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Reimagining Diffusion

Eight building blocks for reconceptualising the generalisation of innovation into society

Douglas K. R. Robinson, Susana Borrás, Wouter Boon

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Abstract

This editorial focuses on the diverse studies and frameworks related to the diffusion of innovations, building beyond Everett Rogers' seminal work from 1962. Despite a renewed interest in diffusion research, fragmentation exists as different academic communities work independently with limited cross-referencing. Seeing great advantage in building bridges and exchanging insights across these conceptual and empirical expansions of Rogers, this editorial explores the heterogeneous nature of diffusion, encompassing various innovation types, systems, geographies and pathways. Using "generalisation" as a broad umbrella term that captures the essence of these expansions on diffusion theory, whilst remaining open to different conceptualisations, eight building blocks were identified from the literature to characterise generalisation, offering new research avenues. The special issue encompasses nine articles in which a broader understanding of diffusion is explored. Key lessons include recognising diffusion as a set of heterogeneous activities involving different innovations, actors, and institutional logics, considering temporal aspects, anticipating repercussions on user groups, and envisioning ethical, legal, and societal impacts for responsible diffusion. These lessons are relevant for policymakers who are increasingly interested in understanding diffusion to address grand challenges. Transformative innovation policy calls for new policy frameworks incorporating diffusion policy measures, which should be build on insights and conceptual frameworks offered by scholars and strategic intelligence provided by decision-makers.

JEL: O33; O38; O32; O34; O39

Keywords: Diffusion, innovation policy, generalisation, grand challenges, transformative innovation, mission

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1. Introduction

Innovation is a key component in tackling grand societal challenges around the globe. Challenges such as combating climate change, ensuring food security, and developing treatments for diseases like cancer or Covid-19, are highly urgent. Meeting these challenges requires innovation. . Decision makers willing to direct innovation actions towards grand challenges have to anticipate which innovations – and bundles of innovations – have the potential to contribute to addressing them. Even more so, policy makers have to anticipate the diffusion and wider embedding of the innovations – to maximise impacts in line with their policy goals, and to minimise negative effects or opportunity costs. In other words, policy makers are increasingly aware that it is not only about creating innovative solutions; it is also about diffusing them quickly, widely, responsibly, and effectively.

To address these grand societal challenges there is a surge in activity and interest in developing and experimenting with transformative innovation policy (Schot and Steinmueller, 2018), and with mission-oriented innovation policy (Robinson and Mazzucato, 2019). In view of informing these policy efforts, current understandings of innovation processes are being opened up and reimagined particularly in relation to missions and deep sectoral transformations (Klerkx and Begemann, 2020; Janssen, Torrens et al., 2021). An important dimension of innovation processes to be reimagined is diffusion being of paramount importance in the transformation of socio-technical systems.

At the same time, diffusion of new technologies remains understudied in the literature about transformative innovation policy. Current theoretical underpinnings of transformative policy approaches have mainly focused on stimulating and guiding the emergence of new technologies and there has been little reappraisal of and engagement with diffusion theories in scholarly studies of policies for transformative change (Geels, 2018; Andersen et al., 2023). Hence, our understanding of diffusion mechanisms for transformative change remains underdeveloped.

The dominant theory of diffusion as the adoption of new technologies in the market, based on Roger's seminal work (Rogers, 1962), still pervades current understanding of diffusion in the context of innovation policy. Recently, however, scholars interested in diffusion in the context of transformative innovation policy have started to criticize and refine the conceptualization of diffusion. On one hand, they start from the premise that Rogers' dominant diffusion theory is overly centred on firms promoting homogeneous product adoption through markets (Frenken & Punt, 2023), emphasizing the traditional focus of innovation studies on the one-size-fits-all dissemination of technologies. On the other hand, there is a large number of studies which do well in exploring the local adoption and contextualization of innovation in placed-based contexts (Seyfang et al., 2016; Hossain, 2016), yet they also miss the perspective of wider spread throughout systems and the way in which diffusion is key for the transformation of socio-technical systems.

