell & Zhu, 2012

Regarding social innovation, Mumford (2002) reached back to historical lessons, in particular, ten cases from Benjamin Franklin. The author defines social innovation as ***"the generation and implementation of new ideas about how people should organize interpersonal activities, or social interactions, to***

meet one or more common goals" (Mumford, 2002, p. 253). Based on the analysis of the historical cases, eight conclusions were highlighted for supporting the social innovation activities of modern organizations, as presented in Table 9.

	Social innovation principles
Problem definition	1) Experience-based problem definition, responding to a practical need, recognizing emergent ideas and envisioning broader implications 2) A limited number of manageable key causes, finding central and essential elements
Idea and solution search	3) Building on talented, marginal individuals and unique, experimental approach 4) Finding a solution which opens the door for further developments
Implementation	5) Ensuring dedicated resources, mainly time and resources 6) Quick demonstration with low cost, generating culturally and technologically appropriate benefits, orchestration of (experimental) projects
Long-term effects	7) Involving persuasion, but the idea must be more important than the recognition of the innovator 8) Willingness to restructure social relationships

Table 9. Principles of social innovation based on historical examples

Source: Authors, based on, based on Mumford, 2002

3.4. Cultural and/or design innovation

3.4.1. Australia

The study of Beverland (2005) aimed to solve the potential conflict between design innovation and brand marketing, as designers *"value professional ideals that are often in conflict with corporate mental models of a 'good product'. Instead, they respond to positive press reviews and peer awards"* (p. 195). As this is a frequent case in many luxury segments, including winemaking, the author focused its empirical research on this industry and found five design innovation values which can be against branding and marketing:

1. Remaining true to craft, i.e., retaining traditions even if trends are changing
2. Remaining true to the expressions of place, i.e., which induces a unique and pre-defined positioning
3. Stylistic consistency, i.e., evolving the style within narrow boundaries and not according to large markets

4. Live up to the brands' heritage, i.e., being reluctant to change products in relation to new marketing conditions
5. Remaining current, indicating that marketers also know that there is a fine line between tradition and approaching new customer segments.

To ***integrate design innovation and marketing***, a few solutions were suggested: ***top-leadership support and integration at the strategic level, encouraging designers to be in the market, intergenerational teams, and decoupling branding and production*** (e.g., traditional brand, but modern production behind the scenes). (Beverland, 2005)

3.4.2. China

Regarding cultural and design innovation, Chinese institutions seem to collaborate with other countries, as highly cited standalone Chinese research seems to be rare in this area. In line with the findings of the meta-review, influential original research of Chinese institutions is more concerned about design innovation in a technical or business context rather than in a cultural one. Accordingly, based on the collaboration of researchers from England and China, Liu et al. (2020) argued that product engineers could benefit from online customer insights to generate design innovations, however, the capacity of small and medium-sized companies (SMEs) for this activity was limited. As SMEs would be interested in using big data analytics but they sense a risk of choosing the wrong tools, the authors suggested that ***SMEs could follow a cloud-based approach in case of big customer data analytics*** to exploit its potential for design innovation. (Liu, et al., 2020)

Nevertheless, cultural innovation is also apparent, but interestingly, only based on the collaboration with a North American research institute. According to Wang et al. (2011), eco-sustainability is needed for which the approach of the ancient Chinese human ecological philosophy should be followed. Regarding its foundations, there is an ecoscape, which integrates natural, economic, and social subsystems (Figure 7). The authors argue that the ***pathways toward sustainability require not only technological and institutional innovation, but cultural innovation***. The authors also developed an ***ecopolis model***, on the top of which is ***eco-culture***:

"to give people the opportunity to develop their culture and quality of life through an understanding of their own place in nature, their own responsibility for the environment, and their own ability to contribute to maintaining high quality urban ecosystems through applying holistic integrative ecological principles in their every day lives. By combining cultural and ecological traditions with modern eco-technologies, every city can enhance its own special and unique characteristics and its cultural and environmental identity." (Wang, et al., 2011, p. 27)

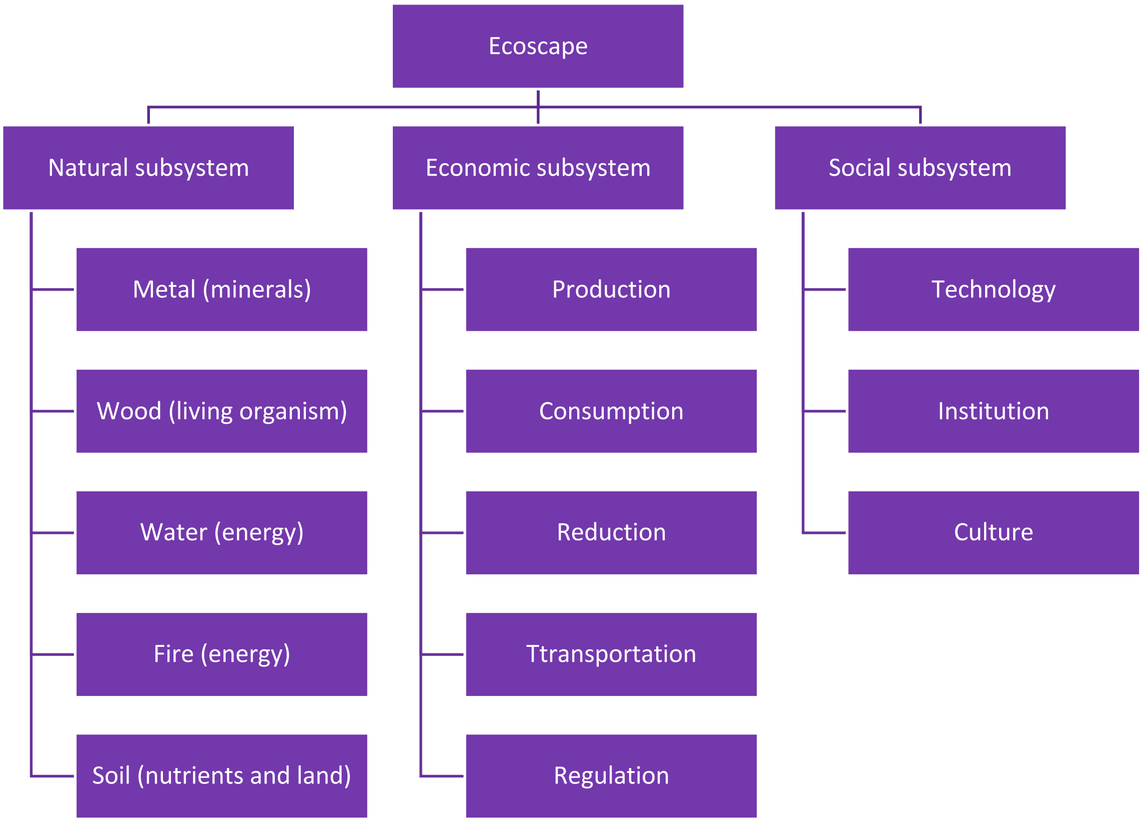


Figure 7. Subsystems of the ecoscape based on traditional Chinese human ecological philosophy

Source: authors, based on Wang, et al., 2011

3.4.3. India

The most influential design innovation article from an Indian research institute is an outcome of a collaboration with the USA (and France). Goyal et al. (2018) highlighted that the linear economic model must be replaced by the circular economy model, because of the limits of natural resource exploitation. The authors examined drivers of companies to implement business models which centrally integrate reduce, reuse, and recycle activities. In the value proposition part of the new business models, *"companies need to focus on* ***design of products and services****, which can address the multiple social or environmental needs of the society"*, but the ***redesign of logistics and distribution channels*** would be also required. (Goyal, et al., 2018, p. 738)

3.4.4. Israel

No highly cited research articles are found in the area of cultural or design innovation, written or co-written by institution(s) from Israel.

3.4.5. Japan

The most cited original research article of Japanese institutes also focuses on technology. Accordingly, Nakamura et al. (2013) mentioned that ***sustainability science would require design innovation, and analyzed a concrete technology (advanced turboprop (ATP) engine) in the aviation industry***. From a theoretical perspective, the authors highlighted that the innovation diffusion-related *"learning processes at multiple stages where the actors related to the niche learn about the design, user needs, cultural and political acceptability, and other aspects of the niche".* (Nakamura, et al., 2013, p. 89)

3.4.6. South Korea

As innovation is one of the success drivers of firms, and product designers can be challenged by the ever-changing customer needs, Moon et al. (2013) aimed to develop a conceptual definition for design innovation. According to the authors, three main constructs must be differentiated, as detailed in Table 10. The authors highlight the role of cultural differences as well. For example, they found that ***customers in the USA might not be less interested in technical features (i.e., technical design value), than in good-looking shape (i.e., humanistic value)***. (Moon, et al., 2013)

Term	Definition	Categories
Design innovation	*"A new or substantially improved product design (aesthetic attributes) and product features that are introduced to satisfy customer needs"* (p. 34)	• Aesthetic attributes • Feature attributes • Emotional attributes
Design value	*"A value that reflects customers' preferences based on improved product shape and features that satisfy their needs"* (p. 34)	• Humanistic value • Technical value
Customer value	*"The difference between what customers receive relative to what they give up"* (p. 35)	• Product-related • Service-related • Promotion-related

Table 10. Key constructs of design innovation

Source: authors, based on Moon, et al., 2013

3.4.7. UK

In the cultural innovation area, Shennan (2001) analyzed the relationship between demography and innovation by computer simulations, as the analogy between genetic transmission of information and cultural transmission processes were dominant research topics. The author found that ***larger populations benefit more from the consequences of innovation compared to smaller ones***, and also, *"the origins of modern human culture in the last 50,000 years […] may be seen not as the result of genetic mutations leading to improved cognitive capacities of individuals, but as a population consequence of the demographic growth and increased contact range which are evident at this time"* (p. 5). Accordingly, demography might have a crucial role in understanding cultural evolution. (Shennan, 2001)

3.4.8. USA

The most influential article on the cultural innovation area is related to a book by Richard Florida, titled "The Rise of the Creative Class: And how it's Transforming Work, Leisure, Community and Everyday" from 2002. Nevertheless, Pack (2005) presents a critical approach to the book. The author summarizes the focal concept as *"urban fortunes increasingly turn on the capacity to attract, retain and even pamper a mobile and finicky class of 'creatives', whose aggregate efforts have become the primary drivers of economic development — has proved to be a hugely seductive one for civic leaders around the world"* (p. 740). However, it is also pointed out that ***the concept of the creative class's emergence or preferred dominance in urban policy, contains politically ambivalent arguments***, as it "*mixes cosmopolitan elitism and pop universalism, hedonism and responsibility, cultural radicalism and economic conservatism, casual and causal inference, and social libertarianism and business realism"* (p. 741). The author identified this trend as a liberal cultural innovation, which is focused on creatives who must feel welcomed (e.g., by diversity, tolerance), but also highlights practical shortcomings and critique of this approach, such as

- the correlation of economic development and certain cultural traits can be contingent and debatable
- even though civic leaders can facilitate creativity, the time and place of creative breakthroughs are almost impossible to predict
- the concept can be offensive for certain stakeholder groups, such as, those who would promote business-oriented development strategies of cities, suburban lifestyle, or conservative values. (Peck, 2005)

Cultural innovation, however, can not only induce new socio-economic development structures but new organizational forms as well, as argued by Rao et al. (2000). Their approach emphasizes that organizational forms can be also induced by a political process with collective action, not only TI or transaction costs. The authors highlight two main factors in this process which can induce intraorganizational change and discontinuities, and four sources of change which are mainly related to organizational or market failures (Table 11).

Category	Factor	Brief description
Direct drivers of change	***Social movements***	De-institutionalize beliefs, norms, and values
	Institutional entrepreneurs	Identify political opportunities, frames issues, and mobilize people
Sources / Basis of change, problems with legitimacy	***The failure of trade associations***	Organizational decisions can affect the distribution of benefits, but stakeholder groups attempt to influence these decisions at others' expense (influence costs)
	The inadequacy of "normal" incentives	Early entrants and pioneers bear the costs of legitimization (e.g., technical standards), which can be lower in case of later entrants. Although actors can choose to become early entrants hoping larger market share than later entrants, sometimes these incentives do not exist or are not enough to accelerate progress.
	The failure of market mechanisms to reduce social costs	Market mechanisms are unable to reduce negative externalities when transaction distance is too large or victims are uniformed (e.g., polluting air in another country)
	The exclusion of actors from conventional channels	Certain actors or groups can be excluded from access to certain tools, e.g., legal recourse, media exposure, support of state agencies, because of which they discredit existing arrangements

Table 11. Cultural and social factors which can drive and legitimate the creation of new organizational forms

Source: authors, based on Rao, et al., 2000

4. Supplementary perspectives

4.1. Trending research in 2020-2022 concerning innovation and design interplays

Since interplays of innovation and design areas are key change drivers (besides sustainable development), the following sections provide an overview of the emerging topics and the dominant countries based on the highly cited research from 2020-2022[9]. The analysis focuses on the integration of 2-2 areas of innovation and design (e.g., TI and SBMI). Moreover, in this phase, "author keywords" should be in scope instead of the "index keywords". Author keywords are more diverse, and so, could indicate emerging topics which have not been standardized yet as "index keywords" (Figures 8-12).

