environmental sciences proceedings

Proceeding Paper

Sustainable Innovation as a Driver for Socio-Ecological Transition †

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† Presented at the ICSD 2021: 9th International Conference on Sustainable Development, Virtual, 20–21 September 2021.

Abstract: Societies are facing major and worsening environmental, social and health crises. In order to deal with these challenges, a major socio-ecological transformation is required. Sustainable innovation (SI) is one of the means to achieve this goal. We propose in this article a new definition of SI for sustainable development purposes, guided by the SDGs and setting the context, along with comprehensive literature. The article then highlights the concepts to which SI is related, such as the theory of sociotechnical systems and transitions, as well as its fields of application, such as the circular economy, regenerative design and transformative social innovation.

Keywords: sociotechnical approach; socio-ecological transition; sustainable development; sustainable development goals; circular economy; regenerative design; transformative social innovation

Citation: Genois-Lefrançois, P.; Lefèvre, T.; Elzein, H.; Cheriet, M. Sustainable Innovation as a Driver for Socio-Ecological Transition. *Environ. Sci. Proc.* **2022**, *15*, 29. https://doi.org/10.3390/environsciproc2022015029

Academic Editors: Cheyenne Maddox and Lauren Barredo

Published: 7 May 2022

1. Introduction

Governments and people are facing significant economic, social and environmental challenges. In this era of globalization and a context of a growth-based industrial society model, human activities are exceeding the sustainability thresholds supported by the biosphere [1].

The socioeconomic picture is as worrisome as the environmental one, with increasing wealth and inequality at the national and international levels, and growing disparities in resource use [2]. There are also disparities in the attribution of the environmental impacts [3].

Similarly, while the COVID-19 pandemic has profoundly disrupted communities, large differences have been observed across countries, particularly regarding the uneven distribution of vaccines that threaten the possibility of global herd immunity. The health crisis heavily impacted the populations: a large number of contaminations, deaths and people with long-term effects, upheavals in several sectors of activity, precariousness of employees and organizations, public indebtedness and amplification of social inequalities. The pandemic has also highlighted the links between human activities and environmental degradation since the destruction of ecosystems increases the risks of propagation of zoonoses [4].

These observations show the interrelations between, on one hand, human activities that are harmful to the environment and cause social inequalities, and on the other hand, the pandemic crisis. This situation calls for profound changes in our interpretation of socioeconomic recovery in order to promote more resilient and sustainable models. This "socio-ecological" transition requires, among other things, a dematerialization and decarbonization of the economy, as well as a more just distribution of resources [5].

However, the societal transformations that are required are inhibited or complicated by the evolving and multidimensional nature of societies and the environment, by the interactions between society and nature as well as by societal lock-ins that inhibit the implementation of a socio-ecological transition. Crises also influence our lifestyles in both the short and long term, and they therefore offer opportunities to foster change.

On another level, we can observe the emergence of environmental and social innovations in several sectors of activity. This underlying trend is a trigger of the general context we called "**sustainable innovations**" (**SI**), which can be considered as a powerful tool for accelerating the movement towards sustainability (Figure 1). Indeed, SI could be a key tool for aligning the economy with social, environmental and health constraints. The current conjuncture thus seems opportune to develop a real inter-sectoral and interdisciplinary community of SI.

