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Strategies for Sustainable Transition: The Urban Area of Hammarby Sjöstad as an Experiment in Technology-Driven Change

Einar Iveroth, Sofie Pandis-Iveroth, and Karel Mulder

Abstract—**This article explores the role of technology-driven approaches in facilitating sustainable transitions in urban development. Using the case of Hammarby Sjöstad in Stockholm, we analyze the implementation of eleven sustainable technologies and examine their impact on the broader transition process. Existing literature often frames sustainability transitions in terms of social, technical, or socio-technical approaches. Our findings suggest that a successful technical innovation approach constitutes a well-crafted strategy for managing the supply and demand sides of innovation throughout the extended phases of the innovation journey. Technological advances alone are insufficient: successful transitions also require active engagement from the demand side, including market actors, institutional stakeholders, and consumers, at specific stages. Our study highlights the interaction between the supply side (push), which drives technological innovation, and the demand side (pull), which determines adoption, acceptance, and long-term viability. We identify three recurring mechanisms—infrastructural compatibility, demand-side catalysts, and institutional resistance—that explain when and why technology-driven approaches succeed or fail. The findings emphasize the need to align new technologies with broader systems, ensuring they are not only technically feasible but also institutionally supported and socially desirable. We propose a more nuanced and comprehensive perspective than that of prior transition research, arguing that technological, social, and socio-technical approaches all play essential roles throughout the transition process. In addition, we contribute to innovation policy and transition management research by demonstrating how the interaction between supply and demand influences the outcomes of sustainability initiatives. Also, we respond to calls for greater attention to the demand side of innovation, offering insights that can inform policymakers and technology developers working toward sustainable change. Our research provides a strategic framework for understanding the conditions under which technology-driven transitions can succeed in practice.**

Managerial Relevance Statement—**This study provides actionable insights for managers and policymakers involved in sustainable transitions. Based on an analysis of eleven sustainable technologies implemented in Hammarby Sjöstad, we show that technology management can significantly contribute to sustainable change, provided it is coupled with proactive demand-side engagement. Our findings emphasize that aligning innovations with behavioral patterns, market structures, and institutional dynamics is as critical as technical feasibility. Several unexpected results emerged. Technologically feasible solutions often failed due to neglect of user behavior, weak institutional support, or lack of market readiness. Revolutionary innovations were sometimes blocked by legacy infrastructure or dismissed for clashing with esthetic and cultural norms. These examples reveal the complex barriers that can undermine even well-designed technologies. Using the "transilience" framework, we identify mechanisms that support or hinder innovation adoption, such as infrastructural compatibility, demand-side catalysts, and institutional resistance. Drawing on empirical illustrations from photovoltaic deployment, wastewater treatment, and biosolids management, we translate these mechanisms into three actionable levers—economic incentives, regulatory reforms, and behavioral and informational strategies—to guide future implementation. Ultimately, our study helps practitioners move beyond technical deployment toward integrated, system-aware transition strategies aligned with long-term sustainability goals. This article also contributes to the following SDGs: SDG 6, SDG 7, SDG 9, SDG 11, SDG 12.**

Index Terms—**Innovation policy, socio-technical change, supply- and demand-side innovations, sustainability transitions, sustainable innovations, technological change, technology management.**

I. Introduction

THE central question explored here is how and to what extent technology-focused approaches to change can contribute to sustainable transitions. This question is critical not only because technology can serve as a key enabler of sustainable transitions but also because socio-technical perspectives have historically dominated transition studies, which often criticize technology-focused approaches [1], [2], [3].

Existing research identifies three primary change approaches in sustainable transitions. The first and most common is technology driven, focusing on the supply side of innovation and underpinned by technology management [4], [5]. In this article, we use "technology driven" not to denote radical novelty but to refer to transition strategies in which technological development and deployment are the primary initiators of change, regardless of whether the technologies themselves are newly

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invented or are established but applied in novel ways. Here, new technical solutions are introduced within existing institutional constraints—often referred to as the regime [6]. This approach assumes the continuity of core system values, positioning sustainable transitions as necessary and inevitable adaptations. The objective of technology developers and producers is to provide low-carbon solutions that maintain functionality comparable to that of conventional alternatives, ensuring minimal disruption for users. Yet, end-users are often passive recipients of these changes, rather than active participants. This approach centers on the role of coordinated technical implementation as a strategic driver, even when the technologies involved are not disruptive in isolation. It is the intentional orchestration and systemic configuration of these technologies that defines their role in the transition process. Despite extensive research on organizational and technological change across domains, the field of engineering management has yet to sufficiently address how sustainability transitions unfold under conditions of institutional lock-in, infrastructural inertia, and limited demand-side engagement. These systemic constraints—often sidelined in traditional innovation planning—were central in shaping the outcomes of the technologies analyzed in our study. Our contribution aims to fill this gap by exploring how supply-side strategies interact with these barriers in real-world transitions.

The second approach is socially driven, focusing on demand-side actors, such as users, intermediaries, and regulators. This approach aims to change practices and behaviors to address sustainability challenges [7], [8], [9]. Technological innovations may then follow to accommodate these newly altered consumer practices. The third approach is socio-technical in nature [10], [11], [12]. This approach recognizes that radical long-term changes are necessary and that they must occur simultaneously and interdependently across both social and technical systems. The dual character of metabolic systems, encompassing both technical and social dimensions, can only be transformed through a co-evolutionary learning process in which technological and social structures influence each other. This process may take considerable time before establishing a stable new system.

The potential of any approach to drive transition depends on its ability to compete with the incumbent systems it seeks to replace. Thus, an approach may aim to destabilize these incumbent systems by undermining their legitimacy. In recent years, socio-technical innovation approaches aiming at protecting innovations and fostering learning in niches have attracted significant attention in transition studies [6], [13]. Socially based approaches, which focus on creating awareness, fostering actors and agency, promoting consumer action, and influencing consumer markets, have also been extensively studied [14].

In contrast, the technology-driven approach, in which sustainability transitions begin with the supply side, remains underexplored. This is likely due to its association with traditional engineering management and planning and the top–down technocratic approaches of the past. However, it cannot be denied that this approach has been successfully applied in the past, so the question remains: How can a technology-driven approach facilitate a sustainable transition in the present day?

To address this, we analyze eleven sustainable innovations and their implementation in Hammarby Sjöstad, a green urban district in Stockholm, Sweden. Hammarby Sjöstad is particularly well-suited for this exploration, not only because it is internationally recognized as a model of sustainable urban development [15], but also because its planning and design—ongoing since the early 1990 s—have been driven by a clear technology-driven change approach [16]. The goal was for the area to serve as a steppingstone toward a sustainable transition, with the expectation that residents would experience minimal disruption from the implementation of sustainable technologies [15].