Table 12 summarizes the results. Regarding the countries, the results show that if EEI is relevant, China and Pakistan dominate in terms of the number of highly cited research papers, while SBMI, TI, and CDI areas are more influenced by Western studies. Interestingly, Turkey is also present among these influential countries for the last 2-3 years. The lowest international collaboration seems to be in case of TI and SBMI (based on the number of relations among countries).

Keywords in different groupings show a few patterns of 2020-2022, indicate potential transdisciplinary research directions, and some of them reinforce previous findings from the analysis of 2000-2022:

1) Naturally, the keyword clouds of the combined areas must show overlaps, but the circular economy is dominant in all the areas. This result suggests that the main change driver based on the literature of 2000-2022, i.e., sustainable development, is increasingly discussed in the recent literature (2020-2022) from the aspect of circular economy.
2) Since COVID-19 was a key topic in 2020-2022, it is also reflected in multiple areas of innovation and design research.
3) The most polarized thematic map belongs to the integrated view CDI and SBMI, based on the many different author keywords. This also indicates that the overlap of these two areas could be low.
4) Regarding the less frequent but relevant[10] author keywords, although artificial intelligence indeed appears in case of technological innovation, Big Data and smart solutions are mentioned more times and in more areas. It can be explained by the

[9] The database is the same as detailed in the second working paper.
[10] Based on the direct connection to at least one of the innovation and design areas.

significant novelty of AI research, and the limited number of technological innovation research in the sample[11].

Combined areas (interplays)	Top countries (based on highly cited papers in 2020-2022)	Frequent author keywords (examples)	Less frequent, but relevant keywords (examples)
TI & SBMI	Sweden, USA, Finland, UK, Netherlands, Germany, China	Covid-19, Industry 4.0, IoT, Circular economy, Circular Business models, Digital transformation, Digital technology	Artificial intelligence, Machine learning, Blockchain, Digital Startups, Big data, Lean startup approaches, Smart cities, Telecommunications infrastructure, Sensor networks, Online learning
TI & EEI	China, Pakistan, Spain, Turkey, USA	Fiscal decentralization, Circular economy, Renewable energy consumption, Carbon neutrality	Green growth, Green patents, consumption based carbon emissions, carbon tax, international trade
TI & CDI	USA, China, UK, Spain	Sustainability, Cultural evolution, Circular economy, Covid-19, Industry 4.0	Big data, Smart Product, Smart battery Bioeconomy, Creativity, Branding, UX
CDI & EEI	China, Pakistan, UK, United States, Spain, Turkey, France	Renewable energy, CO_2 emissions, Circular economy, GHG, Globalization, Financial development	Green packaging, Bio-based production, Big data analytics, Zero carbon act, Modern human origins, Human risk assessment tools
CDI & SBMI	UK, USA, Sweden, Germany, Netherlands, Italy	Circular economy, Digital transformation, Dynamic capabilities, Value creation, Sustainability, Covid-19, Nature-based solutions	Knowledge management capabilities, Data-driven design, Multi-dimensional sensing, Population structure, Digital servitization, Agile development, Environmentalism
EEI & SBMI	China, Pakistan, UK, Italy, Spain, Sweden, Turkey	Renewable energy consumption, Circular economy, Dynamic capabilities, Renewable energy, Financial development	Open innovation, Urbanization, Human capital, Energy productivity, Sustainable development goals, System innovation, Quintuple helix model

Table 12. Influential countries, frequent and less frequent keywords based on the combined views of innovation and design areas (2020-2022), indicating potential transdisciplinary research directions

Source: authors

[11] As detailed in the second working paper, the top-cited 250 articles were involved from every area.

Figure 8. Recent trends in technological innovation and social or business model innovation research (2020-2022)

Figure 9. Recent trends in technological innovation and eco- or energy innovation research (2020-2022)

Figure 10. Recent trends in technological innovation and cultural or design innovation research (2020-2022)

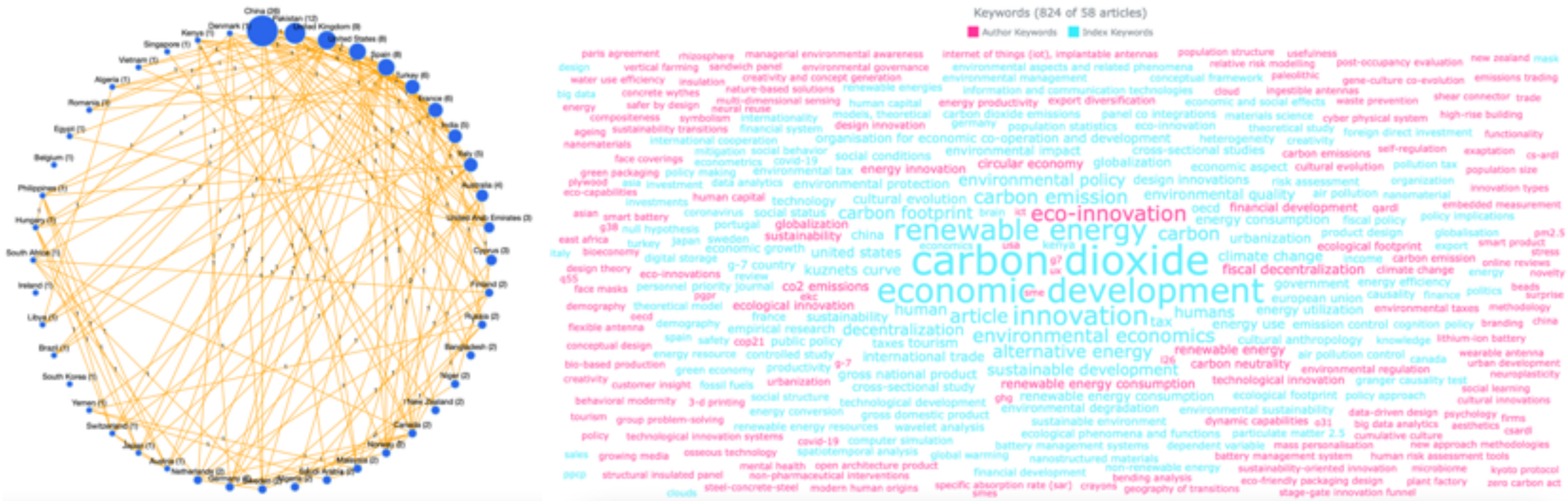


Figure 11. Recent trends in cultural or design innovation and eco- or energy innovation research (2020-2022)

Figure 12. Recent trends in cultural or design innovation and social or business model innovation research (2020-2022)

Figure 13. Recent trends in eco- or energy and social or business model innovation research (2020-2022)

4.2. Absorptive capacity

Absorptive capacity enables an organization or an individual to grasp relevant information, data, or knowledge from the external environment (e.g., the market in case of a firm) and leverage, use them to make better decisions (Shi, et al., 2018). Nevertheless, absorptive capacity is not only related to decisions but innovation as well, as detailed by Cohen and Levinthal (1990) from a corporate perspective. The authors developed a model which shows that learning incentives (to build absorptive capacity) affect R&D spending. If the volume of valuable knowledge to be absorbed and exploited is high, the incentive is also high for learning. For example, there could be new academic knowledge (technological opportunity), and profits could be captured from the potential innovation if this knowledge has not spilled out to competitors and/or the competitors have not exploited it yet (appropriability and competitor interdependence) (Figure 14). Nevertheless, characteristics of knowledge elements may vary: some elements could be more difficult to assimilate and would require prior knowledge from R&D. This argument suggests that absorptive capacity and R&D performance are path-dependent, i.e., ***"lack of investment in an area of expertise early on may foreclose the future development of a technical capability in that area"*** (Cohen & Levinthal, 1990, p. 128).

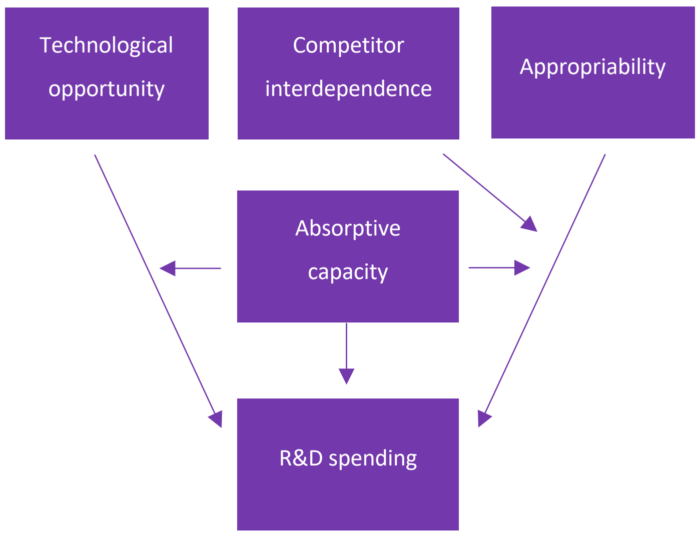


Figure 14. Model of absorptive capacity and R&D incentives

Source: Cohen & Levinthal, 1990

Consequently, corporate decision-makers and public policymakers should support external learning in general, and especially ***prioritize those innovation and design areas which are strategically important before the lack of early investments became a competitive disadvantage because of the more advanced R&D results of the competitors***.

4.3. The potential impact of AI on future innovation and design horizons

4.3.1. AI for innovation and design management

Before addressing the impact of AI, the definition of AI must be clarified. Artificial intelligence is here defined as “*the frontier of computational advancements that references human intelligence in addressing ever more complex decision-making problems.*” (Berente, et al., 2021, p. 12). Furthermore, the dimensions and facets of the AI must be differentiated:

1) The performance frontier means the execution of tasks, which is ever-improving, while the scope frontier means the contexts of application, which is ever-expanding.
2) The autonomy facet of AI means whether the AI can act without human intervention; learning means how improvements are realized based on data and experience; and inscrutability refers to the phenomenon that certain complex algorithmic models will not be (are not) intelligible for many or any human groups. (Berente, et al., 2021)

Based on these differentiation, one can argue that the scope frontier is key for innovation and design management, i.e., how to use AI solutions to enhance innovation and design performance, but the upcoming advancements in the performance dimension, autonomy, learning and inscrutability will open new opportunities (and challenges) for this.

Based on the current state of art, four AI application areas can be identified in the innovation process:

1) **Developing ideas** in case of **information processing constraints:** Identifying and evaluating *more* information to further develop ideas
2) **Generate ideas** in case of **information processing constraints:** Recognizing *more* opportunities, problems, and threats which can lead to new ideas
3) **Developing ideas** in case of **ineffective or local search routines:** Identifying and evaluating more *creative and exploratory* ideas
4) **Generate ideas** in case of **ineffective or local search routines:** Recognizing more *creative and exploratory* opportunities, problems, and threats which can lead to new ideas. (Haefner, et al., 2021)

In contrast, AI-empowered design could not only support the process but also reconfigure the whole design cycle. Accordingly, while the traditional human-intensive design practice is based on cycles of (1) design, (2) make, and (3) use phases, the so-called AI factories work with a problem-solving loop after the design phase (Figure 15). (Verganti, et al., 2020)

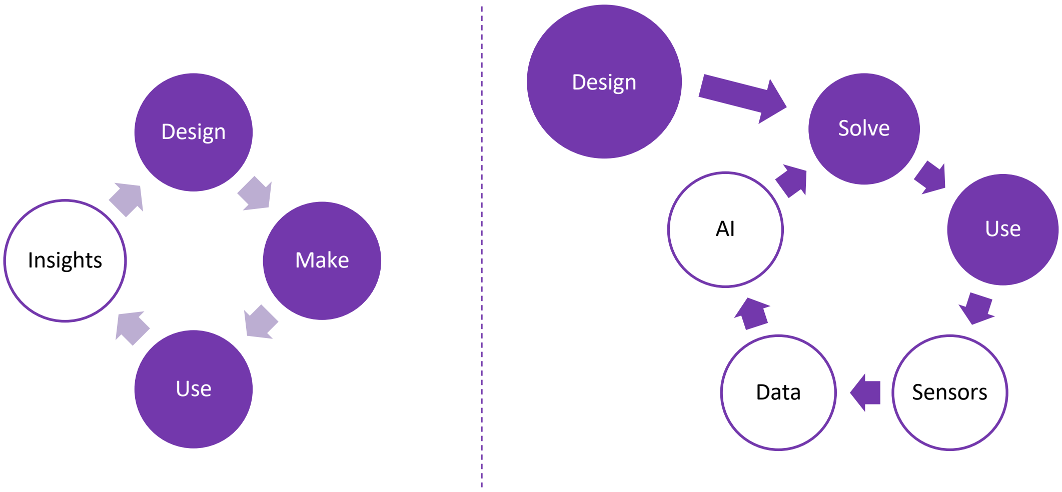


Figure 15. Traditional human-intensive design practice versus AI-based design practice

Source: authors, based on (Verganti, et al., 2020)

4.3.2. AI adoption for sustainable development and innovation

The recent literature also argues that sustainability can be the driver and also the outcome of AI adoption. For example, Mariani et al. (2023) mentions sustainability and waste management among the social drivers of AI adoption, but also highlights many other factors which influence innovation outcomes (Table 13).