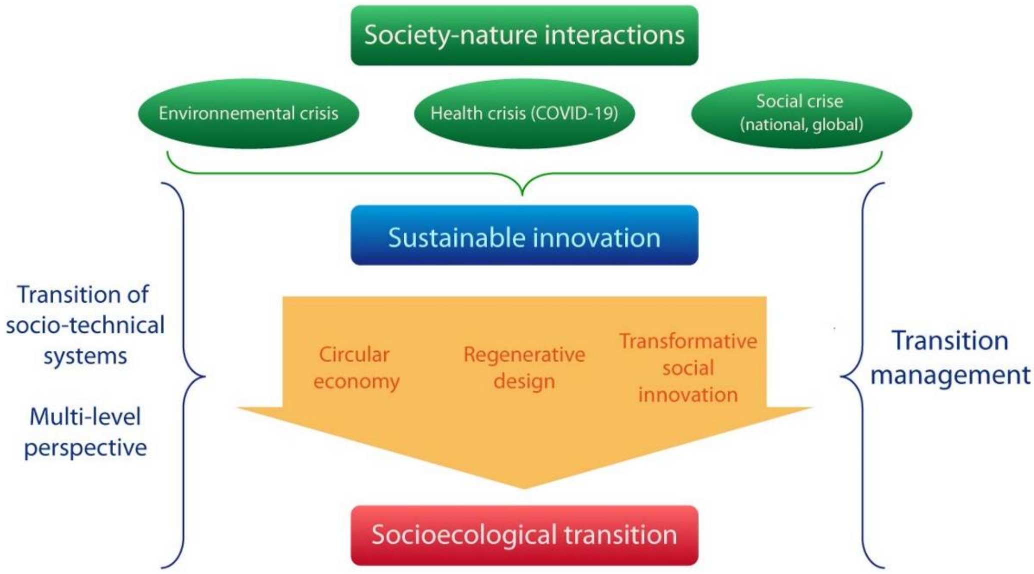

Figure 1. The role of sustainable innovations (SI) in the socio-ecological transition and its environmental, social and health context. The figure shows the application fields of SI (circular economy, regenerative design and transformative social innovation) as well as research domains that may make its implementation successful (i.e., transition of sociotechnical systems, multi-level perspective and transition management).

However, this concept is still in its infancy, both within research and teaching institutions, and among field actors. There are still unclear areas regarding its definition and operationalization. It also has to be supported by academic research in the field of transition theory and complex systems such as modern societies, and by stakeholders.

In order to present the potential benefits of SI in the implementation of sustainable development (SD) and the achievement of the Sustainable Development Goals (SDGs), and to contribute to unify the research community and practitioners around a common and consolidated understanding of SI, this article presents a literature review on SI from an inter-trans/disciplinary perspective, as illustrated in Figure 1.

The origins of this concept, and the context in which it is embedded, are first presented. This work then highlights the fundamental research fields to which SI is linked, namely the theory of transitions of sociotechnical systems, in particular with the support of the multi-level perspective and the transition management. The article then presents the fields of application of SI, including the circular economy, regenerative design and transformative social innovation. The article then sums things up in a brief conclusion.

2. Origins and Definition of Sustainable Innovation (SI)

The aim of this section is to provide a brief portrait of the types of innovations that have preceded and may be associated with SI. Based on the benefits, characteristics and objectives of these innovations, while incorporating the imperatives of the Introduction section, a definition of SI is then proposed.

2.1. Origins and Context

The mainstream of innovation in the 20th century was essentially techno-centric and focused on economic value creation. However, over the past two decades, the acceleration of global crises and the growing popularity of systems approaches to socioeconomic issues have led to an increased focus on social innovation. Social innovation considers the challenges of socioeconomic inequalities and focuses on improving the collective well-being and the capacity to act of individuals and social groups [6]. It is a mobilizing innovation that promotes inclusion, modifies social relations and reinforces the autonomy of individuals.

Another trend is represented by eco-innovations, defined as having a reduced environmental burden (reduced resource or energy use, low-carbon materials and processes, quality and sustainability, etc.). Eco-innovations are often focused on high technologies such as renewable energies, geoengineering or biotechnology, and are often implemented on a large scale. While these innovations can contribute to minimizing the impact of societies, they can sometimes increase consumption by the rebound effect. Above all, they do not challenge an economic model that fails to respect planetary limits or social constraints.

In contrast to eco-innovations, the societal landscape has been giving way in recent decades to grassroots innovations such as urban farms, the use of local currencies, micro-credit and other social or community innovations. These solutions are notably illustrated by frugal innovation, also known as Jugaad innovation, which comes from developing countries such as India. This type of innovation, born from economic constraints, ingenuity, and individual and collective field experience, aims primarily at meeting the needs of the population by offering effective solutions, at lower cost and developed from local resources [7].

In the same family are the retro-innovations, popular in particular in the field of agroecology. This type of innovation implies a certain return to pre-existing or ancestral practices, supported by modern knowledge, which requires fewer resources, less investment, and guarantees a higher level of quality with high yields [8]. This type of innovation is the object of little interest from research teams to evaluate their sustainability, which ends up confining them, as well as frugal innovations, to a still marginal sphere. Yet they constitute a rich pool of SI.