A growing number of scholars have started to become interested in filling the gap between one-size-fits-all and contextualized spreading of technologies. They identify that there is need for capturing the diverse pathways and combinations of market and non-market dynamics; the co-evolution and entanglement of different innovation types (social, technical, organisational) in diffusion; the multi-level, multi-scalar and temporal diversity in diffusion; and the different roles of various stakeholders

and infrastructures that facilitate, inhibit or drive the diffusion of innovations into society (amongst others Wigboldus, et al., 2016; Lam et al., 2020; Augenstein et al., 2020; Bögel et al., 2022;).

Most importantly from the perspective of the contribution of innovation to transformative change, however, is that these lacunae in diffusion theory can be also read in terms of policy making, particularly about how conceptualizations of diffusion can inspire future-oriented analysis and strategic policy-making. Well-articulated diffusion policies can help the current *need for future-oriented strategic intelligence capturing the complexities of how innovations are spread, which in turn can feed into decision-making*.

In this paper, we make a first step in reimagining diffusion; not to create a grand theory of diffusion, but to explore how different re-imaginings complement or reinforce each other in light of these needs. To pursue this, we employ ‘*generalisation*’ as an umbrella term, capturing *the routes and processes that shape, normalise, and embed the outcomes of innovation*. The generalisation umbrella enables us to cover a larger variety in terms of pathways and combinations of market and non-market dynamics, innovation types (social, technical, organisational), levels and scales, as well as stakeholders and infrastructures. By broadening our view of diffusion and placing diffusion at the heart of transformative change, we aim to propose a first sketch of what can be called a transformative diffusion policy.

With this purpose in mind, this paper proceeds as follows. The next section elaborates on the need for re-imagining diffusion in the context of transformative innovation policy, offering the overall rationale behind this special issue. More concretely, this section examines the literature by looking succinctly the main elements of Rogers’ theory of diffusion, and its limitations, as well as more recent approaches to diffusion in the context of transformative innovation processes. Section 3 delves into identifying eight building blocks for a new conceptualisation of innovation diffusion. Section 4 summarises the main contents of the papers that form this special issue, in view of extracting key insights. Section 5 discusses how the new conceptual building blocks might serve to tool up for designing transformative diffusion policy. Last, section 6 concludes by suggesting an agenda for transformative diffusion studies as well as new venues for diffusion policy.

2. Examining diffusion theories and concepts

2.1 Rogers: the rock on which diffusion theory is built.

The predominant understanding of the scale up and spreading of innovations relies heavily on Rogers’ theory of diffusion. The book “Diffusion of Innovations” was originally published in 1962 and has had a significant impact on the dynamics of innovation diffusion, seeing many reissues over the years. It was a major milestone of research on diffusion and continues to be used widely in innovation studies education curricula and in policy circles alike. Constructed from empirical investigations of the diffusion of agricultural innovations at Iowa State University, the book details the construction of a general theory on diffusion.

In a later edition, Rogers (2004) delineates diffusion as “the process through which an innovation, defined as an idea perceived as new, spreads via certain communication channels over time among the members of a social system”. His conceptualisation of diffusion focusses on product adoption through markets and comprises five main elements: the innovation, adopters, communication channels, time, and the social system. Actors in the social system adopt an innovation unequally over time which leads a diffusion curve to take the form of an S-shape (Fisher & Pry, 1971), ultimately leading to (near-)full diffusion. Building on this, Rogers continues to propose ideas on which attributes of innovations enhance diffusion, the process of diffusion decisions, and a categorisation of adopter groups (Rogers, 2003). The categorisation of adopter groups, for example, highlighted navigating the challenge of “crossing the chasm” between early adopters and the mainstream majority (Moore, 1991).