Drivers of AI adoption		**Outcomes of AI adoption**	
Category	**Elements**	**Category**	**Elements**
Economic drivers	Cost Productivity Time Decision-making	Economic outcomes	Performance Effectiveness Efficiency
Technological drivers	Big Data IoT Digital platforms	Competitive and organizational outcomes	Competitive advantage Organizational capabilities
Social drivers	***Sustainability*** Waste management	Innovation outcomes	Development of patents Development of new technology Product, process, and business model

13. Drivers and outcomes of AI adoption

Source: authors, based on Mariani, et al., 2023

Most importantly, the business model-related innovation outcome is in line with the theoretical concept of Di Vaio et al. (2020), who argued that AI can be a tool for developing sustainable business models. Nevertheless, besides AI, knowledge management systems should provide the "cultural drift" which is also needed to achieve sustainable development goals. In particular, the authors argue that policymakers must focus first on this cultural drift before the integration of technology.

AI for sustainable development and innovation has been discussed from multiple perspectives, for example, concerning management education (Goralski & Tan, 2020), or key consequences of AI deployment, such as product and process innovation, business model innovation and also social innovation (Mariani, et al., 2023). Nevertheless, AI for sustainability have serious challenges as well, such as overreliance on historical data or cybersecurity risks. Future studies could focus on "(1) multilevel views, (2) systems dynamics approaches, (3) design thinking, (4) psychological and sociological considerations, and (5) economic value considerations to show how AI can deliver immediate solutions without introducing long-term threats to environmental sustainability." (Nishant, et al., 2020, p. 1)

5. Internal conditions, capabilities, and resources in Hungary, V4, and the Carpathian Basin

5.1. Overview of the Carpathian Basin

The innovation performance of the Carpathian Basin can be compared by using The European Innovation Scoreboard. Table 14 lists the countries according to their recent categories. The Table shows that the countries of the Carpathian Basin belong to Moderate Innovators or Emerging Innovators, similar to the V4 countries. The highest ranking belongs to Slovenia, which partly belongs to the Carpathian Basin, and the Czechia, a V4 country. Hungary is a moderate innovator.

Category	Country	Carpathian Basin*	V4
EU			
Innovation Leaders	DK - Denmark		
	SE - Sweden		
	FI - Finland		
	NL - Netherlands		
	BE - Belgium		
Strong Innovators	AT - Austria		
	DE - Germany		
	LU - Luxembourg		
	IE - Ireland		
	CY - Cyprus		
	FR - France		
Moderate Innovators	EE - Estonia		
	SI - Slovenia	Peripheric	
	CZ - Czechia		■
	IT - Italy		
	ES - Spain		
	MT - Malta		
	PT - Portugal		
	LT - Lithuania		
	EL - Greece		
	HU - Hungary	Central	■
Emerging Innovators	HR - Croatia	Level 3	
	SK - Slovakia	Level 3	■
	PL - Poland	Peripheric	■
	LV - Latvia		
	BG - Bulgaria		
	RO - Romania	Level 2	
Non-EU examples			
Innovation Leader	CH - Switzerland		
Strong Innovator	UK – United Kingdom		
Moderate Innovator	-		
Emerging Innovators	RS - Serbia	Peripheric	
	UA - Ukraine	Level 3	

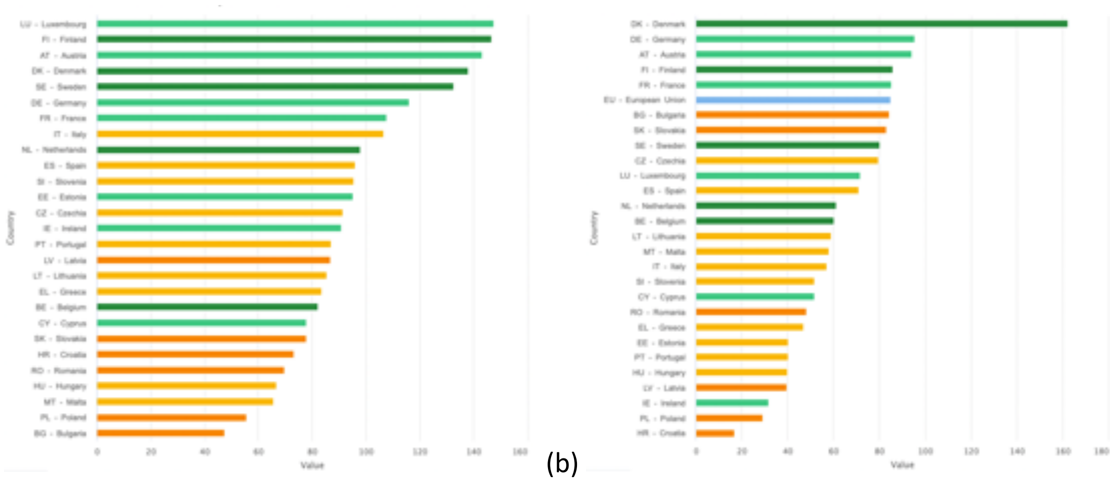
* Position in the Carpathian Basin: Central – – Peripheric

Table 14. Categorization of countries based on the Summary Innovation Index of The European Innovation Scoreboard

Source: Authors, based on based on European Commission, 2023

Nevertheless, there are certain output sub-indicators which might help to generate a nuanced picture of innovation and design performance, even though they do not directly measure the focal innovation areas of this working paper.

1. EEI: There is an “Eco-Innovation” Index, according to which Slovenia and Czechia have a quite high performance, while Poland and Hungary have a quite low performance. The “Environment-related technologies” index shows a similar picture. (Figure 16)

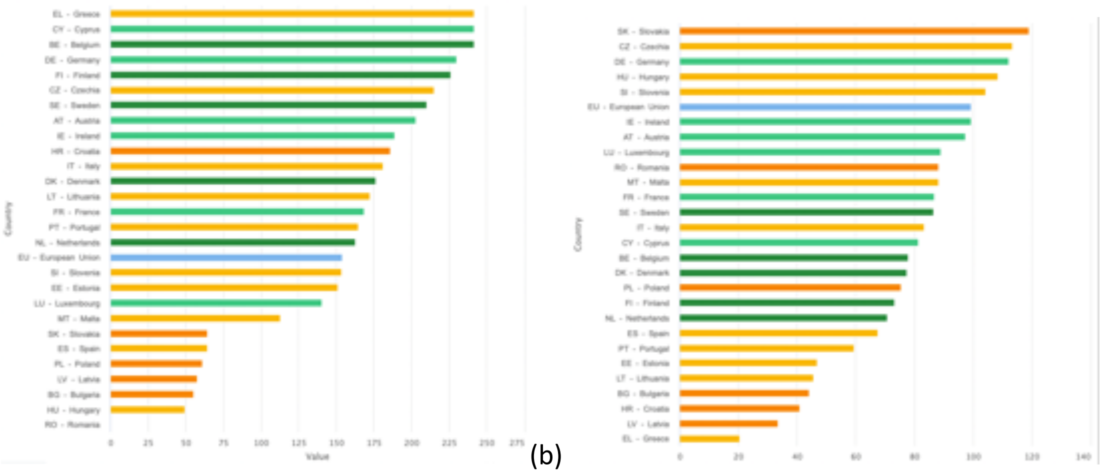


(a) (b)

Figure 16. Eco-Innovation Index (a) and Environment-related technologies (b)

Source: European Commission, 2023

2. TI: Technological innovations are often used to improve business processes or exploit new know-how by exporting, so the indicators about “SMEs introducing business process innovations” and “Exports of medium and high technology products” could be more or less useful. Hungary underperforms in the first dimensions, while overperforms in the second (Figure 17). This phenomenon validates the desired switch from “Made in Hungary” to “Invented and Made in Hungary), mentioned in the Hungarian R&D&I Strategy (see the next Section).

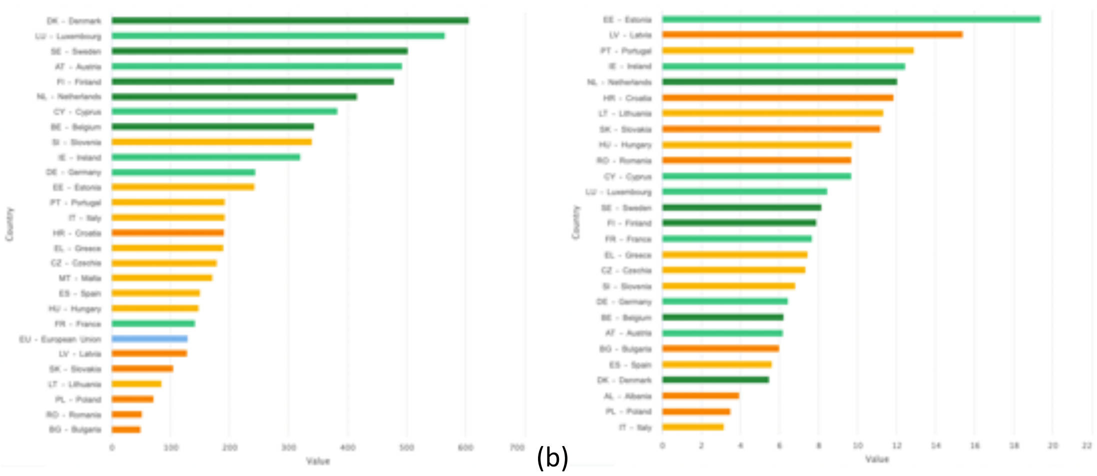


(a) (b)

Figure 17. SMEs introducing business process innovations (a) and Exports of medium and high technology products (b)

Source: European Commission, 2023

3. SBMI: Regarding the social innovation side, the literature often emphasizes the creation of new connections. In this context, the index called “Linkages”, covering sub-indices (such as innovative SMEs collaborating with others, public-private co-publications, and job-to-job mobility in science and technology) could be party relevant. According to this index, Hungary and Czechia are in a better position than Poland or Slovakia. Regarding the business model innovation side, the “Total Entrepreneurial Activity” could be considered (i.e., finding new customer needs (market, value proposition) and satisfying them by new methods (configuration of resources, activates, partners). According to this, Hungary and Slovakia are high-performers.



(a) (b)

Figure 18. Linkages (a) and Total Entrepreneurial Activity (b)

Source: European Commission, 2023

4. CDI: In case of design innovation, the "Design application" index seems to be the most relevant, in which Hungary has the lowest score. However, if cultural innovation aims to generate an entrepreneurial, innovation culture, the innovation potential could be important where Hungary overperforms.

(a)

(b)

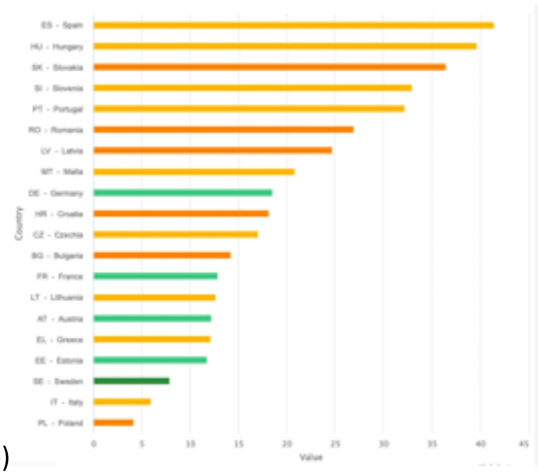


Figure 19. Design applications (a) and Non-innovators with potential to innovate (b)

Source: European Commission, 2023

Based on the above, Hungary and the V4 countries together show a mixed picture. For example, while the entrepreneurial potential is present, synergies are not fully realized yet in terms of the technological, eco-innovative and design application performance.

5.2. V4 countries

As policy recommendations of this working paper should be in line with the existing priorities of Hungary, Czech Republic, Poland, and Slovakia, the strategic documents (and related website information, if necessary) were analyzed to explore the internal conditions of the V4 countries.

In case of every country, innovation-related information was collected based on two types of documents:

1. Recent climate and energy sector-related strategies or plans, because of the dominance of sustainable development and its environmental issues (based on the mapping of the previous phase)

2. Recent general research and development (and innovation, if applicable) strategies, as R&D is the basis of innovation.

In case of the first type, i.e., documents mainly related to sustainable development, EEI and TI dimensions are inherently intertwined. In case of the second type, i.e., general R&D&I strategies, such combinations of two areas are only applied if it is suggested based on the data.

In both cases, the two focus points of the qualitative analysis were the following:

1. Present: Strategic framework, capabilities
   (e.g., What are the main strategic goals, resources, and challenges?)
2. Future: Innovation goals, opportunities
   (e.g., What areas and methods are preferred to increase innovation performance?)

These focus points could sometimes only consider the background, and the underlying factors of innovation. For example, economic and social challenges and opportunities could be often mentioned as the basis of future SBMI.

In the following tables, the focal innovation areas are analyzed in detail from the aspect of the V4 countries' present and future.