Born from the observation of the disconnection between, on the one hand, the global scale of eco-innovations mainly focused on technology, and on the other hand, the local scale of social and community innovations, a new type of innovation that is oriented towards transformation has emerged under the terms mission-oriented and transformative innovations that aim a deep societal change [9,10]. The major challenge of SI lies in its capacity to go beyond top-down policies focused on technologies, since current policies are insufficient to limit environmental degradation and meet social needs. Thus, in order to achieve a radical systemic transformation, not only global, but also multi-scale coordination must be oriented towards common goals.

Open innovation represents an opportunity to bring together the various stakeholders. This type of innovation aims at sharing knowledge, information and best practices within the innovation ecosystem and even beyond [11,12]. With the increasing complexity of the knowledge required to develop innovations, it is almost impossible, even for the largest organizations, to rely on internal expertise. The exchange becomes essential and allows consolidation of both the innovation ecosystem and each stakeholder (companies, organizations, etc.).

2.2. Definition

In order to respect the social and environmental imperatives, SI appears as a type of innovation that can contribute to responding simultaneously to the three dimensions of SD. This type of innovation is all-encompassing, as it offers a range of transdisciplinary and inter-sectoral tools and modes of operation depending on the actors and sectors of activity involved. Whether it is radical or incremental, SI has a systemic and structuring character; it should provoke transformations that contribute to the evolution of our societal systems towards more sustainable trajectories. SI can thus be seen as a leverage tool for the processes and experiments of the socio-ecological transition of anthropic systems, at all societal scales and in an inter-sectoral manner (economy, technology, social, governance, justice, education).

We, therefore, propose the following definition of sustainable innovation (SI):

> *A new service, product, process, or practice, arising from collaboration among different actors, that contributes to operate a socio-ecological, interdisciplinary, structural, and systemic transformation aimed at making society compatible with planetary limits and ensuring human well-being and societal resilience* [13].

Many actors can contribute, interact, and collaborate to stimulate SI. These include educational and research institutions, political leaders, businesses, scientists, social organizations, national and international organizations and citizens. SI is indeed nourished by the interactions between different actors, but it also generates new networks. However, it seems crucial to examine the transformative role that SI can play at the scale of societal systems. To this end, the field of Sustainability Transitions seems relevant to better understand the complex dynamics that can guide profound systemic changes.

3. Understanding the Dynamics of Innovation That Underlies Transformation towards Sustainability: The Field of Sustainability Transitions

To initiate and accelerate a process of transition, it is necessary to recognize the complex and evolving nature of societal systems [14]. It is also required to overcome the issues of "path dependency" and "lock-in" that hinder the structuration of SI, while ensuring the dominance of incumbent systems [15,16]. Applied to societal systems, transitions result from a multiplicity of gradual changes structured on different scales and whose components co-evolve and reinforce each other [17–19]. To apprehend these complex phenomena of deep change, the scientific field of Sustainability Transitions is helpful to understand how innovations can sprout and contribute to the reconfiguration of incumbent systems [20,21]. Two major problems drive this field: the analysis of the dynamics of systems changes and the governance processes that can steer these changes. The sociotechnical and the governance approaches are two subfields providing conceptual and prescriptive tools to address these issues.

3.1. Transition of Sociotechnical Systems (STS)

The sociotechnical approach is concerned with systems that fulfill major functions in society (mobility, agriculture, energy) [22]. STSs are characterized by a complex articulation of social and technical elements: artifacts; infrastructures; user practices; institutions; business models; markets; policies; resources [23]. The interweaving and co-evolution of these components make the trajectory of STSs steady in time and space. They are thus a little subject to the phenomena of radical reconfiguration [24]. However, transitions may occur, fueled by systemic innovations [25]. In this respect, the analytical framework of the Multi-Level Perspective (MLP) allows us to understand the structure and evolution of a transition, as well as how innovations can emerge and transform existing systems [23,26].