Our findings indicate that a technology-driven approach can indeed support sustainable transitions, but only if the demand side—market actors, institutional actors, consumers, and the broader system—is actively engaged and stimulated in the innovation journey. In short, sustainable transitions require interaction between the technology-oriented supply-side (technology-push) and the socially oriented demand-side (demand-pull) strategies of innovation. The overall results underscore the interdependence between technological innovation and broader systems. In doing so, we contribute by proposing a more nuanced and comprehensive perspective than found in previous transition research, arguing that all three change approaches—technological, social, and socio-technical—play crucial roles throughout the transition process over time. Our findings also add to the growing body of research on innovation policy, highlighting the critical interaction between demand- and supply-side strategies of innovation in driving progress [4], [17], [18], [19], [20], [21]. Most importantly, we contribute to innovation research that underscores the key role of the demand-side strategy in this interaction, in terms of facilitating a sustainable transition [9], [22], [23], [24], [25], [26], [27].

The rest of this article is organized as follows. Section II presents the theoretical framework that underpins our study, focusing on different innovation strategies relevant to sustainable transitions. To structure our analysis, we introduce the transilience map, a conceptual lens that captures both technological novelty and market-system alignment. This model enables us to assess how various innovation strategies unfold in practice, particularly in relation to their systemic fit and demand- and supply-side engagement. We then describe our research design, including the multiple-case study methodology applied in the Hammarby Sjöstad urban district. The findings section applies the transilience framework to analyze eleven sustainable innovations implemented in the district. We conclude with a discussion of the theoretical contributions and practical implications for sustainability transitions and engineering management.

II. Demand- and Supply-Side Innovation Strategies

The environmental footprint of citizens can be reduced by 1) replacing the products and services they consume with environmentally preferable alternatives (e.g., replacing a fossil-fueled vehicle with an electric one) and/or 2) reducing their consumption of specific products and services (e.g., travelling less), which implies a greater change in practices.

The first type of change entails innovations in technology, production, and/or logistics to reduce the ecological footprint of products and systems—i.e., influencing the supply side of the innovation system. The second type requires change in both

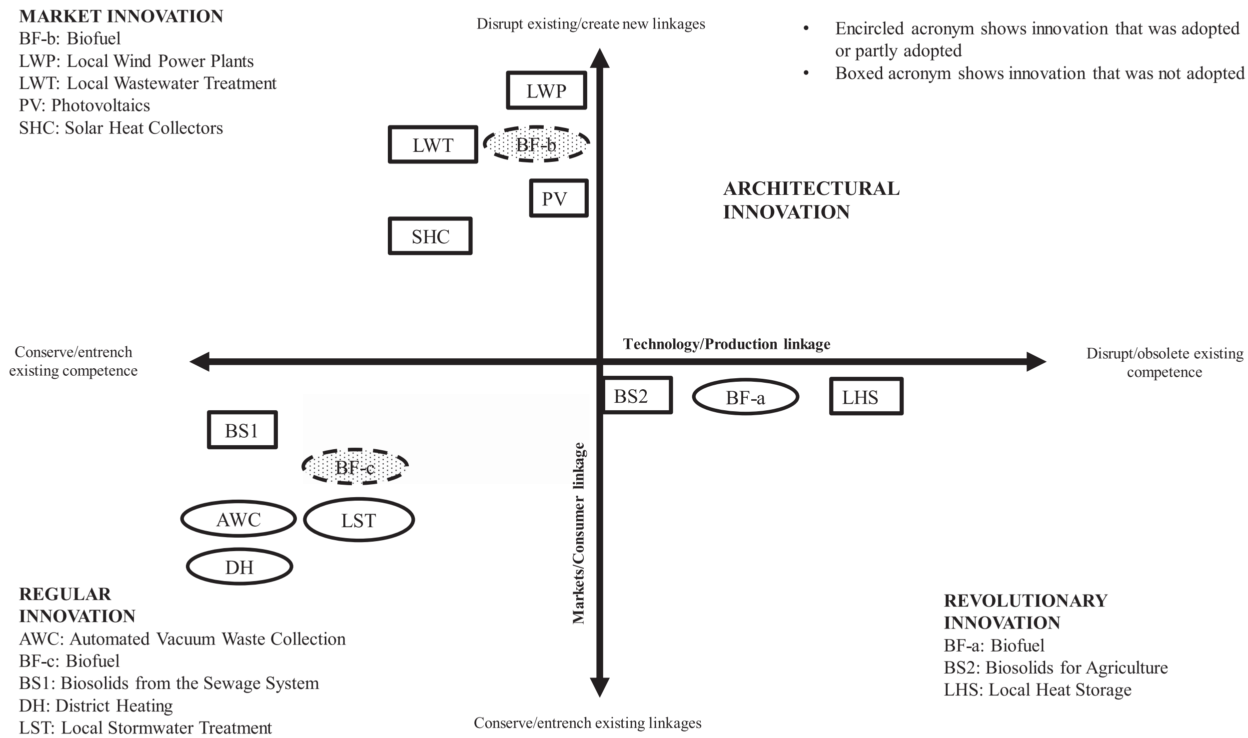

Fig. 1. Transilience map and analysis (adapted from [23, p. 8]).

markets and practices as customers change consumption patterns. This in turn affects markets and may trigger demand-side innovation. A reduction in long-distance travel, for example, may elicit higher demand for local recreation. This distinction between two types of change closely resembles that between the different innovation strategies set out in Abernathy and Clark's [28] transilience map (see Fig. 1), often used to categorize innovations (see, e.g., [29], [30], [31], [32]).

One end of the horizontal axis in the figure represents incremental technological changes that conserve or entrench existing competences, whereas the other end stands for radical technological changes that disrupt existing competences. All the changes on this axis affect the supply side of innovation. The vertical axis represents changes in relation to end-consumers and the market environment and structure (i.e., conserving existing relations with markets and consumers, versus disrupting them). Therefore, this axis influences the demand side of innovation. One main merit of Abernathy and Clark's framework is that it emphasizes both the relations to consumers and wider market forces. It thereby shifts attention from a focus on technological novelty and scientific merit.

In the lower left quadrant of Fig. 1 are *regular innovations*, where both technology and market relations undergo incremental changes (e.g., minor improvements to a technical device that consumers hardly notice). In the upper left quadrant are *market innovations*, which create new market linkages or serve specific consumer groups. The green lease car is an example, designed for occasional users, changing travelling practices, offering value, and creating a new type of market where fewer cars are potentially sold. Marketing is crucial for innovations of this type.

Architectural innovations (in the upper right quadrant) involve both radical technical changes and shifts in market or consumer relations that can significantly advance sustainability. These technological developments often lie outside the dominant paradigm and do not focus on preserving existing assets. While difficult to achieve, architectural innovations can succeed when practices and organizations adapt. When successful, they often pave the way for further advances. *Revolutionary innovations* radically disrupt established technical and production systems while keeping existing market structures largely intact, resulting in only minor changes to consumer behavior. Overall, the transilience map provides a useful analytical lens for understanding the sustainable innovations in Hammarby Sjöstad.