Hungary

	National Clean Development Strategy 2020-2050	
	Strategic framework, capabilities (present)	**Innovation goals, opportunities (future)**
EEI TI	***Need for changes in multiple dimensions of the energy sector*** Vision: Climate neutrality by 2050 (p. 8) "…drastic changes are needed to decarbonize Hungary's energy supply system (including energy generation capacities) and to enable the end-user side to reduce energy consumption and utilize clean energy technologies." (p. 10-11) "The fuel mix of the final energy consumption must change significantly to reach the 2050 climate neutrality target" (p. 12) Investment and support are needed for residential energy saving, electrification of the economy and transportation, CCUS and LULUCF, the waste sector, R&D&I, and education and training (p. 13)	***Clean energy use in numerous areas, involving nuclear capacities*** Supporting only low-carbon solutions that "are ecologically and socially sustainable" (p. 20); "promoting waste recycling with establishing smart *ecological* systems" (p. 114) Energy efficiency improvement; Electrification; Hydrogen, CCUS, RES, and energy storage technologies; Bioenergy, biofuels; Modern agriculture, Natural sink capacities (p. 12-13) Climate neutrality by clean, carbon free (renewable and nuclear) sources (p. 107) Potential innovative technologies in these sectors: Energy, Water management, Waste management, Wastewater management, Transport, Industry, Building sector, Agriculture, Forestry (p. 115)
SBMI	***Aligning environmental and economic goals*** "Hungary starts this endeavor [climate neutrality and economic development] from a strong position, being among the few countries since 1990 where the gross domestic product (GDP) has increased while CO_2 emissions decreased, by 33%." (p. 8)	***Technological innovation combined with business model innovation and social innovation*** "there is also a need for regulations and policies that encourage innovation as well as innovative business models"; "…there is a need to pursue a holistic approach that emphasizes the importance of interaction between technological and social innovations" (p. 115)
CDI	***Existing R&D institution which involves also cultural aspects*** "National Laboratories: an internationally recognized, goal-oriented network center system that brings together domestic knowledge centers in topics of particular interest to the national economy in four main areas of research and development (industry and digitalization; culture and family; health and safe society; environment)," (p. 116)	***Design innovation for zero waste*** "By 2050, the full recovery of industrial waste will be at zero-cost for the waste sector due to proper product design and the closed loop of production systems" (p. 83)

Table 15. Illustrative statements about current and future aspects of innovation and design aimed at clean development - Hungary

Source: Authors, based on based on ITM, 2020

	Research, Development, and Innovation Strategy of Hungary, 2021-2030	
	Strategic framework, capabilities (present)	**Innovation goals, opportunities (future)**
EEI	***Sustainable economy development in the vision*** "A high added value, knowledge-based, balanced, sustainable economy and society in all areas of the country" (p. 23); Energy Innovation Council since 2018, National Energy Strategy 2030 (p. 59)	***Energy innovation for environmental and economic goals*** Knowledge production is important in line with global trends, including environmental ones (p. 90); A focus area of the AI strategy (draft) is energy (p. 58); Energy innovation must contribute to economic performance (p. 59)
TI	***Improving but still deficient basis for cutting-edge technology development*** Weak patenting activity (p. 21) The development of an inciting ecosystem for high-tech, "born global" startups; More STEM-field researchers and developers are needed, based on the labor market demand (p. 90)	***Patent-based technological innovation in multiple sectors*** Overarching support system for patenting and exploiting intellectual property (p. 21); Technological- and non-technological innovations must be interconnected (p. 49); Supporting specific sectoral strategies, inc.: Infocommunication, Digitalization, SMEs, Higher education, Digital Education, Military development, Digital Agriculture, Artificial Intelligence, Environmental protection, Energy, Healthcare (p. 54-59)
SBMI	***New and valuable connections within the innovation system, but not in case of social innovation*** The presence of large foreign-owned companies supported the employment, the market share of innovative products, and connections among the actors of the research and innovation system (p. 5); Weak social innovation-aimed collaborations (p. 90); Social innovation (alone and with technological innovation) is an integral part of the innovation system (p. 27)	***Focus on SME productivity and new societal needs through innovation*** Support is needed for SMEs to increase their productivity, innovation performance, introducing their own new products and services (p. 5) New market demand for R&D&I from developed and developing countries, e.g., regarding health care of the elderly, or satisfying the needs of the growing population (p. 91)
CDI	***"Invented and Made in Hungary" principle*** Transition toward the "Invented and Made in Hungary" approach from the "Made in Hungary" approach; Cutting-edge working culture at many companies, knowledge centers, coordinated R&D programs; Low exploitation of interdisciplinary research outcomes (p. 90)	***Exploiting emerging global opportunities, partly by design innovation*** Connection to the changing and emerging global R&D&I value chain; Supporting open access and open science (p. 90); Accelerate change in SMEs' innovation approach, toward non-technological innovation (inc. *design*) as well; Organizational and cultural paradigm change is need to accelerate collaborations (p. 38); Involving new stakeholders into non-technological innovation, inc. design innovation

Table 16. Illustrative statements about current and future aspects of innovation and design based on research and development - Hungary

Source: Authors, based on based on ITM & NKFIH, 2021

Czech Republic

	National Energy and Climate Plan of the Czech Republic	
	Strategic framework, capabilities (present)	**Innovation goals, opportunities (future)**
EEI	***Primary focus on energy intensity*** Reducing “the total greenhouse gas emissions by 30 % by 2030 compared to 2005”; “The Czech Republic proposes a 22 % contribution to the European target by 2030; “The Czech Republic has chosen a target expressed in the energy intensity of GDP as its primary objective” (p. 2)	***Energy efficiency, renewable and nuclear technologies*** “Research, development and innovation in sustainable energy are one of the priority areas of key strategic documents” (p. 3) The national priorities for oriented research, experimental development, and innovation include Sustainability for energy and material resources (p. 72)
TI	“In June 2019, the Czech Republic and Hungary also initiated the creation of a V4 platform for energy research.... The platform’s priorities are yet to be defined, but it should focus on researching smart grids, energy storage, energy efficiency, etc. Emphasis will also be placed on nuclear research” (p. 159)	Priority areas of R&D&I: Renewable (alternative) energy sources, Nuclear technologies, More efficient use of fossil energy sources, Increasing efficiency and reliability of energy systems and distribution networks, Energy recovery of waste, Transport systems (p. 72-73)
SBMI	***Difficulties in reducing import dependencies*** “The main objectives can be described as increasing the diversification of the energy mix, maintaining self-sufficiency in electricity supply, ensuring sufficient development of energy infrastructure and no significant increase in import dependency. However, import dependence is very likely to gradually increase due to a decrease in the use of domestic brown and black coal and the related increase in imported energy commodities.” (p. 3)	***Knowledge, quality life, healthcare, security*** The national priorities for oriented research, experimental development, and innovation include Competitive knowledge-based economy, Environment for quality life, Social and cultural challenges, Healthy population, Secure society (p. 72)
CDI	***Eco-design in public procurement*** “The following conditions shall apply to public procurement: (i) the highest available class for products with energy labels; (ii) the most efficient product on the market where *ecodesign* applies;...” (p.119)	***Researching social and cultural challenges*** The national priorities for oriented research, experimental development, and innovation includes Social and cultural challenges (p. 72) Use of renewables: “The boilers must be available in all the necessary performance series that meet the future requirements (for small boilers, these are requirements arising from the *ecodesign legislation*” (p.153)

Table 17. Illustrative statements about current and future aspects of innovation and design aimed at clean development – Czech Republic

Source: Authors, based on based on (Ministry of Industry and Trade, 2019)

	Innovation Strategy of the Czech Republic 2019–2030	
	Strategic framework, capabilities (present)	**Innovation goals, opportunities (future)**
EEI	***Improving the currently insufficient basis to become an innovation leader*** “Within twelve years to become one of Europe's innovation leaders and a country of the technological future” (p. 4) “A properly developed STEM (Science, Technology, Engineering and Mathematics) system is missing”; “Polytechnic-oriented universities lack a system to incentivise spin-offs, start-ups, and the creation of natural cooperation between students and companies in advanced technologies” (p. 8)	***Digitalization, Smart Solutions*** Digital State, Manufacturing and Services: “Apply Industry 4.0 principles to the energy sector, especially in the field of smart grids, as well as in smart cities and regions”; Set up a system to support resource optimisation and environmental protection in connection with the implementation of Industry 4.0 in manufacturing plants and services” (p. 10); Innovation and Research Centres, Smart Investment, Smart Marketing: Focus on “Energy-Saving Solutions” (p.11)
TI		***Specialization based on change in multiple levels*** Polytechnic Education: “Promoting lifelong learning and re-skilling – preparing for the use of breakthrough technologies”; ”Creating a system of ongoing assessment of the impact of the industrial revolution on the innovation ecosystem, labour market, education and citizens’ lives.” (p. 8)
SBMI	***Advanced digitization but a concept is needed*** “A number of important tools for digitisation have been introduced…with more than 700 online solutions implemented in the public sphere. On the other hand, the system for digitization implementation in the Czech Republic has been chaotic so far” (p.10) “There is a lack of a comprehensive national concept for their establishment, development and funding” of startups (p.9)	***Overarching digitalization and start-up-focused strategies and programs*** Digital State, Manufacturing and Services: “Prepare society for trends such as IoT, AI, BigData, new types of human-machine interface, etc.”…“Involve small and medium-sized businesses in the use of digital business tools.”…“National Strategy for AI linked to the Coordinated Plan for AI.”, etc. (p. 10) National Start-up and Spin-off Environment: “Create a comprehensive funding programme with national support for the start-up segment”…” Create an environment of interest for foreign start-ups and technology teams”…” Introduce training for entrepreneurship”, etc. (p. 9)
CDI	***Unexploited opportunities*** “there is insufficient motivation to use academic outputs,…the approach of corporations and small and medium-sized firms to cooperation with start-ups is inflexible” (p. 9)	***Developing an entrepreneurial culture*** National Start-up and Spin-off Environment: “Create a start-ups map to link them up with investors and support providers”…”Ensure an exchange of information and best practice between startups at national level” (p. 9)

Table 18. Illustrative statements about current and future aspects of innovation and design based on research and development – Czech Republic

Source: Authors, based on based on Council for Research, Development and Innovation, 2019

Poland

	Poland's National Energy and Climate Plan for The Years 2021-2030 (Executive Summary)	
	Strategic framework, capabilities (present)	**Innovation goals, opportunities (future)**
EEI **TI**	***Environmentally and economically equally promising transformation goal*** "establishing a stable framework for a sustainable, economically effective and just transformation in energy sector and the whole economy" (p. 1) "7% reduction of CO_2 emissions in non-ETS sectors by 2030, compared to 2005"; 21-23% of RES share in gross final energy consumption by 2030"; 23% increase in energy efficiency (p. 2); Energy security (p. 3) "The implementation of nuclear energy in Poland is indicated in the national plan as important from the point of view of ensuring stable and zero-emission electricity supply, as well as diversifying energy sources" (p. 3)	***Energy efficiency in focus, partly by digital technologies*** "taking into account the principle of 'energy efficiency first'" (p. 1) "reducing emissions in transport, construction and agriculture, taking into account the beneficial effects of CO_2 absorption by ecosystems and the flexibility associated with land use, land use change and forestry" (p. 2) Advanced biofuels, wind energy, RES micro installations (p. 3) "Development of ecological and effective heating systems, the production of heat in cogeneration, intelligent networks"; "Creation of a coherent, sustainable, innovative and user-friendly transport system" (p. 3) "automation, robotization and digitization of enterprises", "acceleration of technology sales by Polish companies on foreign markets" (p. 4)
SBMI	***Improving market and social conditions*** "Development of a competitive (energy) market" (p. 4) „Improve the quality of life of Polish society" (p. 4)	***Quality of life, healthcare, and air quality improvement through stakeholder involvement*** "improve the quality of life of the inhabitants of Poland, especially to protect their health and living conditions, including environmental protection. This applies in particular to solve the problem of air quality…" (p. 2) "increase consumers' knowledge and to encourage them to play a more active role" (p. 4)
CDI	***Civilization gap*** "Reduce the civilization gap between Poland and economically highly developed countries" (p. 4)	***Increasing scientific impact*** "…growing importance and competitiveness of Polish science on the international stage" (p.4)

Table 19. Illustrative statements about current and future aspects of innovation and design aimed at clean development – Poland

Source: Authors, based on based on Ministry of Climate and Environment, 2019

	National Research Program (2011) and recent strategic programs (from website)	
	Strategic framework, capabilities (present)	**Innovation goals, opportunities (future)**
EEI	***Need for sectoral transformation*** "The domestic energy sector should undergo a long-term transformation"; "outdated and inefficient infrastructure of the Polish energy sector, dependence on external supplies of energy fuels, the strong negative impact of the sector on the environment"; "The development of modern energy technologies is key to the process of transformation towards a green economy" (p. 9)	***Low carbon economy development*** …by traditional energy, renewable energy sources, nuclear energy, energy efficiency improvement; Strategic directions (2011): New energy technologies; Environment, agriculture and forestry (p. 6) New strategic programs (2020-29): "New technologies in the field of energy" with solar energy, onshore and offshore wind energy, production and use of hydrogen, energy storage, etc. "Hydrostrateg" – efficiency of water use and management (website)
TI	***Productivity challenge*** "A challenge for Poland in the medium and long term is to raise the productivity of Polish enterprises while reducing the unemployment rate. Meeting this challenge will require raising the internal capacity to adapt technologies with the appropriate potential for increasing the productivity of capital and labor" (p. 6)	***Healthcare, materials, ICT*** Strategic directions (2011): Civilization diseases, new medicines and regenerative medicine, Advanced information, telecommunications and mechatronic technologies, Modern material technologies (p. 6); New strategic program (2020-29): "INFOSTRATEG -Advanced information, telecommunications and mechatronic technologies" with AI, blockchain, robotics, automation (website)
SBMI	***Aging society*** "In the near future we will be dealing with a profound demographic change, expressed by the progressive aging of society. At the same time, as a result of economic and scientific freedom, spatial mobility will increase (p. 21)	***Improving social activation and capital*** Strategic directions (2011): Social and economic development of Poland in the conditions of globalizing markets, Security and defense of the state (p.6); "Research on the conditions of professional and social activation of older people" (p. 21); New strategic program (-2028): "GOSPOSTRATEG" to increase in social capital and wider involvement in various forms of public activity (website)
CDI	***Digital technologies for cultural participation*** "New digital technologies will change forms of civic, social and cultural participation" (p. 21-22)	***Considering cultural heritage in a digital age*** "In a world dominated by technologies… society needs permanent points of reference, such as a sense of connection with cultural heritage….It is extremely important to conduct research related to the preservation of the material and spiritual heritage of Polish society" (p. 21)

