Sustainable disruptive innovation

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Sustainable disruptive innovation (SDI) exhibits characteristics of disruptive innovations while also supporting positive ecological, economic, and societal conditions. An SDI therefore includes the following disruptive characteristics, SDI…

- brings new and different value propositions to market, based on new performance parameters;
- changes how customers prioritize one product or service over another;
- typically underperforms established products in mainstream markets;
- is typically commercialized and nurtured first in emerging or insignificant markets;
- is typically cheaper, simpler, smaller, and frequently more convenient to use than existing products;
- typically promises lower margins, not greater profits;
- typically enables new markets to emerge;
- must be measured with different performance attributes than those relevant in established value networks;
- is systemic in nature;
- changes existing unsustainable socioeconomic structures;
- reduces negative environmental impacts (widely understood to include all societal, economic, and ecological components); and
- considers the full lifecycle of a product when assessing its impacts.

1 Sustainable disruptive innovation

Sustainability refers to the maintenance of balance in environmental, economic, and social domains as actions are taken and change processes take place (UN, 2005). In recent times, sustainability considerations have permeated all levels of society. These considerations also increasingly factor into individuals' personal choices. This can include, for example, individuals' choices about their electricity usage, such as whether to use electricity produced from a renewable energy source. Such considerations also inevitably include calculations of whether sustainable decisions are economically viable; renewable sources may be pricier. However, some individuals may also perceive a social value or even pressure to make sustainable choices if their friends for example are using renewables. Economic, environmental, and social components therefore form the three pillars of sustainability decisions. These elements are interdependent, as captured in the Sustainable Development Goal, SDG 8 description: "Sustainable economic growth will require societies to create the conditions that allow people to have quality jobs that stimulate the economy while not harming the environment" (UN, 2018).

The economic pillar of sustainability refers to the efficient use of assets to create profits and improve overall standards of living. However, economic profit cannot override the other pillars of sustainability, and profit maximization to the exclusion of other factors is unsustainable over the long run. Sustainable businesses are therefore adopting compliance practices, risk management and mitigation programs, and corporate social responsibility programs. The social pillar of sustainability emphasizes community, quality of life improvements brought by sustainable practices, including access to key services, generational equity, community participation, etc. (McKenzie, 2004). Social sustainability also takes note of the impacts that businesses have on stakeholders, such as employees, customers, value chain partners, and communities, and seeks to manage those impacts responsibly. Finally, the environmental pillar of sustainability emphasizes the need to protect natural resources from harm and to support actions that enhance the environment's natural ability to flourish. Environmental sustainability can be defined as "a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity" (Morelli, 2011).

Sustainable development (as introduced by the Brundtland Commission, 1987) has been defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development must therefore take into account unlimited population growth, over-consumption, and climate change, and create sustainable innovations in order to achieve balanced change processes.

Sustainable innovation seeks to mitigate harmful change processes and to reinforce sustainable actions. Narrowly defined, sustainable innovations reduce environmental burdens and focus on environmental technologies in order to drive sustainability; more broadly, sustainable innovations take a holistic approach to the economic, ecological, and social impacts of commercialised products and services (e.g., Lupova-Henry & Dotti, 2019; Schiederig et al., 2012). Sustainable innovation changes socioeconomic structures rather than merely fixing existing ones or producing temporary solutions for long-term problems (Sarkis et al., 2010). Sustainable innovations are therefore systemic in nature, and a wide range of perspectives and actors must be considered when studying or introducing them. In addition, sustainable innovation should be seen as an ongoing process, wherein sustainability considerations are built into company processes such as new product development, operations, and commercialization (Charter & Clark, 2007), and organizational processes, energy and raw material use, etc. must be continuously improved to achieve leaner, more efficient operations.

Sustainable innovations need to meet a few basic requirements in order to successfully penetrate markets (Boons & Lüdeke-Freund, 2013). First, they must provide measurable ecological and social value as well as economic value. Second, the whole value chain must be managed responsibly according to stakeholder interests. Third, sustainable innovations must encourage responsible consumption over the long run. Finally, sustainable innovations must reflect appropriate and responsible cost and benefit distribution accounting for all the value chain participants' actions and impacts.

In contrast, disruptive innovations offer inferior performance along accepted performance dimensions in comparison to existing offering (Christensen & Bower, 1996). Typically, existing products and services provide performance that overshoots typical customer needs and meets the most demanding customers' needs (Christenssen et al., 2018), leaving low-demand customer needs unmet and underserved. When initially introduced, disruptive innovations seek to serve these neglected market segments (Christensen, 1997). Moreover, disruptive innovations are typically cheaper than existing offerings and have a good price to performance ratio at low performance levels (Christensen et al., 2015). Furthermore, disruptive innovations typically introduce new performance parameters that are valued by specific niche market segments. For example, although a disruptive innovation delivers inferior performance in accepted performance dimension, it might be smaller, lighter, and/or more convenient to use than competing offering (Christensen, 1997).