Although Rogers advanced a problematisation and easy-to-apply conceptualisation of diffusion, criticism has gained momentum. Empirically his S-shaped diffusion curves fit the real-life diffusion of home entertainment electric devices like radio and television (Lebergott, 1976; US Bureau of Census, 1998), yet they are less appropriate to model other type of innovations that are not product nor market related. Rogers’ contributions have faced other criticisms, such as that his theory assumes innovations disseminating without modification, and for neglecting the changes the social system go through – e.g. in terms of institutional, cultural or organizational aspects – as a result of the introduction of an innovation (Redmond, 2003; Wigboldus et al., 2016).

On the other end of the spectrum of Rogers’ system-level theory of diffusion, the spreading of innovation has been studied on a more micro-level. Here, the focus has been on the local adoption of innovation. There is a vast range of studies on the basic question what drives implementation of new products and services, and there is ample attention for the specific context of which innovation need to become part of and the role end users play in domesticating new technologies (e.g. Silverstone et al., 1992). In their focus on micro-level circumstances, it is difficult for this branch of literature to take into account the wider distribution of products as well as broader institutional and cultural pressures. Through zooming in on local implementation, longer-term co-evolution of artefacts and their social settings of use are neglected (Pollock et al., 2016).

2.2 Building on Rogers with a view to transformative change

Innovation studies and sustainability transitions studies literature have made attempts to bridge the system-level and the micro-level approaches to diffusion. In doing so, they take into account the criticisms of both approaches, most prominently on the modification made to both the innovation, the social system in which it is embedded, the geographical dimension, and the various scaling typologies.

These literatures question the foundational diffusion theory described by Rogers, by identifying four additional considerations regarding the diffusion of innovation, which are outlined below.

First, these literatures introduce considerations about the diversity of innovation and take malleability and the modifications of innovation during the diffusion process seriously. Studies have forwarded notions like re-innovation and reconfiguration, concerning the tinkering with technologies during adoption and implementation to make these technologies better suited for the context in which the user is functioning (Lie & Sorensen, 1996). Innofusion goes one step further in the sense that developers proactively include flexibilities in the design a product in such a way that it allows for

customization (Fleck, 1988). Related to this is the notion of generification work: the way in which suppliers advance products embodying characteristics common across many users at the same time acknowledging local and specific needs (Pollock et al., 2016).

Second, the way in which radical novelties spread throughout society has also been conceptualized through the notion of system building or transitions from one socio-technical system to the next. System building or change perceive diffusion processes originating in experimental settings or niches with a large role for users, living labs or entrepreneurs (Dewald & Truffer, 2012; Meelen et al., 2019; Smith et al., 2014; Kanger et al., 2019). Others focus more on the role of incumbent players and policy makers that stimulate regime-level changes that lead to diffusion (Fuenffschilling & Truffer, 2014; Rogge et al., 2020). In general, these studies emphasise that the selection environment in which the radical novelties are trying to take hold should not be seen as static. Rather, there are various actors and institutions making up these environments that co-evolve during the experiment and diffusion stages (Kanger and Schot, 2018; Geels and Johnson, 2018).

A specific perspective on changes in the socio-technical system is that widespread use of innovations means that these innovations should relate to existing rules, regulations, norms, etc. Often innovators attempt to align with these institutions and provide ‘institutional work’ to maintain and adhere to them. However, radical novelty might require destruction of existing institutions and/or creation of new ones (Boon et al., 2019; Fuenffschilling and Truffer, 2016; Lawrence and Suddaby, 2006). We should therefore see diffusion as a precarious period during which innovation co-evolves with institutions through which legitimacy is established amongst users and wider groups of society (Geels and Verhees, 2011).

Third, innovation and transition scholars have taken the geographical dimension of diffusion into account. The sustainability transitions literature describes how experiments, answering to local, idiosyncratic needs, aggregate into an ecology of projects that share stabilized rules. In turn, these shared rules frame and coordinate future local projects (Geels & Raven, 2006). Different mechanisms are at play in these interactions between the local and the global levels. Meelen and colleagues (2019) highlight that the iterative cycles where the innovation undergoes continuous decontextualization and recontextualization in various locations should be seen as ‘geographical circulation’. Sengers and Raven (2015) illustrate this in the case of the Bus Rapid Transit where both place-specific factors as well as the global dynamics play a role in diffusing an innovation, and that local and global processes are inseparably linked. For example, local knowledge might become codified and shared and some experiments become to be known as best practices and reference points, reinforcing the global narrative of an innovation which in turn influences local experiments. Another mechanism is ‘anchoring’ which means that an innovation becomes connected to a local practice (Elzen et al., 2012) and can be targeted by national or regional innovation policy (Uyarra et al., 2017).