Table 20. Illustrative statements about current and future aspects of innovation and design based on research and development – Poland

Source: Authors, based on based on National Centre for Research and Development, 2011 and The National Centre for Research and Development, 2023 – Translations from Polish

Slovakia

	Integrated National Energy and Climate Plan for 2021 to 2030	
	Strategic framework, capabilities (present)	**Innovation goals, opportunities (future)**
EEI	**Smart Specialization includes sustainability measures and advanced ICT technologies** "The Slovak Republic takes air quality, reducing greenhouse gas emissions, mitigating climate change, the security of supplies of all energy types and their affordability, extremely seriously" (p. 7) Basic pillars: Energy security, energy efficiency, competitiveness and sustainable energy, science, research and innovation, decarbonisation (p. 7) Reducing GHG emissions by 20% (non-ETS) by 2030 (p. 8)	***RES, nuclear energy, and green innovation*** "It is therefore necessary to change technologies, processes and habits on both the generation and consumption sides" (p. 8) "The optimal use of renewable energy sources, nuclear energy, decarbonised gases and innovative technologies" (p. 10) "Green public procurement, …support for green innovation" (p. 16) "Installing innovative district heating technologies" (p. 85)
TI	"Knowledge for Prosperity - Research and Innovation Strategy for Smart Specialisation of the Slovak Republic" (p. 82) "The Slovak Republic has the potential to use knowledge and domestic expertise acquired through Big Data in the processing, analysis, prediction and visualisation of large volumes of data in real time, as well as to use artificial intelligence... (14)	
SBMI	***Existing programs to generate economic and social benefits*** "The State R&D Programmes address key issues in developing and meeting the needs of society. They specify the science and technology fields on which research and development should focus or that should be intensified to achieve increased economic and social benefits and contribute towards their high standard and international recognition." (p. 14)	***Using technological advancements for economic growth and employment*** "Establishing a technological lead in alternative energy and reducing energy consumption will create huge export and industrial opportunities. It will also support *growth and jobs*" (p. 14)"
CDI	***Design innovation potential for circularity*** "The circular economy affects all aspects of resource use, from *product design*, resource extraction and production to distribution, use and disposal" (p. 42)	***Environmental design as a strategic measure*** "Environmental design and use of products - The aim of this measure is to reduce the environmental impact at all stages of the product life cycle" (p. 86)

Table 21. Illustrative statements about current and future aspects of innovation and design aimed at clean development – Slovakia

Source: Authors, based on based on Slovak Ministry of Economy, 2019

	R&D&I: National strategy for research, development and innovation 2030 (from website); R&D & Innovation Sector in SLOVAKIA (2021)	
	Strategic framework, capabilities (present)	**Innovation goals, opportunities (future)**
EEI	***R&D for sustainable development*** "R&D is the fundamental precondition for increasing competitiveness and maintaining sustainable development" (p. 3)	***Eco-innovation-related specialization areas*** National R&D specialization areas: "Agriculture & Environment"; "Sustainable Energetics & Energies" (p. 7)
TI	***A need for a narrowed strategic scope*** "A small, heavily industrialized country that does not have a sufficient concentration of talent and resources to concentrate on everything" (website)	***Nanotechnology, Biotechnology, Industry 4.0*** National R&D specialization areas: "Material Research / Nanotechnology"; "ICT & Electronics"; "Biomedicine & Biotechnology" "Slovak Industry 4.0 Ecosystem elements: Industrial IoT; Digital Twin Solutions; VR. & AR; Process Optimization & Robot Integration; Visual Quality Checking; AI, Big Data & Predictive Maintenance" (p. 12)
SBMI	***Retaining and attracting talents*** Increasing the competitiveness of the economy and the quality of life…by supporting research, innovation and talent…and investments in science and the innovation ecosystem; A lot of talented people leave Slovakia; Facing increasingly unpredictable challenges, crises and trends (website) Investment incentives (p. 14)	***Institutional changes to enable socio-economic progress*** Increasing investment in research, higher innovation ranking position, attract highly qualified people from abroad (website) "introduced measures linked to reducing bureaucratic burdens, amending legislation, defining standards, changing education programmes and conditions on the labour market or cofinancing research." (p. 7)
CDI	***Past achievements in product and game design*** "Design is an integral part of developing new products. Apart from technical aspects, many Slovak companies also focus on aesthetics", "Creativity and technology also come together in game design and development, a rising segment in which Slovak companies are beginning to play an important role." (p. 5)	***Creative industry*** Perspective areas of specialization: Creative industry (p. 7)

Table 22. Illustrative statements about current and future aspects of innovation and design based on research and development – Slovakia

Source: Authors, based on based on SARIO, 2021 and VÝSKUMNÁ A INOVAČNÁ AUTORITA, 2023 – Translations from Slovak

6. Conclusions and recommendations

The main research question of this working paper was the following:

What kind of strategic changes could facilitate innovation and design in Hungary, V4, and the Carpathian basin related to the policy, institutional, research, and corporate context?

The different parts of the research question are separately answered:

1. **Policy recommendations** are outlined based on the strategic analysis of the V4 countries' innovation directions, the theoretical background (detailed in the first working paper), and the influential models from frontier countries' research.
2. **Institutional recommendations** are also outlined based on those models from the literature, which are less related to direct policy but more to the institutional environment which influences "the rules of the game in the society" (North, 1990, p. 3) or in the economy.
3. **Research recommendations** are outlined based on mapping of the change drivers (detailed in the second working paper), concerning the role of absorptive capacity building (i.e., gathering and leveraging know-how from different (geographical) areas through collaborations).
4. **Corporate recommendations** are outlined based on the analysis of the V4 countries, the theoretical background and the influential models from frontier countries' research which are more relevant for corporate decision-makers.

As presented in the previous working papers, the transdisciplinary approach was an influential theoretical framing for understanding potential policy opportunities, while the dynamic capabilities framework served a similar role in case of corporate opportunities.

The summary of the answers for the research sub-questions is presented in Table 23. According to the fundamental approach of this research, recommendations outline strategic change directions (detailed in the first working paper), which could lead to improved innovation and design performance in the focal areas.

In line with the main strategic change drivers of innovation and design horizons (detailed in the second working paper), sustainable development and/or transdisciplinarity underlies all the recommendations by the goal (e.g., building) sustainable business models) or the realization (e.g., real-world problem-solving by stakeholder engagement or entrepreneurship).

	V4 analyses		Recommendations based on the theoretical background, recent literature, mapping, and frontier countries' research			
	Strategic framework, capabilities (present)	Innovation goals, opportunities (future)	Policy (with V4 focus)	Institutions	Research	Corporations
EEI (SQ1)	**HU:** Need for changes in multiple dimensions of the energy sector; Sustainable economy development in the vision **CZ:** Primary focus on energy intensity **PL:** Environmentally and economically equally promising transformation goal; Need for sectoral transformation **SK:** Smart Specialization includes sustainability measures and advanced ICT technologies; R&D for sustainable development	**HU:** Clean energy use in numerous areas, involving nuclear capacities; Energy innovation for environmental and economic goals **CZ:** Energy efficiency, renewable and nuclear technologies **PL:** Energy efficiency in focus, partly by digital technologies; Low carbon economy development **SK:** RES, nuclear energy, and green innovation; Eco-innovation-related specialization areas (e.g., agriculture)	Eco-innovative technological ecosystem based on aligned energy strategies Primarily market-based instruments for improved environmental and financial performance of firms	Forming shared meanings for circular economy development Institutional support eco-(re)design, smart solutions, and technological diffusion	Absorbing eco- and energy innovation knowledge from the East	Developing sustainable business models and related organizational capabilities
TI (SQ2)	**HU:** Improving but still deficient basis for cutting-edge technology development **CZ:** Improving the currently insufficient basis to become an innovation leader **PL:** Productivity challenge **SK:** A need for a narrowed strategic scope	**HU:** Patent-based technological innovation in multiple sectors **CZ:** Digitalization, Smart Solutions; Life-long learning and specialization based on change in multiple levels **PL:** Healthcare, materials, ICT **SK:** Nanotechnology, Biotechnology, Industry 4.0	Focus on agriculture, healthcare, and ICT (inc. AI) Proactive regulation to balance market mechanisms and protect SMEs	Institutionalization of open innovation	AI research for innovation management and sustainable development, based on Western collaborations	Exploration by open innovation, developing core and supplementary innovation assets

Cont.

	Strategic framework, capabilities (present)	Innovation goals, opportunities (future)	Policy	Institutions	Research	Corporations
SBMI (SQ3)	**HU:** Aligning environmental and economic goals; New and valuable connections within the innovation system, but not in case of social innovation **CZ:** Difficulties in reducing import dependencies; Advanced digitization but a concept is needed **PL:** Improving market and social conditions; Aging society **SK:** Existing programs to generate economic and social benefits; Retaining and attracting talents	**HU:** Technological innovation combined with business model innovation and social innovation; Focus on SME productivity and new societal needs through innovation **CZ:** Knowledge, quality life, healthcare, security; Overarching digitalization and start-up focused strategies and programs **PL:** Quality of life, healthcare, and air quality improvement through stakeholder involvement; Improving social activation and capital **SK:** Using technological advancements for economic growth and employment; Institutional changes to enable socio-economic progress	Transition management for sustainable development	Supporting social innovators and SME-sized business model innovators to avoid strategic concealment Holistic innovation in cities	Circular economy research on policy level, sustainable business model research on corporate level	Social innovation by substantial organization changes or new ventures Sustainable business model innovation following technological, organizational, social archetypes
CDI (SQ4)	**HU:** Existing R&D institution which involves also cultural aspects; "Invented and Made in Hungary" principle **CZ:** Eco-design in public procurement; Unexploited opportunities in cooperation **PL:** Civilization gap; Digital technologies for cultural participation **SK:** Design innovation potential for circularity; Past achievements in product and game design	**HU:** Design innovation for zero waste; Exploiting emerging global opportunities, partly by design innovation **CZ:** Researching social and cultural challenges; Developing an entrepreneurial culture **PL:** Increasing scientific impact; Considering cultural heritage in a digital age **SK:** Environmental design as a strategic measure; Creative industry as perspective area	Cultural drift toward eco-culture and AI-supported sustainable business models	Moderate and balanced incentives for exploitative and explorative routines Analyzing social needs, monitoring social dynamics	Exploring the cultural and design aspects of sustainable development	Design innovation based on versatile value categories, supported by marketing integration

Table 23. Summary of the V4 analyses and strategic change directions for policy, institutions, research, and corporations in the focal innovation areas

Source: authors

6.1. Eco- and energy innovation (SQ1)

6.1.1. Policy recommendations

V4 eco-innovative technological ecosystem based on aligned energy strategies

The in-depth analysis of V4 climate and energy strategies highlighted that V4 countries have similar strategic frameworks and innovation opportunities, which could induce further cooperation for EEI. The synthesis of the strategic directions is the following:

1. Ecological aspects:
    a. Developing low-carbon solutions
    b. Low-carbon / climate neutral economy development
2. Energy aspects:
    a. Significant transformation of the energy sector
    b. This transformation must provide not only environmental but economic benefits as well
    c. Focusing on energy efficiency, nuclear energy capacities, renewable energy, and bioenergy.

Even though the research protocol excluded ecological and energy-related subject areas in case of technological innovation, not only economic but environmental performance also appeared among the most cited TI studies of frontier countries. Accordingly, economic growth and ecological footprint can be associated with an inverted U-shape. However, as TIs can decrease ecological footprint, policymakers must find ways by which natural resources can be used efficiently and sustainably, even with the introduction of new measures and taxes to discourage fossil fuel consumption and incite

1. the reduction of carbon emissions, and promote environmentally friendly technologies,
2. green and sustainable urbanization by using more renewable energy,
3. reforming heavy and chemical industries, reducing energy waste,
4. scientific and international research and development.

Primarily market-based instruments for improved environmental and financial performance of firms

Besides, as economic and environmental value creation is equally emphasized, those policy interventions are especially relevant which could contribute to this goal. First, the literature also reinforces that *“environmental performance and improving economic performance are not a zero-sum game”* (Cai & Li, 2018, p. 116). Concerning economic growth, however, while green process innovation, green product innovation, and green image are proven to increase (Chinese) manufacturing firms’ financial performance, the positive effects of green subsidies on financial performance are unclear (but it can obviously reduce environmental harm). Instead, researchers argue that eco-innovation policies must support organizational capability building, e.g., through innovation platforms, and introduce strict regulatory frameworks as well for decarbonization. Accordingly, policymakers can have two types of instruments to drive eco-innovations: (1) command and control instruments and (2) market-based instruments. From these two, market-based policy instruments are found to be more effective in driving eco-innovations. In line with this, environmental innovation performance is lower when firms must implement environmental management involuntarily.