The transilience map allows us to assess not only the technical and market novelty of sustainable innovations but also their relation to the demand and supply sides of innovation. Each quadrant of the transilience map highlights a distinct challenge in aligning technological and market systems. As we show in the Hammarby Sjöstad case, these categories have explanatory power in understanding why certain innovations succeeded while others faltered. In the next section, we apply this framework to analyze eleven sustainable innovations implemented in Hammarby Sjöstad.

III. Research Context and Methods

A. Contextual Background

Hammarby Sjöstad, a residential district in Stockholm, began construction in the mid-1990 s; its 12 700 residential units cover 200 hectares. The area is home to approximately 21 000 people. Planners aimed for its environmental performance to be "twice as good" as that of comparable areas. Rather than expanding outwards and increasing urban sprawl, Stockholm chose to redevelop inward, reviving urban life. In 1995, Stockholm proposed Hammarby Sjöstad as the site of the 2004 Olympic Village, emphasizing its environmental credentials. Good environmental performance was crucial, as the International Olympic Committee required an environmental focus in the applications. Consequently, the city adopted an environmental program with a leading vision stating: "The environmental performance of the city district should be 'twice as good' as the state-of-the-art technology available in the present-day construction field" [33]. "The city district," moreover, "was to be planned and built in accordance with the principles of the natural cycles" [33]. A technical solution with an urban symbiosis perspective was proposed [34]. *The Hammarby model* was developed to meet the environmental program's goals, using technologies such as energy generation from household waste and biogas production from wastewater sludge [15], [16]. The core idea of the model was that the area's technical systems would create a sustainable urban district by themselves, without any need for residents to change their practices, and where several sustainable technologies would become be central. For our purposes, Hammarby Sjöstad constitutes a natural experiment in technology-driven sustainable development. Its technology-change approach and clear ambition to support the sustainable transition make it an ideal case study.

B. Research Design, Data Collection, and Analyses

Several sustainable innovations were initially discussed for Hammarby Sjöstad [35]. While some never moved beyond the idea stage, eleven innovations advanced to the testing and implementation stage, with two (i.e., local wind-power plants and local heat storage) terminated early. We selected these eleven innovations for study because they progressed past the idea stage and were integral to the planning and implementation process. The acronyms for all eleven innovations are listed in Fig. 1 for easy reference. Our exploration applied a multiple-case-study design using literal replication logic [36], [37], in which cases are selected based on the expectation that they will produce similar results, each functioning as an independent unit of analysis [38].

The primary data for this study were collected between 2008 and 2014, a period capturing the critical implementation and early operational phases of the sustainable innovations in Hammarby Sjöstad. This timeframe was selected because it corresponds to the most active years of planning execution, stakeholder coordination, and infrastructure deployment (to increase transparency, we have included examples from different stages of the research process in the supplementary material, which consists of: a list of organizations participating in focus groups and interviews; e.g., of empirical data; e.g., of the method, data sources, and investigator triangulation process; and the finalized classification of each innovation based on the transilience map). First, 29 in-depth and semi-structured interviews with 29 respondents were conducted. The interviews lasted approximately 1.5 h and were all transcribed verbatim. Second, we also conducted six 1.5-h focus group meetings, each with 10–15 participants, in which notes were taken. A total of 74 stakeholders (13 of whom also took part in the in-depth interviews) attended the focus group meetings. The interviews and focus group meetings explored the planning process, governance and control issues, infrastructural solutions, and technology implementation, with participants drawn from 49 organizations involved in planning and building Hammarby Sjöstad (see Supplementary Material, Part A) and their roles included: city planners, city managers, city and urban developers, architects, builders, engineers, consultants, policymakers, building proprietors, and industry experts. Third, we also gathered over 1500 pages of internal project reports, minutes of stakeholder meetings, and presentations, along with approximately 2000 pages of public documents (e.g., reports, articles, and government documents; for an example of published archival material, see column three in the table in Supplementary Material, Part B). Both sets of documents were analyzed for qualitative and quantitative insights. These sources provide comprehensive insights into strategic intentions, institutional dynamics, and real-time responses to the innovation process. While some technological systems have matured or stabilized since then, key structural patterns—such as the continued use of biogas and the persistent challenges concerning waste sorting and decentralized systems—remain consistent, confirming the ongoing relevance of our findings (see Table I).

The majority of the analytical process comprised three phases (see Supplementary Material, Parts C–D). First, we coded the data for each case/innovation based on the different aspects of the two dimensions of the transilience map (i.e., the *x*- and *y*-axes in Fig. [1]; see also [28, pp. 4–7]), i.e., the conceptualization of the four types of innovation and the recurrent themes connected to sustainability transitions. The main objective of the first phase was to categorize the sustainable innovations according the four types of innovations.

The second phase consisted of using the *x*- and *y*-axis scales to determine more precisely where a certain innovation was placed within one quadrant of the transilience map. In this process, the first and second authors performed the mapping individually. They then compared and discussed their respective results (checking intercoder agreement), which were later reviewed by the third author, who functioned as an outsider and "devil's advocate" [39], until agreement was reached, resulting in Fig. [1].

The third and final phase focused on validation. The validation was conducted within the government-funded project "Innovation Platform for Sustainable Stockholm" [40], [41], supporting the broader implementation of innovative solutions as means of sustainable urban development. One key activity of the project was to gather practitioners, industry experts, and researchers in several workshops, seminars, and conferences to discuss key lessons learned in the areas of innovation, sustainability, and urban districts [42], [43]. This provided a rich environment where one of the authors (employed by the project) could continuously discuss, dispute, and validate the emerging findings from phase two (enabling "member checks" enhancing internal validity, see [44, p. 191]).

However, a case study design has its limitations, and a number of tactics, if combined, can ensure aspects of reliability and validity [37], [44]. Three additional tactics were used to strengthen reliability and validity. First, we maintained a "chain