Disruptive innovations are initially offered to small market segments at a low price and thus typically have lower profit margins. One result is that incumbent actors are reluctant to invest in serving these market segments. However, disruptive innovations typically evolve over time until their performance parameters reach levels that are satisfactory for mainstream customers. At this point a majority of customers will switch to the disruptive innovation, which in addition to being cheaper often has additional performance parameters that create novel value for mainstream customer segments. As a result, customers change how they evaluate and prioritize products in favor of the disruptive innovation that provides a better price to performance ratio in addition to other performance advantages. Disruptive innovations thus create new markets and present new value propositions that must be measured by new performance attributes.

This traditional view of 'low-end' disruptions have been contended with 'high-end' or 'top-down' disruption notion (e.g. Carr, 2005) or 'high-end encroachment' (van der Rhee et al., 2012). In these scenarios, disruption happens as innovation is providing high performance solution to the most demanding, underserved customers that are willing to pay even more for the performance. However, for 'high-end' disruptions price-performance ratio may be poor in accepted performance dimension but customers are willing to pay extra for performance. High-end disruptive innovation may also introduce new performance parameters, coined by demand discovery in Zuckerman (2016). Thus, disruptive innovation diffuses from above to lower demanding segments.

Sustainable disruptive innovation (SDI) is thus attained by taking into consideration the three pillars of sustainability while socio-economic processes and structures are disrupted. The three pillars are intrinsically linked and present a systemic whole; one cannot consider, for example, the economic profit of an innovation in isolation of its social and environmental impacts. SDIs hence may be viewed as systemic innovations from few angles and this perspective can be further used to define SDI in this dimension. Henderson & Clark (1990) differentiate systemic (architectural) innovation from other innovation types with this type of innovation making knowledge of system or architecture redundant and preserving the value of component level knowledge. Hence, as physical products are considered systemic innovation is triggered by component level change as this changes linkages and/or interactions between components. Systemic nature of SDIs may be extended from this product-system view to include wider socio-technical environment like for example Midgley and Lindhult (2017) have done in presenting four ways of thinking about systemic innovation. The first one extends the systemic view beyond single organization to include all the parties delivering complementary offering needed for its value delivery. The second view links the policy system into systemic innovation enabling its development and value delivery. The third view explicitly considers the purpose of systemic innovation to change societal structures and nature of society. Finally, fourth view outlined considers the process of creating innovation systemic when innovation pushes participants in the development process to engage in systems thinking, hence this process is systemic.

SDIs as systemic changes further present “socio-technical transitions” toward sustainability and these have some unique characteristics (Geels, 2011). First, such transitions purposefully address environmental problems. Few actors have incentives to seek sustainability, since existing, unsustainable solutions provide less risk and more profits and hence, new entrants or new actions are needed for transitions to take place. Second, socio-technical transitions do not necessarily present immediate user benefits and they often provide a worse price to performance ratio compared to existing solutions. This also reduces the incentives for existing actors to take risks in seeking new solutions if policy changes are not introduced to support such risk taking; the status quo typically supports preexisting, safer options. Third and finally, socio-technical transitions typically address empirical domains in which sustainability transitions are the most greatly needed, such as in energy, agriculture, and transportation, which have strong established systems and structures. Furthermore, these fields are dominated by large corporations that have the necessary assets to conduct large-scale economic activities. In order for these fields to transition to sustainable models of production, they must reorient their activities to prioritize all the pillars of sustainability; by definition, this would require SDIs to renew the socio-economic structures.

2 Ways to design and evaluate SDI

The features and attributes of an SDI should be identified and detected as the SDI is developed and commercialized. However, there is always some uncertainty, as the true disruptive and sustainable nature of an innovation can only be fully assessed post-hoc—that is, its disruptive effect cannot be fully assessed before the disruption has taken place. This has been a central criticism of disruptive innovation theory; disruption can be hypothesized, but it cannot be established with certainty beforehand.

Nevertheless, there are ways to evaluate and develop SDIs from the point of view of both sustainability and disruptiveness. Following recognized principles of sustainable development and design can help ensure that the processes are sound and appropriate. The nine Hannover principles (McDonough & Braungart, 1992) of sustainable development are widely applicable. The first principle emphasizes that humanity and nature must coexist to create healthy, supportive, diverse, and sustainable conditions. This applies not only to the development and manufacture of SDIs, but also to their use and impact to all relevant stakeholders. The second principle emphasizes the holistic and systemic nature of SDI design, wherein the elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale. SDI designs should therefore consider all the effects across the life cycle and use of the innovation.