6.1.2. Institutional recommendations

Forming shared meanings for circular economy development

Eco-innovation could be accelerated by ecosystem building, as radical innovation and eco-design often need partnerships (e.g., for reusing industrial waste in a different sector). Nevertheless, one of the first tasks should be developing shared meanings by taxonomy development, involving stakeholders. For example, in case of circular economy (CE) development, the CE indicators, which orient innovation activities, should be interpreted according to different levels (e.g., micro, meso, macro), loops (maintaining, reusing, recycling), units (quantitative, qualitative), performance perspectives (actual, potential), transversality (generic, sector-specific), usages (improvement, benchmarking, communication).

Institutional support eco-(re)design, smart solutions, and technological diffusion

Not only new product development should be encouraged (i.e., eco-design) for eco-innovation but also the environmental-friendly improvement of existing systems (i.e., eco-redesign). Also, since the customers' energy demand can become larger when the energy efficiency increases ("rebound-effect"), reducing the overall energy consumption should be also aimed, and green technologies should be combined with smart solutions (e.g., IoT). In general, drivers of the EI-based transition belong to the softer factors (e.g., waste management directives, social awareness), while hard barriers hamper the transition process (e.g., lag between technology design and diffusion, large capital requirements). Consequently, sustainability-oriented change by eco- or energy innovation would require "patient capital", institutional support, broad collaborations, and cluster initiatives.

6.1.3. Research recommendations

Absorbing eco- and energy innovation knowledge from the East

As sustainable development was found a main driver of innovation and design horizons, its environmental dimension is directly related to eco- and energy innovation. Based on the mapping of the previous phase, EEI became a global topic in 2012-2022 and Chinese institutions started to dominate the research field, based on the number of highly cited articles. Following the theory of absorptive capacity development, this means that Eastern research and innovation partnerships could be valuable to obtain and leverage know-how for EEI.

As mentioned above, V4 strategic frameworks also emphasize the parallel value creation in environmental and economic dimensions. This is also in line with the Eastern research approach to sustainable development, as Eastern research often refers to “economic development” which suggests more of a top-down policy implementation. Also, the most frequent Eastern keywords seem to be more operational (e.g., CO_2, renewable energy, environmental economics, decision making, biotechnology), compared to influential Western research.

For potential collaborations about EEI management research, there are relevant Eastern research institutions in the frontier countries (based on the affiliations of the highly cited studies), for example:

1. China: School of Management, Shanghai University, China; Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hong Kong; School of Economics and Management, Fuzhou University
2. India: Department of Humanities and Social Sciences, National Institute of Technology Rourkela
3. South Korea: Department of Materials Chemistry and Engineering, Innovative Environmental Technology center, Konkuk University
4. Japan: Research Institute for Economics and Business Administration, Kobe University; Graduate School for International Development and Cooperation, Hiroshima University.

6.1.4. Corporate recommendations

Developing sustainable business models and related organizational capabilities

The literature suggests that firms could increase their eco- and/or energy innovation and design performance through the following strategic change directions:

1. Developing strategic sustainability behaviour, step by step through five phases (from resistant to reactive, anticipatory, innovation-based, and sustainability-rooted)
2. Reconfiguring their business models in line with the circular economy strategies. For example:
    a. Green process innovation must come with the reconfiguration of production activities
    b. Green product innovation could require a new value proposition
    c. Green image building means a new marketing and communications approach
3. This reconfiguration requires the development of organizational capabilities and technological capabilities, as well, for example:
    a. Introducing eco-processes, e.g., using cleaner production technologies
    b. Accelerating eco-organization development, e.g., introducing an environmental management system.

6.2. Technological (non-eco, non-energy) innovation (SQ2)

6.2.1. Policy recommendations

Focus on agriculture, healthcare, and ICT (inc. AI) by V4 cooperation

Based on the analysis of common points of V4 innovation strategies and opportunities, the following focus points would be important to improve technological innovation and design performance:

1. Improvement of the insufficient basis in STEM fields for advanced research and development
2. Specific emphasis on:
    a. Agriculture
    b. Healthcare
    c. Advanced ICT solutions (e.g., AI, automation, Industry 4.0).

Proactive regulation to balance market mechanisms and protect SMEs

Industrial change is realized by technological innovation cycles which have four phases (technological discontinuity, era of ferment, dominant, and the era of incremental change) and four levels (basic component, second-order subsystem, first-order subsystem, and system). Policymakers could trigger technological discontinuity, i.e., variation, by interventions on these levels, and prioritize the most promising technologies after the “era of ferment”, i.e., to influence the selection of dominant designs. It can be necessary if standard market mechanisms would be harmful to the society. For example, companies which are strong in technological capabilities, collaboration history, and commercial assets, can obtain partners more easily. It means that anti-trust policies do not affect market leaders and smaller firms similarly, and industries with high network externalities, e.g., software, can become anticompetitive without restrictive regulation (i.e., smaller firms will struggle to attract new technological innovation partners).

6.2.2. Institutional recommendations

Institutionalization of open innovation

While inciting open innovation and combining interfirm capabilities are general recommendations (in line with above-mentioned the ecosystem concept), these can be institutionalized in several ways:

1. Developing and communicating clear policies, promoting certain sectors which are relevant for (open) innovation;
2. Strategically planning the location of new research institutions
3. Encouraging competition by reducing entry barriers;
4. Providing financial support by subsidies, preferential rates, loans, tax credits;
5. Establishing new institutions to support the internalization of firms;
6. Creating meeting places where entities can collaborate and ideate;
7. Promoting the creation of clusters.

Besides project resources and technological know-how, government policies are also important to facilitate technological development through a supportive context, quality standards, incubation centers, knowledge-sharing platforms. Knowledge-sharing platforms could be combined with international cooperation with neighboring countries (i.e., V4).

6.2.3. Research recommendations

AI research for innovation management and sustainable development, based on Western collaborations

Regarding technological innovation and design, the mapping in the previous phase did not show radical differences in an East-West context, but the importance of smart health-related, agricultural, and biotechnological advancements was highlighted, which also appeared in the strategic framework in case of at least one V4 country. Regarding the trends of the international network evolution, collaboration among Western European countries became even more intense between 2012-2022 compared to 2000-2012, and Australia became more involved in research activities in the past decade, which indicates that partnerships with Australia could be valuable to gather new knowledge.

Additionally, the role of AI could be crucial, especially because the literature highlighted that AI could facilitate the innovation process, design practice, and sustainability as well. Consequently, research on AI for sustainability-oriented innovation could be relevant. Based on the initial screening of the recent literature, Western frontier countries have research institutions which seem to be relevant for collaborative research on AI-supported innovation management and sustainable development, for example:

1. UK: Henley Business School, University of Reading
2. US: Weatherhead School of Management, Case Western Reserve University; Quinnipiac University; Department of Political Science, Radford University; Mendoza College of Business, University of Notre Dame.

6.2.4. Corporate recommendations

Exploration by open innovation, developing core and supplementary innovation assets

The literature suggests that firms could increase their technological innovation and design performance through organizational changes, such as:

1. Managing strategic ambidexterity by limited process management in a turbulent environment, and instead, prioritize exploration over exploitation
2. Preparing for and realizing open innovation through
    a. Develop interfirm linkages based on technical capital, commercial capital and/or social capital, build inter-organizational networks for searching, enabling / filtering, and acquiring external ideas
    b. Integrate ideas through improved absorptive capacity, culture development to avoid the "not invented here" attitude, introducing incentives to cooperate, develop competencies
    c. Commercialize the new ideas and solutions by the reconfiguration of business models
    d. Give and get feedback from customers and other stakeholders
    e. Enable co-creation with communities and value networks
3. Initiating organizational changes focusing on systems, culture, capabilities, learning, managerial attitudes, and developing core and also supplementary innovation assets:
    a. Core innovation assets
        i. Research and development (e.g., linking R&D to strategy and tech-competence, competent team leader)

   ii. Production / Manufacturing (e.g., involvement into new product development, adjustable production process according to new design)
   iii. Marketing (e.g., market monitoring)
  b. Supplementary innovation assets
   i. Learning (e.g., transforming knowledge in R&D guidelines)
   ii. Organization (e.g., flexible structure for new projects, autonomy of managers)
   iii. Resource exploitation (e.g., using external technologies, steady capital supplement)
   iv. Strategy planning (e.g., support from top management, adjusting innovation strategy based on competition).
4. Enable technological innovation by exploiting
  a. internal resources (e.g., technological know-how, intrapreneurs)
  b. linkages within the industrial network (e.g., among entrepreneurs, SMEs, subcontractors)
  c. technology infrastructure (e.g., ICT, project capabilities)
  d. government support (e.g., government funding for technology development or research).

6.3. Social and business model innovation (SQ3)

6.3.1. Policy recommendations

Transition management for sustainable development of V4 countries

The social and business model innovation and design dimension of the V4 analysis highlighted similar challenges and goals which are closely related to the social and economic dimensions of sustainable development:

1. Social aspects:
   a. Building a competitive knowledge-based economy
   b. Combining technological and non-technological innovation
   c. Improving healthcare and the quality of life
   d. Ensuring social (and energy) security
2. Economic:
   a. Solving the productivity challenge of SMEs
   b. Supporting digitalization and entrepreneurship.

A key policy framework for achieving these goals can be transition management which combines the vision of sustainable development with short-term experimental learning with a time horizon of 25-50 years, i.e., it supports policies for social learning, and finding ways of social innovation. Transition management should be built on:

1. Stakeholder management: Broad societal discourse; New principles and guidelines for participant selection and interactions among actors who co-produce new solutions; Developing change visions by participants according to feasibility, creative and normative aspects
2. Holistic evaluation: New concepts and solutions must be evaluated according to broad techno-economic and societal aspects, and alternative pathways as well, for which legitimacy comes from Inclusivity, participation, and transparency.
3. Responsible innovation: Responsible innovation is about innovating with and for society. Responsible innovation has four principles, i.e.,
    a. anticipation (systematic thinking about the desirable futures),
    b. reflexivity (exploring underlying values),
    c. inclusion and deliberation (frequent or continuous negotiations with stakeholders),
    d. responsiveness (shaping innovation directions based on stakeholder values).
4. Entrepreneurship for social and environmental purposes: Policymakers could incite organizations to build sustainable business models based on certain archetypes:
    a. technological (e.g., create value from waste),
    b. social (e.g., product redesign for durability),
    c. organizational (e.g., new partnerships for an infrastructural change).

6.3.2. Institutional recommendations

Supporting social innovators and SME-sized business model innovators to avoid strategic concealment

Governments can incite and support social innovators, e.g., through prizes, as pure social innovations and social business models generate only public goods, for which private markets are unlikely to show significant interest. In the context of social innovation, working against inequality could be a main driver from an innovation perspective, as inequality could reduce economic development and inhibit entrepreneurship. In contrast, a higher quality and volume of human capital could increase creativity and capacity for invention and innovation. Moreover, even though potential entrepreneurs could realize business model innovation (BMI), they might hide ideas related to and implementation of BMI (strategic concealment), because of the power of the incumbents who might easily copy the model with other competitive advantages based on their existing resources. This strategic concealment does not help improving social welfare and the progress of SMEs.

Holistic innovation in cities

According to the literature, cities can be incubators and catalysts of social, economic, and environmental change – besides their inherent relevance in the urbanized world. One of its key pathways is the so-called embedded holistic innovation which induces changes in individual behavior, social behavior and/or structure, and technology. It can be based on a community-oriented urban governance mode for welfare, inclusion, education, and care.

6.3.3. Research recommendations

Circular economy research on policy level, sustainable business model research on corporate level

The mapping of change drivers highlighted that SBMI plays a connecting role between EEI and fundamental economic concerns of sustainable development, through two globally relevant themes: circular economy development and sustainable business model innovation. Based on the influential studies, the following research topics could be relevant:

1. Influential topics from the Eastern research
    a. Reshaping urban policy for sustainability transition
    b. Supporting holistic innovation
    c. Building on human capital and consciousness
    d. Strengthening exploratory orientation
    e. Deployment of ICT applications
    f. Developing an open innovation strategy
2. Influential topics from the Western research
    a. Accelerating the interplay between social change and new technologies
    b. Supporting social entrepreneurship
    c. Introducing new business models (startups), mixing new and traditional business models (incumbents) for competitive advantage
    d. Focus on sustainable value creation

Besides leading Western research institutions of frontier countries in this area (e.g., Harvard Business School), Eastern university departments could be also relevant to collaborative SBMI research, such as:

1. China: School of Business, Renmin University of China; Department of Management CUHK Business School, The Chinese University of Hong Kong
2. South Korea: Department of Urban Planning and Engineering, Yonsei University.