TABLE I
SUMMARY OF FINDINGS

Regular innovations	• AWC, LST, and DH were all aligned with the incumbent socio-technical system. Their ambition was limited, so they were regular innovations. As such, they did not disrupt existing infrastructure or production systems, merely refining current supply-side technologies without full acceptance in the ruling paradigm. BS1 had great potential as fertilizer, but "got stuck" as a regular innovation because market actors (i.e., the demand side) viewed it as contaminated.
Market innovations	• PVs and SHCs were "add-on" technologies that threatened centralized control and existing procedures of the electricity and DH systems. Their introduction was less than efficacious because there was a monopolistic supply situation: PVs and SHCs threatened the existing energy system, potentially decreasing the demand for DH and electricity. • LWP, like SHCs and PVs, was based on old technology, but it was novel in relation to the system into which it was introduced. Like PVs, there was no actual demand for LWP-generated electricity, as it aimed for the local control of electricity networks. It never became an official part of the energy system of Hammarby Sjöstad, since it was at odds with the paradigm of the incumbent system. As for the supply side, there was no evidence of an active strategy promoting LWP. • LWT, for its part, clearly was not aligned with the waste treatment regime of the period, which emphasized large-scale treatment. There were also problems with sunk costs, a lack of distribution channels, and locked-in practices on the part of inhabitants. There was thus no demand for an LWT plant built alongside Hammarby Sjöstad's development.
Revolutionary innovations	• BS2 was hard to implement as not enough effort was put into developing a strategy for managing the demand side or the supply side (via improved waste-sorting practices). The organic waste was contaminated and consequently still incinerated. • LHS could have substituted for waste incineration, ensuring a transition to sustainable heating. Even so, the market demand for LHS was weak, due to the existing integration of the DH systems, on one hand, and combustible-waste management, on the other. Storing heat did not seem necessary or economically feasible • BF turned out to be a success, mainly due to exogenous serendipitous events. Starting out as a revolutionary innovation (BF-a), it "travelled" on the transilience map to being a market innovation as demand for BF increased (BF-b), ending up as a regular innovation (BF-c).

of evidence" across archival data, interviews, and focus groups to explore potential "rival explanations" [36]. For example, respondents' views of the role of SL (the public transport company in Stockholm) in the success of biofuel in Hammarby Sjöstad was triangulated with, for instance, earlier research, policy documents, project reports from the European Commission, and an SL annual report (see last row in the table in Supplementary Material, Part B). Second, we undertook constant comparison and validation over time, as the longitudinal nature of the multiple-case study enables us to do. This longitudinal design allowed us to capture both retrospective reflections and ongoing developments in implementing and adapting sustainable technologies. By using interviews, focus groups, and archival material spanning several years, we reconstructed the innovation trajectories of the eleven selected technologies across shifting policy phases, governance arrangements, and market conditions. For example, the biofuel case illustrates a trajectory—extending from revolutionary (BF-a) to market-based (BF-b) and regularized (BF-c) dynamics—as external actors such as SL and national policies reshaped the conditions for adoption. Likewise, we could follow the innovation of sewage system biosolids (BS1) from initially being described as "a really great idea" (see row six in the table in Supplementary Material, Part B), to the discovery of low demand and perceptions of contamination, and ultimately to their use as fill material in northern Sweden (due to a change in legislation, certified sewage-system biosolids have been used as fertilizer since 2019). This time-sensitive perspective let us trace deviations between initial objectives and eventual outcomes, which we systematically coded and compared across cases. Third and finally, a logbook was kept throughout the data collection process to achieve transparency, which increased the reflexive nature of the research [45].

Overall, the research team's proximity to the planning and implementation of Hammarby Sjöstad shaped both data access and the interpretive lens applied here. One author's affiliation with the government-funded "Innovation Platform for Sustainable Stockholm" granted privileged access to planning documents, stakeholder interactions, and informal insights over time. While this insider perspective enhanced contextual depth, it also posed potential risks of bias. To mitigate this, we implemented several triangulation strategies to ensure rigor and credibility (see Supplementary Material, Part C). Triangulation was achieved through multiple methods and data sources—combining interviews, focus groups, and extensive archival material from a wide range of stakeholders. Investigator triangulation was ensured through independent coding by multiple authors, internal peer review, and the use of a "devil's advocate" to critically challenge interpretations. All data were collected in Swedish, the native language of both the participants and researchers, with bilingual checks applied during translation. These measures strengthened the study's transparency, reflexivity, and analytic robustness in navigating a complex, real-world sustainability transition.

IV. Implementing Sustainable Technologies in Hammarby Sjöstad

The following analysis examines how each of the 11 sustainable technologies implemented in Hammarby Sjöstad fits into the innovation typology presented above. Each case is evaluated based on its alignment with the dimensions of the transilience map. We assess both the market and technological novelty [46] of the sustainable innovations, and their relation to the demand and supply sides of innovation

The construction of Hammarby Sjöstad exemplified macro-scale niche management. It created a protected space for implementing new methods but was not a socio-technical experiment, as stakeholders were not consulted and the innovations were expert driven [15]. Instead, the technical solutions aimed to minimize the district's environmental impact. The extent of their application depended on their market maturity—i.e., their fit with existing practices and the current regime (represented by the *y*-axis of the transilience map). Our analysis of the eleven innovations, shown in Fig. 1, is based on the conditions present during their implementation.

A. Regular Innovations

1) District Heating (DH): DH was a regular innovation in 1997, widely applied in the urban districts of Northern and Eastern Europe. In Hammarby Sjöstad, it was based on the Högdalen plant, adjacent to Hammarby Sjöstad. This plant had generated electricity and DH since 1979 by incinerating domestic waste from the Stockholm agglomeration. In 1986, the Hammarby thermal plant started operating as well. It produces heat partly with oil and electric boilers, and partly with heat pumps that recover heat from treated wastewater. When DH was introduced in Hammarby Sjöstad, relations to the demand and supply sides of the innovation were therefore already established. The task of developing and maintaining the necessary infrastructure was assigned to energy companies. In the early 1990 s, new environmental laws prohibited the landfilling of household waste, making more waste available for DH. DH has considerably reduced the district's need for external energy provision. In this respect it has been a successful innovation; we have therefore circled it in Fig. 1.

2) Automated Vacuum Waste Collection (AWC): AWC was also a regular innovation at the time. It used existing technology and it fit well with existing infrastructure. The first such system, designed by Envac AB, was introduced in Sweden in the 1960s. The first vacuum system for household waste collection was installed in 1965 in the new residential district of Ör-Hallonbergen. AWC transports waste at high speed through underground tunnels to a collection station, where it is compacted and sealed in containers. It facilitates the separation and recycling of household waste, as well as the reduction of truck traffic in residential neighborhoods. A successful innovation, with well-established relations between the supply and demand sides of innovation, AWC was used throughout Hammarby Sjöstad in the 1990 s, and in several other places in Sweden.

3) Local Stormwater Treatment (LST): Local stormwater treatment was a regular innovation in 1997. It only needed existing technology and it fit well with the market and existing infrastructure. It represented an important innovation for the sewage system, reducing its peak inflow and thereby preventing uncontrolled discharge, and it did not compete with any existing infrastructure. LST's technological novelty was slightly greater than that of AWC. But as the interest in LST was high (i.e., demand side), it was used substantially in Hammarby Sjöstad and in several other places in Sweden.