The third principle seeks to respect the relationship between spirit and matter. Designing and using SDI needs to carefully seek understanding of all aspects of human settlement. This is necessary in order to ensure that the disruptive effects cause the intended positive long-term impacts. This is also related to the fourth principle, which requires the creators of an SDI to accept responsibility for the consequences of their design decisions on human wellbeing, to preserve the viability of natural systems and their right to coexist with human development, and to guard against harm to these facets during their design processes and eventual operations. This in turn leads to the fifth principle, which requires the design and creation of objects with long-term value rather than short-term profit maximization; SDIs should not burden future generations with unnecessary maintenance requirements or risks due to careless design, operations, or standards.

The sixth principle seeks to eliminate waste by evaluating and optimizing the full life cycle of products and processes. To the greatest extent possible, SDIs should mimic the cyclical nature of natural systems in which there are no waste products, only materials that circulate within systems. Related to this is the seventh principle of energy efficiency, which requires SDI desing, creation, production and uses to consider renewable energy sources and to use energy efficiently and safely. The eighth principle seeks understanding of the limitations of design and hence, design process must acknowledge that SDIs cannot solve all problems, while the ninth and final principle reiterates the need for continual improvement and knowledge sharing. This knowledge sharing should take place among all stakeholders like users, customers, producers, colleagues, and suppliers in order to establish communication feedback loops that will help ensure the longevity and ultimately the sustainability of an SDI.

The design and creation of SDIs require an estimate of the disruptive potential of a proposed innovation. Based on the attributes of previous disruptive innovations, disruptiveness has been measured by its technological, marketplace, and environmental elements (Guo et al., 2019). Assessments of marketplace disruptions must consider an innovation's potential to reduce the cost of acquiring product functionalities; innovations should provide profit opportunities for all associated collaborators, but cost reductions are particularly necessary since disruptive innovations are generally introduced at a market's low end, typically targeting small, niche markets. Assessments of technological disruptiveness begin with the innovation's integration into existing paradigms and its potential to lead to further technological developments; innovations that are highly integrated into existing uses and infrastructures will be more easily adopted by users. Furthermore, technological considerations should include an assessment of the maturity of supporting technologies and infrastructure, as these are needed for the innovation to be usable to end-users, which in turn is necessary for strong disruptive potential. Finally, high level of simplification in comparison to existing solutions and high level of diffusivity, i.e. easiness to adopt among users, increase disruptive potential.

To support the design and creation of SDIs in an organizational setting, a triple bottom line (TBL) accounting framework introduces measurable standards for social, environmental, and financial considerations (e.g. Elkington, 1998). The first bottom line (social standards) seeks to account for organizations' activities in relation to social equity and human capital. This measures up- and downstream activities, responsible behaviors, and maintenance of sustainable value chain practices across stakeholders. Success on this measure thus considers the benefits to all constituencies and stakeholders within the innovation's sphere of activity. SDIs can also have negative effects, for example in disrupting the workforce in existing businesses, and these negative effects need to be carefully considered and remedied to the greatest extent possible as part of responsible change management practices.

The second bottom line (environmental standards) refers to effects on the natural environment and minimizing the harmful effects caused by organizational activities, including assessments of an innovation's full life cycle, from its initial use of raw materials to its disposal and the reuse of component materials. SDIs in many cases dramatically alter value chains, and, due to increasing efficiencies related to smaller size or cheaper and more easily accessible materials, may have surprising environmental benefits.

Finally, the third bottom line (financial profit) seeks to calculate economic value in a way that includes all input costs and their consequences. This includes not only the organization's direct costs, but also those incurred by society at large; this reflects the innovation's true economic impact. For SDIs, considerations of an innovation's holistic economic value are particularly important, since these innovations may seem at first to operate at a financial disadvantage in comparison to traditional offerings with higher performance and profit margins.