Fourth, quite some typologies of diffusion or scaling mechanisms, pathways and dynamics have been proposed in recent years in the fields of transition studies, social innovation, and urban experimentation. Table 1 provides an overview of a few frequently referred to scaling typologies, which are also reflected in other comprehensive literature reviews (Westley et al., 2014); Moore et al (2015); Lam et al., 2020; Van Lunenburg et al., 2020).

Table 1: Examples of typologies of diffusion or scaling.

Object of scaling	Scaling focus	Key concepts and dynamics
Transition experiments <i>Von Wirth et al (2019)</i>	Types of diffusion processes	<ul style="list-style-type: none"> • <i>Embedding</i>: adoption and integration into existing local structures • <i>Translating</i>: experiment being replicated and reproduced elsewhere • <i>Scaling</i>: experiments become bigger in geographical scale, domains, actors and/or resources
Transition pilots and experiments <i>Naber et al (2017)</i>	Patterns of upscaling	<ul style="list-style-type: none"> • <i>Growth</i>: number of users increases or scale of technology increases • <i>Replication</i>: main concept is applied in other contexts and locations • <i>Accumulation</i>: experiment is linked to bigger initiative • <i>Transformation</i>: experiment leads to institutional change in regime
Smart city pilot projects <i>Winden & Buuse (2017)</i> <i>Borrás & Bundgaard (2021)</i>	Types of upscaling	<ul style="list-style-type: none"> • <i>Roll-out</i>: bring to the market or apply to whole organization • <i>Expansion</i>: add more partners, functionalities or geographical locations • <i>Replication</i>: reproduce the solution in another context
Climate experiments <i>Sengers et al (2020)</i>	Embedding mechanisms	<ul style="list-style-type: none"> • <i>Replication and Proliferation</i>: inspire adoption in different domains • <i>Expansion and Consolidation</i>: growing beyond original initiative to foster system change • <i>Challenging and Reframing</i>: engender institutional change • <i>Circulation and Anchoring</i>: foster transmission of policy-relevant knowledge
Niche-regime relations <i>Geels and Schot 2007, 2016).</i>	Types of transition pathways	<ul style="list-style-type: none"> • <i>Technological substitution</i>: innovation overthrows regime • <i>Transformation</i>: innovation accommodated by incumbents • <i>Reconfiguration</i>: innovations and new entrants symbiotically incorporated in regime • <i>De-alignment/re-alignment</i>: decline of incumbents, niche players and technologies benefit

Taken together, the four elaborations of Rogers' original theory show a move towards taking into account more variety, in terms of innovations types, systems, geographies and pathways. Arguably, the diverse community of academics working on reimagining diffusion have used various concepts to capture several dimensions and aspects of different, similar, or partly overlapping, yet not the same,

diffusion processes. Taken together, they share the willingness to move forward by conceptualising these complex and varied processes of diffusion, overcoming the limitations of previous models.

However, to advance reimagining diffusion and allow for broader perspective on diffusion, i.e. generalisation, we propose to take stock of various crucial aspects of diffusion. In exploring these cross-cutting themes – or what we will call building blocks – we aim to provide clearer guiding posts for further research, and for policy-makers. The building blocks can then serve as a support for the notion of generalisation as a wider concept that captures most of these broader dynamics of innovation diffusion.

3. Eight building blocks for a new conceptualisation of diffusion

We suggest the development of eight conceptual building blocks for a new, higher-order conceptualisation of diffusion – generalisation – which might serve as guideposts for an encompassing new research agenda as well as for tooling up a new approach to innovation diffusion policy supporting transformative change. More concretely, we suggest eight building blocks.