4) Biosolids From the Sewage System (BS1): Two biosolids innovations were applied in Hammarby Sjöstad. In one case (BS1), biosolids were generated from the central wastewater treatment plant in Henriksdal, a plant built in 1941 and serving all of southern Stockholm. In the other case (BS2, covered later), biosolids were taken from sorted organic waste. Both BS1 and BS2 had great potential since they could be transformed into fertilizer and soil that are crucial for the development of a more sustainable agricultural and food supply system. Where BS1 was concerned, it was planned to make the product available to farmers and gardeners, as a replacement for synthetic fertilizer. BS1 was a regular innovation, since the biosolids were a barely noticeable side-product building on earlier competences, and no significant changes would be needed to ensure the supply of BS1 in a slightly new market. However, there was no real demand for BS1, mainly because the market viewed BS1 as "contaminated" with chemicals and bacteria from human activities. For example, the Federation of Swedish Farmers declined to support BS1, on the grounds that customers would have a very negative attitude toward its origins. In the end, BS1 was used as fill material for Boliden's mines in northern Sweden (due to new legislation BS1 has been used as fertilizer since 2019).

B. Market Innovation

1) Photovoltaic Panels (PVs) and Solar Heat Collectors (SHCs): Both PVs and SHCs were standard technical solutions, although not widely applied in Stockholm in 1997. For buildings in Hammarby Sjöstad, therefore, both innovations were in fact market innovations (SHCs are placed further left in the transilience map, since they are based on older technology). Adding PVs and SHCs to an existing technological system requires radical changes in relation to markets, customers, and the system, and in relation to laws and regulations. At the time, the district heating (DH) was already integrated with the combustible-waste management system, generating both heat and electricity at the Högdalen plant. Also, the price of electricity in Sweden was low at the time, weakening the incentive for investments in PVs. Complicating matters further was that Stockholm Energi considered PVs and SHCs as potential threats to its existing system, potentially decreasing demand for district heating and electricity. Furthermore, previous research has revealed that Stockholm Energi was not really interested in owning a large number of SHCs in Hammarby Sjöstad. With Stockholm Energi having a strong mandate for power supply, no energy decisions could be made without its approval. SHCs and PVs thus required a system transition, as both the market and technological systems needed structural changes. PVs further complicated matters due to their reliance on localized electricity generation, unlike the centralized system in place. Technologically, implementing PVs and SHCs alongside the DH system should not have been an issue in 1997. A national report published around that time confirmed the efficiency of PVs and SHCs in the Nordic region. However, fluctuating heat and electricity sources posed challenges for system control and operation. DH systems used SHCs as a backup for the primary power source. Introducing SHCs and PVs would have increased the supply of heat and electricity in the summer, creating a need for storage technologies, which were underdeveloped. In addition, the relevant laws and regulations were complex, making it difficult for individuals and property owners to navigate the red tape, especially given the relatively low cost of electricity and DH at the time. Another important problem was that architects, city planners, and the Stockholm Beauty Council strongly resisted accommodating PVs and SHCs on the flat roofs of buildings in Hammarby Sjöstad. They thought the panels were "ugly," and that they would damage the silhouette of the district. Swedish law did not encourage SHCs or PVs (changes have since been made to facilitate their broader implementation). Rather, legal provisions in connection with taxes and the ownership of power plants obstructed the broad use of SHCs and PVs. For the most part, SHCs and PVs were not adopted by the inhabitants of Hammarby Sjöstad, due to several major obstacles posed by the ruling socio-technical regime (i.e., regulation, existing infrastructure, competition, markets, and economic incentives).

2) Local Wind-Power Plants (LWPs): LWPs, a market innovation, had problems similar to those of SHCs and PVs. Wind turbine technology as such was not new, but it was new as an element of a local electricity system and new to its users. The innovation was unsuccessful, and there is no local wind-power plant in Hammarby Sjöstad today. There were four main reasons for this. First, there was resistance due to landscape and noise issues. Second, LWPs were supposed to form part of a localized energy system, but this provoked resistance because both producers and consumers were used to centrally controlled energy systems (the same problem as with PVs). Third, the innovation had high investment costs. Fourth, wind conditions were not optimal for LWPs in dense urban areas such as Hammarby Sjöstad. A paradigm of "localized solutions" was emerging in sustainability thinking, but LWPs had to find a place within what city planners and builders viewed as the system boundaries. The technology was there, and it could be realized "at a distance," but the decision to apply strict geographical boundaries to the system meant that LWPs could not be realized. Reflecting on the relation between LWPs and the supply and demand sides of innovation, it is evident that—as with PVs—there was no actual demand for LWP-generated electricity. On the supply side, there was no indication of an active strategy to promote or integrate LWPs, for instance, by Stockholm Energy.

3) Local Wastewater Treatment (LWT): In 1997, an LWT plant—Sjöstadsverket—was suggested as a technological solution for Hammarby Sjöstad. This innovation was central to the Hammarby Model and to efforts to "close the loop" in this urban district, since LWT could generate high-value pollutant-free sludge that could be used as fertilizer, as well as methane gas that could be added to the energy system. On one hand, LWT built on existing competences, had little technological novelty, and required only incremental changes in the grid. On the other hand, it would require users to change their practices and operators to change their organization. Users would have to be more careful about what they flushed down the drain, because nonbiodegradable substances would contaminate end products. Operators, for their part, would need to shrink from large-scale organizations to small-scale decentralized units. Successful adoption of LWT could have meant cleaner sludge than that produced by large-scale facilities, due to the opportunity it would have offered to trace the source of pollutants. However, since there was no demand for such sludge at the time, and no established distribution channel, full implementation of LWT became problematic. It would have competed with the existing infrastructure in Stockholm, i.e., in the "wastewater market." The idea of a local treatment plant in Hammarby Sjöstad conflicted with the paradigm of large-scale centralized wastewater treatment. For Sjöstadsverket to succeed, it would have had to disrupt existing market and actor relations. However, significant investments had already been made in the large-scale Henriksdal plant to handle additional wastewater from new districts. Moreover, small treatment plants required different management and maintenance arrangements. There was thus no demand for an LWT plant built alongside Hammarby Sjöstad's development. Ultimately, Sjöstadsverket was never fully realized as an LWT plant: it was only partly built, and now serves research purposes. Wastewater from Hammarby Sjöstad is treated at the Henriksdal plant.

C. Revolutionary Innovations

1) Biosolids From Organic Household Waste (BS2): Biosolids from organic household waste hold considerable promise as they could be used as soil and fertilizer for the agricultural market. This was a revolutionary innovation, since it required a new system of logistics and distribution, as well as new recycling practices among inhabitants and operators. However, not enough effort was put into developing a strategy for managing the demand side as well as the supply side, aiming at making improvements in waste-sorting practices (e.g., BS2 was contaminated with plastic). Consequently, much of the organic household waste was still incinerated together with other household waste, and the market for soil produced from organic household waste remained small (in 2025, Stockholm City actively sorts organic waste due legislative changes.)