Recently, the conception of the TBL has been evolving toward an Integrated Bottom Line standard, as companies increasingly include TBL elements in their balance sheet reports (Sroufe, 2018). TBL has also been criticized for being overly oriented toward the financial viewpoint; however, if used as part of organizational processes, it can nonetheless help to evaluate the appropriateness of any given SDI. However, measuring TBL is necessarily difficult, as it includes elements that are not easily quantifiable, and some studies have suggested similar frameworks and methods that may be more easily measured (e.g., Hubbard, 2009). In particular, “Circles of Sustainability” designs have been proposed to help manage far-ranging and complex innovation activities, particularly in urban environments (James, 2014). Circles of Sustainability include not just economic and ecological considerations but also political and cultural concerns; political considerations include social power, legitimization, regulation, and community negotiations, while cultural considerations include identity, engagement, and health. Regardless of the assessment method chosen, evaluating the potential of an SDI and creating and designing it require a multi-level, holistic approach. Understanding both the sustainable and disruptive potentials of an innovation is especially important when assessing SDIs impact and influence and properly managing its design, creation, use, and long-term impacts.

3 Obstacles for SDIs

Once an innovation has been identified as an SDI, it is important to anticipate possible difficulties in designing, creating, and commercializing it as well as managing its impacts. The systemic nature of an SDI renders multiple stakeholders and actors important in its design, and an SDI also influences and impacts numerous stakeholders as it is commercialized. Systemic considerations of innovation strategies are therefore needed with all the actors engaged in creating an SDI (Adner, 2006). In such a systemic context, it is vital to manage iteratively the performance target and user value of an SDI. Careful consideration is also needed of different actors’ complementary interdependences and values from performance and temporal points of view. An SDI’s performance delivery must also be secured to ensure that each necessary component is in place when needed. Finally, consideration should be given to integrating an SDI into existing intermediaries’ and ecosystem actors’ value chains before offering it to end-users. For example, a new technological solution will need to be serviced, and service suppliers will need to understand and adopt an SDI before it can be successfully rolled out to end-users. Taken together, all of these factors require cautious management and careful iteration planning for an SDI involving multiple actors.

Besides these systemic obstacles, market, financial, policy, and internal capability barriers may also impede the development of an SDI (e.g., Charter & Clark, 2007). Overall, market awareness of sustainability issues is still nascent; there is no sense of urgency reflected in user behavior, and product ownership versus service use considerations still dominate consumer behaviors. In short, there exists an action-awareness gap among consumers. Most markets are still typically dominated by price considerations and economies of scale, and SDIs must have a strong price impact. Financial obstacles include scarce venture financing for risky SDIs when value proposition may present ample uncertainties and SDIs offer smaller profit margins. At the same time, however, SDIs promise more socially responsible investment opportunities. The value of such opportunities has risen in recent years, and this additional value may partly compensate for the risks inherent in SDI investments.

SDIs also face a confusing landscape of environmental policies that vary across national borders and may also change rapidly over time (e.g. Charter & Clark, 2007). National and international policymakers may present ambiguous or uncoordinated policies that can prevent SDIs from successfully penetrating new markets. In addition, a lack of internal organizational capacity and leadership can also inhibit the growth of an SDI. Achieving a mature management vision and securing commitments have been particularly difficult because sustainability issues are seen as threat-driven rather than opportunity-driven. Organizational structures may also inhibit the creation of systemic new value propositions, such as SDIs. Furthermore, the traditional difficulties faced by any disruptive innovation are also present for SDIs—namely, corporate reluctance to enact risky changes and the inherent trade-off between current profits versus uncertain and lower profits as unit profit margins decline.

4 Managing SDI processes

As described above, the processes of designing, creating, and commercializing SDIs face a number of specific obstacles that require careful attention that are somewhat different from the attention required for typical innovation processes. For example, the systemic nature of an SDI renders obligatory the inclusion of multiple stakeholders quite early in the design process. Innovation practices and processes that target the design and development of SDIs should include anticipation, reflexivity, inclusion, deliberation, responsiveness, and knowledge management components (e.g., Lubberink et al., 2017).

Designing an SDI requires a deep understanding and anticipation of the innovation's context and interrelations and linkages influencing SDI, including social trends, technological possibilities, market developments, legislative environments, user problems and attributes, etc. An SDI's decision-making processes therefore need to consider its long-term vision and should explicitly attempt to anticipate these future developments. Creation and decision processes therefore need to have broad environmental monitoring capabilities and resources. Future-oriented anticipative decision-making processes may also utilize crowdsourcing or co-creation activities to seek to understand the future developments and needs of potential users.

SDI processes must also clearly outline their priorities, responsibilities, and goals so that processes can reflect continually attainment of these goals. Since an SDI involves multiple layers of contexts and actors, the design process can easily become confusing and chaotic, and reflexivity in decision-making processes is therefore required. Expectations and goals should be outlined and prioritized for all parties. However, the process should not be managed overly strictly; instead, each actor should be empowered to create their own goals and conflict resolution mechanisms should be in place. In this way, all actors will be able to understand their values, goals, and overall responsibilities in a developing organization while delivering value to a larger societal context and resolving any discrepancies. Reflexivity will also create a culture in which capabilities, processes, and the overall purpose of activities can be openly assessed.