Block 1. Not only technology: A diversity of innovation types. The first building block is about widening the focus of what is being diffused, looking beyond the diffusion of *product innovations*. There is an increasing widespread appreciation among practitioners and scholars about the diversity of innovation, ranging from technological, organizational, public sector, social, to user-driven innovation. Diffusion of non-products, such as services, non-commercial items or even ideas should be taken into account, alongside more product or technological innovations.

Block 2. Users play diverse and changing roles in the diffusion of innovation. The second building block concerns the *demand side of innovation*. Some of the early diffusion approaches tend to assume that users only vary in their eagerness to adopt novelty, typically providing feedback, or making changes to original designs (Rosenberg, 1972). A main criticism emerging from newer approaches of diffusion, is the importance of considering the wide variation across users' characteristics (even in similar social contexts or geographical locations, with only apparent similar user profiles) and the wide variation in their every-day practices, tastes, needs and choices. Users might also be co-innovators, and the wider impact of their innovations is based on a very different process than the one described by Rogers (Von Hippel, 2005; Smits & Boon, 2008). More broadly, the demand side of innovation systems should not be treated as static or exogenous to diffusion (Boon et al., 2022). During diffusion processes, the user practices, culture, infrastructure, and so on, will change along the way with the innovation-to-be-diffused (Kanger and Schot, 2018).

Block 3. Innovations can (co) evolve during diffusion processes. The third building block follows from the above, and is about the wider understanding in the literature about the need to move away from considering innovations as *products that remain unchanged* along the way of being diffused. Empirical studies about social innovations or public sector innovations show the importance of changes in innovations during diffusion (de Vries et al., 2018; Prihadyanti et al., 2023). The innovations diffused are not one-size fits all nor fixed over time, but may co-evolve with the users preferences or local contexts over time. When diffusion touches on the demand side, it becomes clear that it is not a linear process with distinctive, progressive steps. Rather, steps like development, adoption and implementation are overlapping: e.g. in healthcare, digitalisation and additive

manufacturing it is quite common that development of an innovation continues during implementation (Janssen et al., 2015; Scarbrough & Kyratsis, 2022).

Block 4. Diffusion can occur at a different pace with varying timeframes. The fourth building block is about aspects referring to the *long-term usage of innovations*. Rogers' theory tends to disregard what happens with innovations in the long run, because his diffusion model ends at the point of widespread adoption of the innovation, and does not consider the contextual changes in the innovation and its context that might subsequently be associated with the long term use of the adopted innovation. By contrast, newer approaches to diffusion often see it as a process without a clear end, as innovation and its diffusion remains ongoing and unfinished (Garud et al., 2013; 2016). Moreover, recently scholars have started to problematize the pacing of change. Building on the societal need for accelerating transitions and socio-technical systems transformations, e.g. the energy transition, they conceptualise acceleration by defining diffusion as such as going faster, broader, and deeper (Andersen et al., 2023).

Block 5. Underlying institutional logics differ: Market processes, community processes and others. The fifth building block has to do with the diffusion pathways themselves, understanding that they are built on *institutional logics* (Thornton & Ocasio, 1999). As indicated above, traditional work is mainly perceiving diffusion through markets, whereas there are also other pathways involved in diffusion (Bauwens et al., 2022). User, social, and frugal innovation might follow a pathway supported by a community logic, whereas governments that are innovating apply a public logic. For instance, grassroots innovation might have an awkward relationship with diffusion because they sometimes do not aspire to grow (Seyfang et al., 2016) out of a fear of losing their original values and focus (Smith, 2012). Various institutional logics co-evolve with *new ways of organizing*. For example, Public Development Partnerships, are non-profit networks to develop drugs for neglected diseases for poor patients where there is a market failure. The diffusion mechanisms of such new drugs (or even the diffusion of those type of partnership practices) is difficult to grasp using Rogers theory. Whereas more empirical evidence about these partnerships are needed, most likely PDPs would need to be combined with market-pull practices and instruments for their diffusion.