The Multi-Level Perspective (MLP)

The MLP provides an evolutionary and structural interpretation of transitions through a "nested hierarchy" divided into three sociotechnical levels: the landscape (macro), the regime (meso), the niches (micro) [27]. It is within the regime that the core of the transition is carried out [17]. As the deep and stabilizing structure of STSs, the regime consists of an alignment of cognitive, regulatory, and normative rules [27]. This alignment corresponds to the dominant way in which STSs performs a societal function. Incremental innovations may arise within the regime itself, but these will contribute to its optimization rather than its transformation. The landscape is the exogenous environment of the STSs and those whose modulations influence the lower levels of the regime and the niche. The landscape includes trends (international agreements, resource scarcity) and shocks (wars, pandemics). The landscape puts pressure on the regime, which most of the time readjusts to adapt itself to it. Niches are virtual or physical spaces outside the regime that offer protection and autonomy for the development of radical innovations. Niches offer latitude for frontrunners to experiment, exchange knowledge and consolidate radical innovations [28].

According to the MLP, a transition requires interactions within processes from the three levels of the STS [29]. At the macro level, the accumulation of pressures from the landscape must destabilize the regime to the point that it cannot readjust. This provides opportunity for radical innovation to overcome the weaknesses of the regime. If the innovation is sufficiently mature and structured, it can transform the configuration of the subsystems of the regime. The new stable realignment within the regime will mark the transition, which will have a long-term impact on the landscape. According to Sustainability Transitions, the accumulation of reconfigurations of different STSs towards sustainable pathways is the key to a global socio-ecological transition [30].

3.2. Governing Transitions through Sustainable Innovations: Transition Management (TM)

To promote the socio-ecological transition, it seems essential to generate and consolidate SI that is likely to bring about profound structural changes in societal systems. In this perspective, the governance of transitions is a stream of Sustainability Transitions that explores analytical and prescriptive tools to stimulate and foster transition processes [31]. The research of this school stems from the idea that transitions cannot be controlled by top-down policies, but rather involve a diversity of actors, experiments, and processes of social learning [18,21]. The most sophisticated tool of this stream is Transition Management (TM), a collaborative and reflexive governance approach aimed at encouraging and channeling societal change [18,32].

The TM is deployed in a four-step cycle mobilizing research, co-creation, innovation support and networking of actors [18]. In the strategical phase, an organizational structure establishes a "transition arena": a network of actors gathered periodically to co-produce a collective intelligence and define major long-term objectives for a societal system. The tactical stage consists of developing prospective scenarios to explore the possible futures of the system, then putting them up for debate through participatory activities. This input will help to articulate a vision of a desirable pathway to achieve the objectives defined in the first step. A backcasting activity is used to plan the measures to be undertaken to reach the envisioned future. This strategic planning will be synthesized into a transition agenda. Intended to the frontrunners, the agenda is a repertoire including experiments to be implemented, coalitions to be established and potential sociotechnical arrangements [33]. In the operational phase, the arena selects transition experiments to be implemented. These experiments have two objectives. First, they explore the transformative potential of SI. More broadly, the experiments are intended to act as showcases of change to foster social learning and collective action in favor of transition [34]. The reflexive phase consists of assessing the entire cycle, but also measuring the impact and scaling-up potential of the experiments. This evaluation will enrich the transition agenda and the knowledge of the system for future TM cycles.

4. The Application Fields of Sustainable Innovation

Through the great diversity of its operationalization modes, SI promotes an interdisciplinary dialogue likely to generate or support structuring solutions. It is therefore an all-encompassing concept that can be mobilized by various fields of research and actions related to sustainability. There are thus several complementary ways of applying SI. Thus, the circular economy, regenerative design and transformative social innovation constitute three examples of applied research fields, of which SI is an integral part.

4.1. Circular Economy

The circular economy (CE) is a systemic approach aiming at a more sustainable mobilization of resources through a looping of material and energy flows within the production and consumption patterns [35]. CE includes strategies that fall into two broad categories: 1. rethinking production–consumption patterns to limit resource extraction and protect ecosystems; 2. optimizing the use of resources that are already mobilized in value chains to limit waste and pollution generation [36]. The strength of CE lies in the possibility of applying it at various scales of operation that are complimentary. For example, organizations can rethink their supply chains, business models or industrial operations. Due to the complexity of value chains, the implementation of organizational strategies also requires a multi-stakeholder collaboration that implies moving from a logic of competition to one of coordination and partnership. CE can also be implemented according to a territorial logic [37]. This implies developing a systemic approach that integrates actors, material flows and infrastructures in a defined geographical area [38,39].