A wide variety of different stakeholders must be included during different stages of the design process in order to gain multiple views and insights on innovation, rendering inclusion important for SDI innovation activities. Such stakeholders can include the wider public, end-users, supply-chain participants, non-governmental organizations, governmental agencies, etc. Their level of inclusion depends on the extent to which they share the organization's values, goals, capabilities, and willingness to contribute. Information sharing is key, but this process must be managed to avoid any negative effects. For example, the organization developing the SDI needs to manage who is involved, when, and how in the SDI design process, including anticipating the need for commitments and participation from a wide network of key actors. Time and resources must be dedicated to careful deliberative processes in order to ensure meaningful and responsive dialogue with all relevant stakeholders. Stakeholder engagements should be based on accurate and transparent information exchanges in which engagement is directed toward common interests and contributors share high levels of mutual trust. Stakeholders can participate by expressing their opinions as external observers, by participating in decision-making processes, or by being directly included in the organization's operations and activities. However, to create enduring stakeholder engagement, it is key that their feedback is internalized and taken into account with joint deliberation processes, as this strengthens the relationship.

As stakeholders are intimately involved in innovation processes, organizations must be responsive to their participation. Responsiveness is built on an organization's ability to respond and adjust to external changes. This ability must be built into routines and processes and requires that decision-makers have the autonomy to act upon changes. Responsiveness also hinges on an organization's ability and willingness to investigate and attempt to resolve social, environmental, or economic challenges rather than catering exclusively to end-user needs and preferences. Responsiveness is therefore consistent with basic SDI goals. Finally, knowledge management, creation, and integration are required to effectively explore new frontiers with multiple actors and exploit opportunities with stakeholders. In a network of actors, knowledge needs to be assimilated and synthesized in order to maintain SDI creation.

In addition, a system that includes all actors needed for SDI development may be viewed as a technological innovation system (TIS) (Purkus et al., 2018). A TIS have few characteristics like it needs to have support mechanisms for entrepreneurs undertaking risky experiments so that policy, investment, environmental, and institutional environments support the desired behaviors. Entrepreneurial activities also need to be supported by knowledge and skill development activities and by mechanisms for knowledge transfer and learning curve exploitation among different actors. Knowledge must also be actively shared in both informal and formal forums to maintain support and feedback processes for new ideas. Experiments should be subject to selection environments in which they receive feedback, are evaluated by investors and regulators, and are exposed to complementary ideas (c.f., strategic niche management, e.g., Kemp et al., 1998). TIS also includes market-making mechanisms as experiments, wherein new ideas are subject to market demand and various stakeholders and commercialization ideas are actively investigated and user feedback gathered. Market exposure is also required for scalability, and resource mobilization among actors from various fields is therefore necessary for SDI development. Finally, TIS as an environment lends credibility and legitimacy to SDIs that otherwise would suffer from liabilities related to their newness or lack of institutional support.

5 Summary and example of SDI

In sum, SDIs initiate systemic changes in socioeconomic structures and induce multi-level changes in institutional settings. Many renewable energy technologies are currently considered disruptive (Johstone & Kivimaa, 2018). For example, PV (photovoltaic) solar panels are not as efficient at producing energy as large production units, but they bring new a performance parameter: a local ability to produce energy. They also hold the potential to disrupt consumer priorities, as consumers can become prosumers i.e. produce energy themselves and may come to value their own production over use of a legacy grid. In mainstream markets, PV solar panels do not provide the same level of service and reliability as centralized utility services, but they have enabled new markets to emerge and were first commercialized in nascent market segments. Furthermore, PV solar panels require less investment than large infrastructure projects, and for incumbents they provide lower profit margins. Finally, solar PVs have changed socioeconomic structures as consumers become prosumers and ownership of utilities has shifted to local communities and new entrants. This has resulted in greater societal inclusion, energy justice, and employment opportunities in local energy cooperatives.

Furthermore, the commercialization and spread of renewable technologies have resulted in institutional changes that have led toward energy transitions, such as new rights and obligations for energy consumers/prosumers, regulatory changes, and new institutional actors (e.g., energy cooperatives) entering the markets. As renewables replace the fossil fuel–based economy, their commercialization has positive social, economic, and ecological effects across a product's life cycle. However, estimations of their impacts across lifecycles and the impact of energy transitions are still under debate (e.g., Sovacool & Geels, 2016), and the true impacts assessed across lifecycles and all sustainability criteria must be cautionary, since by nature they can only be confirmed after the fact.

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