Block 6. Normativities and dilemmas: Bigger and faster is not always better. The sixth building block has to do with the *normative values* underlying many studies of diffusion and their associated dilemmas. This has to do with previous assumptions that 'bigger and faster is better', or that more and faster diffusion of innovations leads inevitably to well-being. This might not necessarily be so, because of the nature and effects of what is being diffused, might pose important dilemmas. For example, electric cars contribute to sustainability transition goals, however their batteries are (so far) material-intensive, hence, an uncontrolled rapid adoption might induce over-mining activities, putting pressure on availability of minerals. Another prominent example of scaling is the way in which digital big tech companies (particularly social media and digital platform firms) have rapidly taken large global market shares given the digital network-effect of their products. This rapid scaling has led to unforeseen and undesired social and market situations. Therefore, there is growing attention in Europe and elsewhere about the need to apply anti-trust laws (their digital products are not exempted from current legal obligations), and to request embedding their *modus-operandi* in ethical norms and democratic accountability principles (Pfotenhauer et al., 2021).

Block 7. Diffusion is related to discontinuation and phasing out. Following from the above, a systemic and transformative view on innovation requires the understanding that diffusion is also

related to the discontinuation, phasing out, and ending undesired technologies and innovations, with implications of systemic transformation (Stegmaier et al., 2014; Rogge & Johnstone, 2017). Introducing innovations goes hand in hand with discontinuing other (previous) innovations (being social, technological, organizational, etc.). This is particularly relevant in the context of sustainability transitions where socio-technical change is as much about the introduction of green technologies, as it is about the discontinuation of undesired ones, along their behavioural practices, at a wider scale. The understanding that innovation diffusion encompasses discontinuation is important for diffusion policy.

Block 8. Diffusion of novel systems: from bundles of innovations to systems. The eight building block is about the need of investigating the *diffusion of systems*, such as (re-, down- or up-)cycling infrastructures or net-zero systems. If innovation is ultimately associated with some specific goals, such as achieving a net-zero society, it requires wide innovation system change, combining value chains and other systemic elements from different sectors. The inability of traditional diffusion theory to capture spreading of and across systems have been particularly noted by sustainability transition scholars who worked on conceptualising system building, circulation and replication, and societal embedding (Geels & Johnson, 2018).

In sum, based on the recent contributions in the literature and our own elaboration, we have suggested eight building blocks for advancing a higher-order conceptual framework from the limitations of traditional diffusion theories and the opportunities opening by newer approaches. Improving our understanding of diffusion is important, amongst others because we are then able to anchor innovation in a wider transformative context. The eight building blocks might help providing stepping stones for policy-makers and scholars alike to working towards diffusion in ways that gives answers to current social expectations about innovation for the greater good, accelerate the transformation of socio-technical systems towards solution of collective complex problems, address the dilemmas and bottlenecks through ethical norms and democratic accountability, secure stakeholders' participation and engagement in diffusion processes, advance the use of anticipatory and strategic foresight approaches for more targeted policy intervention and impact, and draft ideas about specific instruments and toolboxes which would be crucial for implementing a transformative diffusion policy.

An important part in this endeavour was to open a call for papers and invite scholars to reflect on a wider notion of innovation diffusion along these lines.

4. The contributions of the special issue

The nine papers that form this special issue bring to the fore several conceptual and empirical aspects that are highly relevant in relation to the above.