The concepts of CE and SI are directly connected, can feed each other and therefore become reciprocally enriched. Indeed, the circularization of resource flows within an economic model that is mainly linear requires a systemic rethinking of production and consumption patterns and represents an SI in itself [40,41]. Furthermore, the implementation of CE strategies involves many unknown variables, as new ways of understanding resources and their use must be introduced [42]. It is, thus, necessary to mobilize SI throughout the value chains of products and services to create new circular loops.

4.2. Regenerative Design

Regenerative design (RD) can be defined as a set of technologies, practices and strategies that enable the regeneration of socio-ecological systems [43,44]. RD is part of a broader environmental scope than sustainable development, as it aims at rebuilding natural capital and enriching natural conditions. The aim is to develop a relationship of mutualism between anthropic and natural systems. RD is a holistic and transdisciplinary process that adopts a systemic and evolutionary perspective of its objects of analysis (product, service, building, neighborhood, city). This design approach includes human and non-human stakeholders (communities, watersheds, ecosystems) and considers the key processes of the worked system. RD is rooted in the fields of construction and architecture, but the approach can be applied to several sectors of activity and at various scales. One of the most successful applications of the regenerative approach is embodied by permaculture, which allows intensive farming while capturing carbon dioxide and enriching the soil and local biodiversity.

4.3. Transformative Social Innovation

Transformative social innovation (TSI) aims to radically reconfigure social systems towards increased sustainability by proposing new discourses and solutions that break with dominant societal models [45]. TSI thus implies profound changes in the structure of incumbent institutions and relies on the institutionalization of change on a more global scale [46,47]. Its application is mostly the result of bottom-up organizational movements, some examples of which are the Transition Network, the Global Ecovillage Network, and the Slow Food. These different initiatives all propose new discourses and visions accompanied by a set of solutions supported by new structures. The four movements have also initiated changes in the dynamics and relationships between actors in their respective fields of innovation. More specifically, it involves new combinations of ways of doing, organizing, learning, and designing, offering alternatives to the services offered by dominant institutions [47].

The three previous examples illustrate the transdisciplinarity of SI, which allows it to bridge different fields of application while generating a potentially transformative synergy. By its theoretical value and its operational character, SI has the strong potential to play a key role in the transition of our societal systems towards greater harmony with the ecosphere and the more equitable distribution of resources.

5. Conclusions

Faced with many challenges imposed by sustainable development, it remains very difficult to adequately, rapidly and radically transform our socioeconomic models. Sustainable innovation thus appears to be a cross-cutting concept with the potential to act as a powerful lever to accelerate a shift towards fairer and more eco-responsible modes of production and consumption, as well more resilient societies. This still-emerging concept can represent an unquestionable driver of change to achieve a socio-ecological transition that will make it possible to reach the 17 UN SDGs.

SI practice should however be supported by theoretical research on Transition Studies and Transition Management. It is then crucial to mobilize the different actors in research, industry, politics and community organizations in order to create a favorable environment and the appropriate interaction platforms for the deployment of SI on a large scale. Stakeholders and actors of the ecosystem are encouraged to foster the development and the deployment of the major themes and approaches likely to support SI towards a resilient, inclusive and sustainable society.

Author Contributions: Conceptualization, P.G.-L., T.L. and H.E.; methodology, P.G.-L. and T.L.; data curation, P.G.-L., T.L. and H.E.; writing—original draft preparation, P.G.-L. and T.L.; writing—review and editing, P.G.-L., T.L., H.E. and M.C.; project administration, H.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research is funded by The Fonds de Recherche du Québec (FRQ-NT/SC).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors thank the Review Committee of the project and all people that have participated in this work, in particular Leyla Lardja, Thibaut Magalas and Luce Beaulieu.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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