6.3.4. Corporate recommendations

Social innovation by substantial organizational changes or new ventures

The literature suggests that firms could increase their social innovation performance through strategic changes, such as:

1. Combining top-down and bottom-up approaches
    a. Aligning business strategy with impact vision, and a roadmap development to increase the positive impact
    b. Cultural change for employee empowerment and self-reflection
    c. Resource allocation to enable networking, involvement and reorganization of the work with stakeholders
2. Establishing social enterprises to support local and regional development based on
    a. shared and sustainable values
    b. linking stakeholders and potential benefits
    c. promoting collective action and participation in solving problems
    d. making responsible economic decisions and reinvesting profit for social investments.
3. Following the principles of social innovation:
    a. Experience-based problem definition, responding to a practical need, recognizing emergent ideas and envisioning broader implications
    b. A limited number of manageable key causes, finding central and essential elements
    c. Building on talented, marginal individuals and unique, experimental approach
    d. Finding a solution which opens the door for further developments
    e. Ensuring dedicated resources, mainly time and resources
    f. Quick demonstration with low cost, generating culturally and technologically appropriate benefits, orchestration of (experimental) projects
    g. Involving persuasion, but the idea must be more important than the recognition of the innovator
    h. Willingness to restructure social relationships.

Sustainable business model innovation following technological, organizational, social archetypes

Additionally, business model innovation must be enabled by

1. sustainable business model archetypes, for example
    a. maximizing material and energy efficiency based on new technologies
    b. adopting a stewardship role based on engaging with stakeholders for long-term well-being
    c. re-purposing the business for society or the environment with a participatory business approach.
2. improved knowledge management by chief knowledge officers who
    a. orient KM to the ways of value creation and capture
    b. introduce new knowledge-sharing methods
    c. realizes knowledge-driven culture building.
3. exploratory orientation and entrepreneurial bricolage, which means
    a. identifying opportunities, finding changes in market demands and customer preferences
    b. applying combinations of resources at hand (cheap or free) for new purposes to solve problems and seize opportunities.

6.4. Cultural and design innovation (SQ4)

6.4.1. Policy recommendations

Cultural drift toward eco-culture and AI-supported sustainable business models

The cultural and design innovation-related V4 analysis could be synthesized as follows:

1. Cultural aspects:
    a. Involving cultural aspects as one of the main areas of research
    b. Developing an entrepreneurial culture
    c. Respecting the cultural heritage
2. Design aspects:
    a. Eco-design or environmental design for minimizing waste and circularity

These goals suggest that pathways toward economic, social, and environmental sustainability require not only technological innovation, but cultural innovation, which is also reflected in the literature. According to the ecopolis model, the top level is the eco-culture. Eco-culture would be relevant "*to* *give people the opportunity to develop their culture and quality of life through an understanding of their own place in nature, their own responsibility for the environment, and their own ability to contribute to maintaining high quality urban ecosystems through applying holistic integrative ecological principles in their every day lives"* (Wang, et al., 2011, p. 27).

From a technological aspect, the recent literature emphasized that cultural drift is necessary first to enable the potential of AI in developing sustainable business models and achieve sustainable development goals. *"Governments and organisations need to develop pragmatic strategies to educate AI within the workplace"* and "*the integration of AI within organisations and the ethical considerations of the technology is important for the success of SDGs"* (Di Vaio, et al., 2020, p. 311).

6.4.2. Institutional recommendations

Moderate and balanced incentives for exploitative and explorative routines

Even though entrepreneurial culture and eco-design would require predominantly exploration, its exclusive support would be harmful. It is because, the exploration-exploitation trade-off can be interpreted not only in case of businesses but also at individual, group, and social levels, which affects science and cultural innovation as well. From an adaptation perspective, too much exploitation and too much exploration could be harmful to problem-solving.

1. Outcomes of too exploitative routines:
    a. Compulsiveness
    b. Perseveration
    c. Groupthink
2. Outcomes of too explorative routines:
    a. Impulsiveness
    b. Inattentiveness
    c. Failure to leverage social information.

Analyzing social needs, monitoring social dynamics

For example, the inadequacy of "normal" incentives, the failure of market mechanisms to reduce social costs, the exclusion of actors from conventional channels could lead to social movements, which could de-institutionalize beliefs, norms, and values, or institutional entrepreneurs, who can identify political opportunities, frames issues, and mobilize people.

6.4.3. Research recommendations

Exploring the cultural and design aspects of sustainable development

In case of CDI, mainly cultural anthropology and new product design contextualize the global research. As CDI research seems to be less connected to sustainable development than the other three innovation and design areas, the integrative view of culture, design, and other focal topics of sustainable development, e.g., eco-innovation may hold many unanswered research questions which could be answered by V4 researchers.

Based on the affiliations of the most relevant study in this area (i.e., capacity building for eco-culture), further research could be realized through global collaborations:

1. China: State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environment Sciences, Chinese Academy of Sciences
2. USA: Ecological Complexity and Modeling Laboratory, University of California.

6.4.4. Corporate recommendations

Design innovation based on versatile value categories, supported by marketing integration

In case of corporations, the literature is more focused on design innovation compared to cultural innovation.

1. Corporations should manage continuously evolving networks to pursue incremental and discontinuous change according to the technological rules, such
    a. as design for lifecycle (concerning the entire product lifecycle during the strategy formulation),
    b. design for high involvement (relationship management and connecting people)
    c. or design for diffusion (creating practice-based learning opportunities for knowledge transfer)
2. Integration of design innovation and marketing by
    a. top-leadership support and integration at the strategic level,
    b. encouraging designers to be in the market,
    c. creating intergenerational teams, decoupling branding and production.
2. Concerning different categories of
    a. design innovation (aesthetic, feature, and emotional attributes)
    b. design value (humanistic and technical values),
    c. customer value (product-related, service-related, promotion-related).

3. Design innovation for sustainable development by
    a. introducing a multi-life-cycle product system with cradle-to-cradle design and multi-generation products,
    b. redesigned logistics and distribution channels according to circularity.

6.5. Limitations and future research directions

As the scope of this research was inherently broad with multiple innovation and design areas, several dimensions of practical recommendations, and without any sectoral focus, the research results could outline strategic change directions and strategic actions which could help to increase innovation and design performance in the future. Consequently, two main directions seem to be relevant for future research:

1. Narrowing the scope: Analyzing a specific industry from the aspect of a specific innovation area could lead to operative planning. For example, as sustainable development and environmental issues are crucial topics in the innovation and design literature, the energy sector could be relevant for further research.
2. Theoretical contribution: Based on the several theoretical models explored during the research phases, future research could focus on validating, rejecting, extending, or fine-tuning them based on empirical evidence.

7. References

Aczél, P., 2018. Social Futuring - A discursive-conceptual framework. Society and Economy, 40 (S1), pp. 47–75 https://doi.org/ 10.1556/204.2018.40.S1.4

Ahmad, M. et al., 2020. The dynamic impact of natural resources, technological innovations and economic growth on ecological footprint: An advanced panel data estimation. Resources Policy, 69, p. 101817. https://doi.org/10.1016/j.resourpol.2020.101817.

Ahuja, G., 2000. The duality of collaboration: inducements and opportunities in the formation of interfirm linkages. Strategic Management Journal, 21 (3), pp. 317-343. https://doi.org/10.1002/(SICI)1097-0266(200003)21:3<317::AID-SMJ90>3.0.CO;2-B.

Baregheh, A., Rowley, J. & Sambrook, S., 2009. Towards a multidisciplinary definition of innovation. Management Decision, 47 (8), pp. 1323-1339. https://doi.org/10.1108/00251740910984578.

Benner, M. J. & Tuschman, M., 2002. Process Management and Technological Innovation: A Longitudinal Study of the Photography and Paint Industries. Administrative Science Quartlerly, 47 (4), pp. 676-707. https://doi.org/10.2307/3094913.

Benner, M. J. & Tushman, M. L., 2003. Exploitation, Exploration, and Process Management: The Productivity Dilemma Revisited. The Academy of Management Review, 28 (2), pp. 238-256. https://doi.org/10.2307/30040711.

Berente, N., Gu, B., Recker, J. & Santhanam, R., 2021. Managing Artificial Intelligence. MIS Quarterly, 45(3), pp. 1433-1450. https://doi.org/10.25300/MISQ/2021/16274.

Beverland, M. B., 2005. Managing the Design Innovation–Brand Marketing Interface: Resolving the Tension between Artistic Creation and Commercial Imperatives. Journal of Product Innovation Management, 22 (2), pp. 193-207. https://doi.org/10.1111/j.0737-6782.2005.00114.x.

Brooks, J. S., Waring, T., Borgerhoff Mulder, M. & Richerson. P. J., 2018. Applying cultural evolution to sustainability challenges: an introduction to the special issue. Sustainability Science, 13, pp. 1-8. https://doi.org/10.1007/s11625-017-0516-3.

Cai, W. & Li, G., 2018. The drivers of eco-innovation and its impact on performance: Evidence from China. Journal of Cleaner Production, 176, pp. 110-118. https://doi.org/10.1016/j.jclepro.2017.12.109.

Cambridge Advanced Learner's Dictionary & Thesaurus, 2003. Cambridge University Press.

Carrillo-Hermosilla, J., del Río, P. & Könnölä, T., 2010. Diversity of eco-innovations: Reflections from selected case studies. Journal of Cleaner Production, 18 (10-11), pp. 1073-1083. https://doi.org/10.1016/j.jclepro.2010.02.014.

Casadesus-Masanell, R. & Zhu, F., 2012. Business model innovation and competitive imitation: The case of sponsor-based business models. Strategic Management Journal, 34 (4), pp. 383-508. https://doi.org/10.1002/smj.2022.

Cohen, W. M. & Levinthal, D. A., 1990. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly, 35 (1), pp. 128-152. https://doi.org/10.2307/2393553.

Council for Research, Development and Innovation, 2019. Innovation Strategy of the Czech Republic 2019–2030, Office of the Government of the Czech Republic.

Csedő, Z. & Zavarkó, M., 2019. Változás, tudás és innováció a vezetéstudományban: elméleti modellek elemzése és értelmezése (Change, knowledge and innovation in management science: analysis and interpretation of theoretical models). Vezetéstudomány - Budapest Management Review, 50 (12), pp. 173-184. https://doi.org/10.14267/VEZTUD.2019.12.15.

Csedő, Z. & Zavarkó, M., 2020. The role of inter-organizational innovation networks as change drivers in commercialization of disruptive technologies: The case of power-to-gas. International Journal of Sustainable Energy Planning and Management, 28, p. 53–70. https://doi.org/10.5278/ijsepm.3388.

Csedő, Z., 2023. Sustainability change management in inter-organizational innovation networks. Society and Economy 45 (4), pp. 355-371. https://doi.org/10.1556/204.2023.00011.

Csedő, Z., Pörzse, G. & Zavarkó, M., 2021. The Role of Innovation Knowledge Networks in Higher Education: Experiences of the Development of a Power-to-Gas Innovation Ecosystem. Pro Publico Bono, 9 (3), pp. 6-31. https://doi.org/10.32575/ppb.2021.3.1.

Csedő, Z., Zavarkó, M. & Magyari, J., 2023. Implications of open eco-innovation for sustainable development: Evidence from the European renewable energy sector. Sustainable Future, 6, p. 100143. https://doi.org/10.1016/j.sftr.2023.100143.

Csedő, Z., Zavarkó, M. & Sára, Z., 2019a. Innováció-e a digitalizáció? A digitális transzformáció és az innovációmenedzsment tanulságai egy pénzügyi szolgáltatónál. Vezetéstudomány, 50 (7-8), pp. 88-101. https://doi.org/10.14267/VEZTUD.2019.07.08.

Csedő, Z., Zavarkó, M. & Sára, Z., 2019b. Tudásmenedzsment és stratégiai kettős képesség – Felsővezetői döntések elemzése az innovációs stratégia megvalósítása során. Vezetéstudomány, 50 (3), pp. 36-49. https://doi.org/10.14267/VEZTUD.2019.03.04.

Dacin, T. M., Dacin, P. A. & Tracey, P., 2011. Social Entrepreneurship: A Critique and Future Directions. Organization Science, 22 (5), pp. 1121-1367. https://doi.org/10.1287/orsc.1100.0620.

de Jesus, A. & Mendonça, S., 2018. Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy. Ecological Economics, 145, pp. 75-89. https://doi.org/10.1016/j.ecolecon.2017.08.001.

Di Vaio, A., Palladino, R., Hassan, R. & Escobar, O., 2020. Artificial intelligence and business models in the sustainable development goals perspective: A systematic literature review. Journal of Business Research, 121, pp. 283-314. https://doi.org/10.1016/j.jbusres.2020.08.019.

European Commission, 2023. European Innovation Scoreboard 2023 and Regional Innovation Scoreboard 2023. [Online] https://ec.europa.eu/research-and-innovation/en/statistics/performance-indicators/european-innovation-scoreboard/eis# [18 10 2023].

Gaddy, B. E., Sivaram, V., Jones, T. B. & Wayman, L., 2017. Venture Capital and Cleantech: The wrong model for energy innovation. Energy Policy, 102, pp. 385-395. https://doi.org/10.1016/j.enpol.2016.12.035.

Goralski, M. A. & Tan, T. K., 2020. Artificial intelligence and sustainable development. The International Journal of Management Education, 18 (1), p. 100330. https://doi.org/10.1016/j.ijme.2019.100330.

Goyal, S., Esposito, M. & Kapoor, A., 2018. Circular economy business models in developing economies: Lessons from India on reduce, recycle, and reuse paradigms. Thunderbird International Business Review, 60, p. 729–740. https://doi.org/10.1002/tie.21883.

Greenhalgh, T. et al., 2017. Beyond Adoption: A New Framework for Theorizing and Evaluating Nonadoption, Abandonment, and Challenges to the Scale-Up, Spread, and Sustainability of Health and Care Technologies. J Med Internet Res, 19 (11), p. e367. https://doi.org/10.2196/jmir.8775.