2) Local Heat Storage (LHS): LHS was a revolutionary innovation. The technology involved was new, and since locally stored heat could substitute for waste incineration, a transition to sustainable heating methods might have been possible. LHS largely failed, however, for three reasons. First, the idea was introduced by builders, but the city planners argued against the technology on the grounds there was no space for it in the city plans that had already been adopted. Second, the solution itself was technically advanced, and expertise on LHS was lacking. The technology for storing heat had only been tested in smaller research projects, and many issues relating to long-term maintenance were unresolved. Third and most importantly, the market demand for LHS was weak, due to the existing integration of the DH systems, on one hand, and of combustible-waste management, on the other. Storing heat did not seem necessary or economically feasible. It would, after all, have competed with the DH system, which was already producing surplus energy. LHS used heat from nature (i.e., water and the sun) rather than from waste combustion. It was thus technology driven, and entailed a different sustainability mindset. It needed market support and adaptation of the DH system. It required new regulation, a shift in mindset, and disruption of an established socio-technical system. The DH system was only partly adapted, because of new environmental laws prohibiting the landfilling of household waste, building on the idea that burning waste contributed to sustainability. Eventually, the "recycling waste to produce energy" paradigm was replaced by ideas about a circular economy/no-waste society, but this change did not occur in time for LHS to be successful.

3) Biofuel (BF-a): BF was a successful and initially revolutionary innovation (BF-a), but changed over time into a market innovation (BF-b), finally ending up as a revolutionary innovation (BF-c). While its technology was old, it was new and revolutionary at a system level. It was supposed to replace much of the incumbent fuel system, while having only a minor impact on consumers. Developed in 1997, it sought to extract the maximum value from biogas and to reduce greenhouse gas emissions. Biogas was generated naturally at the time, with the treatment of sludge from wastewater. Since 1991, the sludge from Henriksdalsverket had been processed further at a gas refinery, and the resulting biogas was used on site for electricity and heat generation. Thus, BF production in Hammarby Sjöstad built on existing competence. Its novelty lay in upgrading the biogas to BF for vehicles, and in developing a distribution system (see BF-a in Fig. 1). However, exogenous serendipitous events occurring later in the process changed the nature of the innovation and its potential for success. Playing a role were certain outside market actors, the largest being SL, which switched from fossil fuel to biogas for its bus fleet. Consequently, the demand for biogas increased. This shift was promoted by new environmental targets at the national and local levels, as well as within the SL organization. The adoption of BF was also strongly driven by market factors: consumers were switching to biogas stoves, biogas buses for public transport, and biogas-fueled cars (encouraged by, e.g., a recent political decision to offer free parking for such vehicles). All these trends were driven by outside forces (e.g., markets and politics). There was no direct involvement of the city planners or the developers of Hammarby Sjöstad. Due to such developments, BF evolved from BF-a to BF-b, becoming a market innovation.

Overall, the implementation of BF in Hammarby Sjöstad was an achievement. From the mid-1990 s, attempts had been made in the Stockholm region to integrate the wastewater treatment and private transport sectors. At first this involved a technology push with little result. Next a change in demand occurred due to SL's need for biogas, and this "dissolved" the "lock-in" of petrol consumption used in public transport in the Stockholm region. The change was so successful that, in 2007, biogas demand started to exceed its supply in Stockholm Municipality (the start of a shift from BF-b to BF-c). Today, BF is a regular innovation as, for example, gradual BF improvements occur within the existing technological paradigm and are barely noticeable by users and inhabitants. Therefore, BF finally ended up as BF-c in Fig. 1. See Table I for a summary of all the main findings.

V. Discussion

A. Conceptual and Theoretical Discussion

While few of the innovations in Hammarby Sjöstad were technologically groundbreaking, our aim was not to assess radical novelty per se. Rather, we sought to understand how established technologies, when deliberately orchestrated within a technology approach, can serve as central levers in broader sustainability transitions. Here, the term "technology approach" reflects the strategic intent and direction of change, rather than the intrinsic novelty of the technologies themselves. Many of the innovations were technologically mature but introduced in ways that challenged incumbent systems. For instance, LWP and PVs required decentralized energy infrastructure, contrasting with the prevailing centralized models and necessitating new technological, social, and economic control mechanisms. Similarly, LWT, though based on known technologies, threatened centralized sanitation systems.

Indeed, the potential of an innovation depends greatly on its relation to the users and market environment on the demand side, as well as on the incumbent supply system [47]. In other words, one important potential of an innovation lies in its location along the *y*-axis of the transilience map. For example, the innovations that were actually used in the end (i.e., AWC, LST, DH, and BF-c) were ones that already had a clear linkage to markets and consumers, could create such a linkage, or had less need of one. In cases where the linkage to markets and/or consumers was weak or absent, or could not be created, the innovation was not adopted in the end (i.e., BS, LWT, PVs, SHCs, LHS, and LWP).

A main issue with Hammarby Sjöstad's overall technological approach was the lack of direct efforts to strategically manage the relations between the supply side and/or demand side of each innovation. From a technology standpoint, no actor argued that there was anything wrong with the innovation as such. However, as Abernathy and Clarke [28] highlighted, an innovation journey often does not lead to success when its proponents focus solely on technological merits, failing to recognize the importance of the incumbent system—the market environment and structure in which the innovation must operate, i.e., the supply side—or the consumers expected to adopt it, i.e., the demand side.

We found no evidence of any significant attempt by the leaders and city planners of Hammarby Sjöstad to modify, enhance, or develop the connections between the various new technologies and their relations with consumers (i.e., demand) or the market environment (i.e., supply). The only exception was the case of BF, but this was largely due to fortunate serendipitous factors in the broader context. Overall, civil servants and administrators maintained existing practices, which reflected "old" technological solutions, and adopted a "survival-of-the-fittest" approach to innovation—believing that intervention was unnecessary, as natural selection and technological merit would determine the success of any new technology.

The BF case illustrates how successful outcomes can emerge not only from deliberate planning but also from strategic alignment with developments at other governance levels. While we describe the turning point in BF adoption as "serendipitous," it is important to stress that such outcomes reveal the importance of cross-scale coordination, policy responsiveness, and institutional alignment. Rather than diminishing the value of strategic technology management, this suggests that effective transition strategies must incorporate flexibility and foresight to engage with enabling shifts in adjacent systems strategically managing the demand side and/or supply side when needed throughout the innovation process. In this sense, what may appear as exogenous shocks can be better understood as latent opportunities, recognizable and amplifiable by adaptive systems through institutional entrepreneurship and policy synchronization.

The prospects of many of the innovations might have differed if alterations had been made in the system, or if changes had occurred in market environments or among consumers and inhabitants. BS1 and BS2 could have supplied agriculture with soil and fertilizer, breaking with the prevailing system and creating a closed local eco-cycle. However, this would have required direct attempts to change not only distribution systems but agricultural practices as well. No such attempts were made, but the potential was there. Another example was LWT, which also had great potential and was central to the Hammarby model of closing loops. However, no efforts were made to alter residents' practices or change organizational and distributional structures. More importantly, LWT necessitated changes in the "wastewater market" and the socio-technical regime, changes for which there was no support or political will in Hammarby Sjöstad. In other words, the prospects of BS1, BS2, and LWT could have been improved significantly if changes had been made to their respective relations with the *y*-axis (i.e., the demand side).