Guan, J. & Ma, N., 2003. Innovative capability and export performance of Chinese firms. Technovation, 23 (9), pp. 737-747. https://doi.org/10.1016/S0166-4972(02)00013-5.

Guimarães, J. C. F., Severo, E. A. & Vasconcelos, C., 2018. The influence of entrepreneurial, market, knowledge management orientations on cleaner production and the sustainable competitive advantage. Journal of Cleaner Production, 174, pp. 1653-1663. https://doi.org/10.1016/j.jclepro.2017.11.074.

Guo, H., Su, Z. & Ahlstrom, D., 2016. Business model innovation: The effects of exploratory orientation, opportunity recognition, and entrepreneurial bricolage in an emerging economy. Asia Pacific Journal of Management, 33, pp. 533–549. https://doi.org/10.1007/s10490-015-9428-x.

Gupta, H. & Barua, M. K., 2016. Identifying enablers of technological innovation for Indian MSMEs using best–worst multi criteria decision making method. Technological Forecasting and Social Change, 107, pp. 69-79. https://doi.org/10.1016/j.techfore.2016.03.028.

Haefner, N., Wincent, J., Parida, V. & Gassmann, O., 2021. Artificial intelligence and innovation management: A review, framework, and research agenda. Technological Forecasting and Social Change, 162, p. 120392. https://doi.org/10.1016/j.techfore.2020.120392.

Halachmi, I., Guarino, M., Bewley, J. & Pastell, M., 2018. Smart Animal Agriculture: Application of Real-Time Sensors to Improve Animal Well-Being and Production. Annual Review of Animal Biosciences, 7, pp. 403-425. https://doi.org/10.1146/annurev-animal-020518-114851.

Haldar, A. & Sethi, N., 2022. Environmental effects of Information and Communication Technology - Exploring the roles of renewable energy, innovation, trade and financial development. Renewable and Sustainable Energy Reviews, 153, p. 111754. https://doi.org/10.1016/j.rser.2021.111754.

Heidenreich, P. A. et al., 2013. Forecasting the Impact of Heart Failure in the United States. A Policy Statement From the American Heart Association. Circulation: Heart Failure, 6 (3), p. 606–619. https://doi.org/10.1161/HHF.0b013e318291329a.

Holmström, J., 2022. From AI to digital transformation: The AI readiness framework. Business Horizons, 65 (3), pp. 329-339. https://doi.org/10.1016/j.bushor.2021.03.006.

Hur, T., Lee, J., Ryu, J. & Kwon, E., 2005. Simplified LCA and matrix methods in identifying the environmental aspects of a product system. Journal of Environmental Management, 75 (3), pp. 229-237. https://doi.org/10.1016/j.jenvman.2004.11.014.

ITM & NKFIH, 2021. Research, Development and Innovation Strategy of Hungary.

ITM, 2020. National Clean Development Strategy 2020-2050.

Kesidou, E. & Demirel, P., 2012. On the drivers of eco-innovations: Empirical evidence from the UK. Research Policy, 41 (5), pp. 862-870. https://doi.org/10.1016/j.respol.2012.01.005.

Kudyba, S., Fjermestad, J. & Davenport, T., 2020. A research model for identifying factors that drive effective decision-making and the future of work. Journal of Intellectual Capital, 21 (6), pp. 835-851. https://doi.org/10.1108/JIC-05-2019-0130.

Lee, K.-H. & Min, M., 2015. Green R&D for eco-innovation and its impact on carbon emissions and firm performance. Journal of Cleaner Production, 180, Part A, pp. 534-542. https://doi.org/10.1016/j.jclepro.2015.05.114.

Liu, X. & Bae, J., 2018. Urbanization and industrialization impact of CO2 emissions in China. Journal of Cleaner Production, 172, pp. 178-186.

Liu, Y. et al., 2020. Cloud-based big data analytics for customer insight-driven design innovation in SMEs. International Journal of Information Management, 51, p. 102034. https://doi.org/10.1016/j.ijinfomgt.2019.11.002.

Lozano, R., Ceulemans, K. & Seatter, C. S., 2015. Teaching organisational change management for sustainability: designing and delivering a course at the University of Leeds to better prepare future sustainability change agents. Journal of Cleaner Production, 106, pp. 205-215. https://doi.org/10.1016/j.jclepro.2014.03.031.

Magyari, J., Zavarkó, M. & Csedő, Z., 2022. Smart knowledge management driving green transformation: A comparative case study. Smart Energy, 7, p. 100085. https://doi.org/10.1016/j.segy.2022.100085.

March, J. G., 1991. Exploration and exploitation in organizational learning. Organization Science, 2 (1), p. 71–87.

Mariani, M. M., Machado, I. & Nambisan, S., 2023. Types of innovation and artificial intelligence: A systematic quantitative literature review and research agenda. Journal of Business Research, 155, Part B, p. 113364. https://doi.org/10.1016/j.jbusres.2022.113364.

Mariani, M. M., Machado, I., Magrelli, V. & Dwivedi, Y. K., 2023. Artificial intelligence in innovation research: A systematic review, conceptual framework, and future research directions. Technovation, 122, p. 102623. https://doi.org/10.1016/j.technovation.2022.102623.

McCauley, S. & Stephens, J., 2012. Green energy clusters and socio-technical transitions: analysis of a sustainable energy cluster for regional economic development in Central Massachusetts, USA. Sustainability Science, 7, pp. 213–225. https://doi.org/10.1007/s11625-012-0164-6.

Ministry of Climate and Environment, 2019. Executive Summary of Poland's National Energy and Climate Plan for The Years 2021-2030 (Necp Pl).

Ministry of Industry and Trade, 2019. The National Energy and Climate Plan of the Czech Republic.

Mirabella, N., Castellani, V. & Sala, S., 2014. Current options for the valorization of food manufacturing waste: a review. Journal of Cleaner Production, 65, pp. 28-41. https://doi.org/10.1016/j.jclepro.2013.10.051.

Moon, H., Miller, D. R. & Kim, S. H., 2013. Product Design Innovation and Customer Value. Journal of Product Innovation Management, 30, pp. 31-43. https://doi.org/10.1111/j.1540-5885.2012.00984.x.

Mumford, M. D., 2002. Social Innovation: Ten Cases From Benjamin Franklin. Creativity Research Journal, 14 (2), pp. 253-266. https://doi.org/10.1207/S15326934CRJ1402_11.

Murmann, J. P. & Frenken, K., 2006. Toward a systematic framework for research on dominant designs, technological innovations, and industrial change. Research Policy, 35 (7), pp. 925-952. https://doi.org/10.1016/j.respol.2006.04.011.

Nakamura, H., Kajikawa, Y. & Suzuki, S., 2013. Multi-level perspectives with technology readiness measures for aviation innovation. Sustainability Science, 8, pp. 87–101. https://doi.org/10.1007/s11625-012-0187-z.

National Centre for Research and Development, 2011. Krajowy Program Badań ZałoŜenia polityki naukowo – technicznej i innowacyjnej państwa.

Nishant, R., Kennedy, M. & Kennedy, C., 2020. Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda. International Journal of Information, 53, p. 102104.

Nishitani, K., Jannah, N., Kaneko, S. & Hardinsyah, 2017. Does corporate environmental performance enhance financial performance? An empirical study of indonesian firms. Environmental Development, 23, pp. 10-21. https://doi.org/10.1016/j.envdev.2017.06.003.

North, D., 1990. Institutions, institutional change and economic performance. Cambridge: Cambridge University Press.

OECD, 2023. OECD Science, Technology and Innovation Scoreboard. [Online] https://www.oecd.org/innovation/scoreboard.htm [15 08 2023].

Oxford Advanced American Dictionary, 2011. Oxford University Press.

Peck, J., 2005. Struggling with the Creative Class. International Journal of Urban and Regional Research, 29 (4), pp. 740-770. https://doi.org/10.1111/j.1468-2427.2005.00620.x.

Pol, E. & Ville, S., 2009. Social innovation: Buzz word or enduring term?. The Journal of Socio-Economics, 38 (6), pp. 878-885. https://doi.org/10.1016/j.socec.2009.02.011.

Pörzse, G., 2008. Innovációmenedzsment. Budapest: Semmelweis Kiadó.

Pörzse, G., 2011. Kutatásszervezés és innovációmenedzsment az egészség- és élettudományok területén. Budapest: Semmelweis Kiadó.

Qu, X., Alvarez, P. & Li, Q., 2013. Applications of nanotechnology in water and wastewater treatment. Water Research, 47 (12), pp. 3931-3946. https://doi.org/10.1016/j.watres.2012.09.058.

Rao, H., Morrill, C. & Zald, M. N., 2000. Power Plays: How Social Movements and Collective Action Create New Organizational Forms. Research in Organizational Behavior, 22, pp. 237-281. https://doi.org/10.1016/S0191-3085(00)22007-8.

Sára, Z. et al., 2013. A korszerű információ-technológiai megoldások szerepe az orvos-beteg kommunikáció javításában. IME, 12 (4), pp. 20-24.

SARIO, 2021. R&D Innovation Sector in Slovakia, Slovak Investment and Trade Development Agency.

Sharif, A., Mehmood, U. & Tiwari, S., 2023. A step towards sustainable development: role of green energy and environmental innovation. Environment, Development and Sustainability, pp. https://doi.org/10.1007/s10668-023-03111-5.

Shen, H. et al., 2020. The Impact of the COVID-19 Pandemic on Firm Performance. Emerging Markets Finance and Trade, 56 (10), pp. 2213-2230. https://doi.org/10.1080/1540496X.2020.1785863.

Shennan, S., 2001. Demography and Cultural Innovation: A Model and its Implications for the Emergence of Modern Human Culture. Cambridge Archaeological Journal, 11 (1), pp. 5-16. https://doi.org/10.1017/S0959774301000014.

Shi, W., Connelly, B. L. & Cirik, K., 2018. Short Seller Influence on Firm Growth: A Threat Rigidity Perspective. Academy of Management Journal, 61 (5), pp. 19892-1919. https://doi.org/10.5465/amj.2016.1010.

Šlaus, I. & Jacobs, G., 2011. Human Capital and Sustainability. Sustainability, 3, pp. 97-154. https://doi.org/10.3390/su3010097.

Slovak Ministry of Economy, 2019. Integrated National Energy and Climate Plan for 2021 to 2030.

Sun, H. et al., 2021. Energy efficiency: The role of technological innovation and knowledge spillover. Technological Forecasting and Social Change, 167, p. 120659. https://doi.org/10.1016/j.techfore.2021.120659.

Szántó, Z. O. et al., 2020. Social Futuring Index: Concept, Methodology and Full Report 2020, Part I, Budapest: Corvinus University of Budapest.

Szántó, Z. O., 2018. Social Futuring - An Analytical Conceptual Framework. Society and Economy, 40 (S1), p. 5–20. https://doi.org/10.1556/204.2018.40.S1.2.

Szántó, Z. O., et al., 2019. Foundations of the Social Futuring Index. Információs Társadalom XIX (4), pp. 115–132. https://dx.doi.org/10.22503/inftars.XIX.2019.4.8

Szántó, Z. O., et al., 2023. Future Potential Index | 2022 Concept, Measurements and Results. Future Potentials Observatory: Budapest.

Teece, 2007. Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. Strategic Management Journal, 28 (13), pp. 319-1350. DOI: 10.1002/smj.640.

The National Centre for Research and Development, 2023. Strategic programmes. [Online] https://www.gov.pl/web/ncbr-en/strategic-programmes [17 10 2023].

Verganti, R., Vendraminelli, L. & Iansiti, M., 2020. Innovation and Design in the Age of Artificial Intelligence. Journal of Product Innovation Management, 37 (3), p. 212–227. https://doi.org/10.1111/jpim.12523.

Výskumná A Inovačná Autorita, 2023. Národná stratégia výskumu, vývoja a inovácií 2030. [Online] https://vaia.gov.sk/sk/narodna-strategia-vyskumu-vyvoja-a-inovacii-2/ [18 10 2023].

Wang, R., Li, F., Hu, D. & Li, B. L., 2011. Understanding eco-complexity: Social-Economic-Natural Complex Ecosystem approach. Ecological Complexity, 8 (1), pp. 15-29. https://doi.org/10.1016/j.ecocom.2010.11.001.

West, J. & Bogers, M., 2014. Leveraging External Sources of Innovation: A Review of Research on Open Innovation. Journal of Product Innovation Management, 31 (4), pp. 814-831. https://doi.org/10.1111/jpim.12125.

Wolfram, M., 2018. Cities shaping grassroots niches for sustainability transitions: Conceptual reflections and an exploratory case study. Journal of Cleaner Production, 173, pp. 11-23. https://doi.org/10.1016/j.jclepro.2016.08.044.

Wu, J. Y., Liu, W.-J. & Yuan, C.-H., 2020. A mobile-based barrier-free service transportation platform for people with disabilities. Computers in Human Behavior, 107, p. 105776. https://doi.org/10.1016/j.chb.2018.11.005.

Xie, X., Huo, J. & Hailiang, Z., 2019. Green process innovation, green product innovation, and corporate financial performance: A content analysis method. Journal of Business Research, 101, pp. 697-706. https://doi.org/10.1016/j.jbusres.2019.01.010.