Taken as a whole, Hammarby Sjöstad underlines the crucial connection between the forces along the *x*- and *y*-axes of the transilience map. The former is more aligned with technology and the supply side, while the latter is socially oriented, emphasizing the demand side. In other words, technical change approaches require a social change approach to succeed, and vice versa.

A key contribution of our analysis is the recognition that innovation trajectories are not static but evolve over time in response to shifting institutional, market, and behavioral contexts. While the transilience map offers a snapshot-based categorization, our empirical findings reveal how several innovations transitioned across quadrants as adoption conditions changed. For example, the BF case illustrates how exogenous factors such as national policy incentives and public transport decisions transformed an initially top–down innovation into one that eventually enjoyed widespread uptake. Similarly, the intended impacts of innovations such as BS2 and LWT were not realized due to a lack of sustained policy support and behavioral engagement over time. By embedding our multiple-case study in a longitudinal frame, we highlight the value of assessing sustainability transitions in terms of not only technical design but also their evolving interaction with broader socio-political systems. Building on this, interpreting our findings from a socio-technical systems perspective [48] emphasizes that sustainability outcomes arise from more than technical capability; rather, they also require coherence across institutional, behavioral, and market-related subsystems.

To move beyond descriptive insights and toward theoretical generalization, we identify three recurring mechanisms that explain when and why technology-driven approaches enable or hinder sustainable urban transitions. These mechanisms—infrastructural compatibility, demand-side catalysts, and institutional resistance—constitute the study's three main theoretical insights. We formalize them below as propositions to guide future research and facilitate analytical generalization beyond the Hammarby Sjöstad case.

Proposition 1. Infrastructural compatibility: *Technology-driven transition strategies are more likely to succeed when new innovations exhibit high infrastructural compatibility with incumbent systems, thereby minimizing technical and institutional friction during adoption.* Technologies such as district heating and automated waste collection succeeded because they could be integrated into existing infrastructures without disrupting established supply or demand relations. Compatibility reduces coordination costs and institutional resistance, enabling incremental yet scalable transitions.

Proposition 2. Demand-side catalysts: *Technology-driven transition strategies are more effective when external demand-side catalysts—such as policy incentives, market actors, or consumer trends—amplify adoption and create positive feedback loops across the innovation system.* The biofuel case demonstrates how external actors (e.g., public transport operators and policy mandates) can transform a supply-side initiative into a self-reinforcing adoption process. Demand-side engagement shifts innovations from isolated experiments to system-level transitions.

Proposition 3. Institutional resistance: *Technology-driven transition strategies are likely to fail when institutional resistance—manifested in regulatory misalignment, sunk investments, or esthetic and planning norms—prevents the reconfiguration of incumbent systems.* Despite technical feasibility, solar collectors, local wastewater treatment, and biosolids innovations were blocked by institutional lock-in and conflicting governance priorities. Such resistance constrains the interaction between the supply and demand sides, impeding systemic change.

Together, these propositions advance theory on sustainable transitions by specifying the boundary conditions under which technology-driven approaches shift from isolated technical efforts to system-level transformations. They also offer an analytical framework for examining how infrastructural compatibility, demand-side engagement, and institutional alignment jointly shape the trajectory of sustainable innovations.

Beyond technical feasibility and market readiness, our findings further show that institutional resistance—shaped by power dynamics, path dependencies, and vested interests—played a decisive role in determining which innovations succeeded or failed. For example, the reluctance of Stockholm Energi to support solar heat collectors reflected not merely technical concerns but a strategic effort to protect the incumbent district-heating monopoly from decentralized competition. Likewise, the city's hesitation to advance local wastewater treatment stemmed from organizational lock-in to centralized infrastructure and sunk investments that planners and engineers were unwilling to challenge. These cases illustrate that sustainability transitions depend as much on managing institutional authority, planning norms, and governance processes as on technical or market design. Recognizing and addressing these dynamics provides a critical bridge between the theoretical mechanisms identified above and the practical strategies discussed in the following section.

B. Managerial and Policy Implications

This study provides crucial insights for managers and policymakers engaged in sustainable transitions. By analyzing the implementation of 11 sustainable technologies in Hammarby Sjöstad, we highlight the importance of aligning technological innovations with market and institutional dynamics. Our findings challenge the conventional socio-technical perspective that often critiques technology-driven approaches, demonstrating that technology management can play a pivotal role in sustainable change—provided that the demand side and/or supply side of the innovation system is strategically managed. For practitioners, this research underscores the necessity of integrating supply- and demand-side strategies, and we offer a model of how such analyses can be conducted. Our analysis also reveals several counter-intuitive patterns: even the most technically feasible innovations often failed; demand-side dynamics were largely overlooked, with adverse consequences; revolutionary solutions were obstructed by legacy infrastructure; and some technologies were rejected due to misalignment with local esthetic or cultural norms. These surprising outcomes emphasize the need for system-aware implementation.

To operationalize these insights, we recommend several instruments to strategically manage the demand and supply sides throughout the innovation process (each illustrated with a short empirical vignette from Hammarby Sjöstad).

1) *Economic incentives*, such as targeted subsidies, tax relief, or green procurement programs, can lower the cost barriers to adopting sustainable innovations. For instance, photovoltaic (PV) panels in Hammarby Sjöstad failed partly because the low national electricity price and absence of local subsidies removed any financial motivation for residents or developers to invest. A modest feed-in tariff or procurement incentive could have offset these disincentives and signaled long-term policy commitment.

1) *Regulatory tools*, including environmental performance standards, flexible zoning laws, and updated national legislation, can provide the structural conditions needed for uptake. The local wastewater treatment (LWT) initiative illustrates how rigid regulations favoring centralized plants prevented decentralized alternatives, despite technical viability. A more flexible legal framework could have enabled pilot licensing and accelerated learning.

2) *Behavioral and informational strategies,* such as nudging techniques, public awareness campaigns, user education, participatory design processes, and participatory planning forums, can encourage user acceptance and foster a supportive innovation culture. In Hammarby's biosolids case (BS1/BS2), residents resisted waste sorting due to perceptions of contamination. Early engagement campaigns and transparent communication could have enhanced participation and trust, aligning user behavior with technical design.

As our findings demonstrate, the failure to apply such instruments in Hammarby Sjöstad led to missed opportunities, particularly in, for example, the BS1/BS2, LWT, PV, and SHC cases. Managers and policymakers must therefore ensure that new technologies are not only feasible but also desirable, supported, and socially embedded within broader socio-economic systems.

TABLE II
POLICY ROADMAP LINKING EMPIRICAL INSIGHTS TO ACTIONABLE LEVERS

Key Findings	Policy/Managerial Levers	Stakeholders
Institutional resistance undermining SHC and PV adoption	Regulatory reform enabling the innovation process and upscaling	National politicians, lawmakers, and municipal planners
Behavioral misalignment	Public engagement campaigns,	Waste treatment
impeding BS1 adoption	nudging, user education, awareness campaigns, and resident incentives	companies, municipalities, and residents
Infrastructural lock-in hindering technological innovation (e.g., LHS)	Innovation subsidy scheme, environmental performance standards, and participatory planning forums	Municipal planners, law makers, and energy companies

Also, Table II illustrates how some of the key empirical findings relate to underlying mechanisms, actionable policy, or managerial levers, and identifies the stakeholders best positioned to intervene. It clarifies who should act, on what issue, and how based on barriers identified in the Hammarby Sjöstad case. This example of a roadmap strengthens the practical relevance of our findings by offering clear, targeted guidance for implementing sustainability transitions.

C. Limitations and Future Research

This study offers in-depth insight into the role of technology-driven approaches in urban sustainability transitions, yet its findings are shaped by several contextual boundary conditions. Hammarby Sjöstad's development occurred within a Swedish planning context characterized by centralized governance, strong environmental regulation, and high levels of public trust. These enabling conditions may not be present in more fragmented, market-driven, or politically diverse urban settings. Although we applied replication logic across eleven embedded cases, our findings are rooted in a single urban ecosystem. We therefore view this study as contributing to analytical generalization and theory development rather than statistical inference.

Future research could extend and test our three propositions—infrastructural compatibility, demand-side catalysts, and institutional resistance—in other settings. Comparative analyses of eco-districts such as HafenCity (Hamburg), Ørestad (Copenhagen), and Western Harbour (Malmö) could reveal how these mechanisms operate under different institutional, cultural, and infrastructural conditions. For example, comparative studies might examine whether infrastructural compatibility remains decisive in less regulated environments, or whether demand-side catalysts have greater leverage in market-oriented urban systems.

Longitudinal research could further explore how innovations evolve across the transilience map over time—shifting between technology-driven, socio-technical, and socially driven phases—as institutional and behavioral dynamics change. Quantitative or mixed-method approaches could also test the relative influence of supply- and demand-side factors on adoption rates across sectors such as energy, waste, or mobility.

Finally, emerging technologies—particularly artificial intelligence and digital monitoring systems—open new avenues for studying how data-driven feedback loops can serve as demand-side catalysts or reinforce institutional resistance. Investigating these developments would help clarify how technology-driven strategies can be designed, governed, and scaled to accelerate sustainable transitions in diverse socio-technical contexts. Building on this study, future research could develop a strategic framework that integrates technical and demand-side dimensions and can be applied early in the innovation process. Such tools are urgently needed to advance innovation within existing socio-technical systems, and this work may serve as a stepping stone toward that goal, preparing the ground for the broader implementation of sustainable solutions.

VI. Conclusion

This article set out to explore how, and to what extent, a technological approach can contribute to sustainable transitions. Our findings suggest that such an approach can indeed be effective, but only if the demand and supply sides of the innovations—i.e., market actors, institutional actors, consumers, and the broader system—are actively engaged and stimulated in the innovation process. Put another way, our findings suggest that sustainable transitions, across time, require interaction between the forces along the *x*-axis (i.e., the supply side of innovation) and *y*-axis (i.e., the demand side of innovation) of the transilience map. Building on this, we identify three key mechanisms—infrastructural compatibility, demand-side catalysts, and institutional resistance—that together explain when and why technology-driven approaches succeed or fail. These mechanisms, formalized as propositions in the discussion, define the boundary conditions under which technical change translates into system-level transition.

However, the innovation process is not necessarily a constant and continuous process of socio-technical change; rather, it is a process characterized by distinct periods when efforts primarily aim for social, technical, *or* socio-technical change. In this way, the three forms of change do not need to operate simultaneously but can alternate over time, with one approach being more dominant than the others at any given point, often following a fluctuating rhythm. It is the dynamics of the innovation process itself that lead to the alternating objectives that create scope for all three forms of innovation management: technology-driven, social, and socio-technical approaches.

Although the overall process leading to transitions may be characterized as socio-technical change, such a process consists of technology-driven change, social change, and socio-technical change in a narrower sense (i.e., aligning technological supply systems and social demands by means of, e.g., niche experiments). Our three mechanisms help clarify how these forms of change interact over time: infrastructural compatibility facilitates incremental integration, demand-side catalysts trigger wider diffusion, and institutional resistance explains the persistence of lock-in and failure. Further study of the dynamics of innovation *management* in sustainable transitions, and the success rates of these transitions, might result in greater success.

Overall, this article makes several contributions. First, transition studies are often dominated by mutually exclusive perspectives, typically advocating for either technological, social, or socio-technical solutions to sustainability challenges. We contribute by proposing a more nuanced and comprehensive perspective than that of previous research, arguing that all three change approaches play crucial roles throughout the transition process over time.

Second, the article provides empirical evidence highlighting the risks of overemphasizing supply-side (push) innovations while neglecting the demand side (pull) in sustainable transitions. In Hammarby Sjöstad, initial efforts strongly focused on technological changes and supply-side innovation. However, as the projects progressed, many were derailed due to insufficient market and consumer interest (i.e., demand side) and a failure to cultivate such interest. Altogether this suggests an interaction between the supply and demand sides of innovation (i.e., interaction between the *x*- and *y*-axes of the transilience map). By specifying the mechanisms that mediate this interaction—compatibility, catalysts, and resistance—our study transforms this observation into an empirically grounded theoretical model.

While research and policy on innovation have traditionally focused on either supply- or demand-side factors [49], a growing body of work emphasizes the critical interaction between both in driving innovation forward [17], [18], [20], [21]. However, there have been relatively few empirical studies illustrating this interaction between supply and demand in the context of sustainable development and transitions. More specifically, we contribute to the current discussion in innovation policy of the crucial role of the demand side of the interaction for achieving sustainable transition [9], [22], [23], [24], [25], [26], [27].

Differently stated, our research aligns with Creutzig et al.'s [50, pp. 260–261] view that a "better understanding of demand-side solutions is missing." We respond to their call for a "transdisciplinary approach" using "common frameworks [that] can serve as inclusive focal points for discussion and research." We believe that models such as the transilience map (or its modifications) can supply "important pieces of this big jigsaw" [50] of achieving a transition to sustainability (see also [51], [52]). Indeed, transition studies in general are regularly criticized for excessive preoccupation with technology and the supply side, and for taking too functionalist and rationalist an approach [53].

Our final contribution is for policymakers and practitioners. When dealing with large complex innovations that challenge the existing regime, we cannot afford to leave different change approaches to chance. To avoid this, we contend, policymakers and practitioners should use models such as the transilience map as "sensitizing devices" and planning tools. Doing so would enable them to more easily understand the social and technical change approaches that can arise in connection with particular innovations. It would also, and more importantly, provide some "important pieces" [50] for assembling the big jigsaw of making the transition to a more sustainable society.

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