The article of **Hyysalo and Juntunen (2024)** explores how new technologies generalise in society, and how user activities shape and are shaped by this process. The article uses the concept of “series of configurational movements” (SCM) as a conceptual register for analysing the generalisation process of the changes in the technology, the actors, and the contexts involved. It applies this concept to the case of heat pumps in Finland, which is one of the most advanced energy transitions in the world. The article shows nine configurational movements, each featuring a change in the character

of the technology, the ecology of actors relevant to it, and the contexts in which the technology spreads. Their suggested SCM approach also shows eight types of user activity, which shape in different ways how the technology is defined, it is deployed, and its markets evolve. These eight are: adoption and routine use, adaption and adjustment, championing, user innovation, community building, peer intermediation, market creation and production of legitimating discourse on heat pumps. The SCM approach offers new way of understanding innovation diffusion, paying particular attention to both the local adaptations and stabilities in the process, as well as emphasising the (changing and multiple) roles of users as active agents in socio-technical change.

Finstad and Andersen (2023) ask the question of how multi-purpose technologies anchor and diffuse in multiple sectors simultaneously, and of what the main challenges are. The article examines how a niche technology, carbon capture, becomes widespread in different sectors of society. It combines insights from niche anchoring and technology speciation to explain how carbon capture adapts to different contexts and actor networks. They articulate the concept of ‘niche splintering’ as a multidimensional view of technology speciation in processes of anchoring and diffusion. Empirically, the article shows that carbon capture is anchoring in multiple sectors at the same time. Yet, this also leads to niche splintering, where actors have different visions and strategies for the technology. The article argues that niche splintering can hinder the diffusion of carbon capture, unless actors can align their expectations and sense-making. In their article the authors take an actor-centred approach, as it empirically finds that actors are the main enablers of anchoring and splintering, and that their strategies and sense-making are more relevant than any technical aspects.

The **Borrás, Gerli and Cenzato** article (2024) explores how technology transfer offices (TTOs), key intermediaries between universities and industry in the diffusion of innovation, cope with their new role for facilitating the diffusion of transformative innovation. The TTOs’ traditional approach based on intellectual property licensing and market-oriented commercialization of university knowledge is not entirely suitable for the diffusion of transformative innovation. Comparing two European TTOs that have participated in projects related to transformative innovation, the article shows that the enactments of their new role for the diffusion of transformative innovation are very diverse, and only one of the TTOs embraced a proactive role for a new diffusion approach, aligning research outputs with societal needs through the co-creation of innovations with users. The article suggests some implications for innovation diffusion policy, namely, the relevance of reconsidering the role of intermediary organisations (like TTOs and others) in important ways, not least, building their organizational capacity for enacting a “beyond-IPR-market- commercialisation” impact approach to diffusion policy.

Coehlo Rodrigues and colleagues (2024) examine how an innovative public practice in the healthcare sector, initiated by the government, is generalised across different settings. The innovative practice is a diabetic retinopathy screening program in the North of Portugal, which has a low adoption rate among potential implementers. The paper adopts a configurational approach to implementation, which views socio-technical systems as composed of interrelated elements that form coherent wholes. Configurational theories suggest that each implementation process is unique and depends on the alignment of structural, technical, and capacity factors in the local context. The paper proposes a conceptual model that can guide both the operational management of each implementation and the generalisation of the practice to other settings. The model is based on a holistic and generic framework that can be adapted to the specific characteristics and needs of each case. The paper argues

that this configurational perspective enables a balanced implementation strategy that combines controlled and organic elements in innovation diffusion as generalisation processes.

In their article, **Roysen and colleagues** (2024) explore the role of grassroots innovations (GIs) in sustainability transitions, using the notion of embedding as a theoretical lens. The article challenges the conventional three-pathway model of GI diffusion (replication, scaling up and translation) and proposes an alternative embedding framework that captures the diversity and complexity of GI diffusion processes. Empirically, the article applies this framework to the case of ecovillages, which are intentional communities that pursue ecological and social sustainability, in both the Global North and South. The paper demonstrates that ecovillages embed themselves in the broader society through various mechanisms, such as expanding their networks, reframing their narratives, circulating their knowledge, shifting their material practices, and replicating their models.

The **Scharnigg and Sareen** article (2023) in this special issue investigates the governance of niche diffusions and the changing power dynamics among actors involved in sustainability transitions. It focuses on the practices of legitimation that occur within an accountability regime, which defines the rules and norms for evaluating and justifying actions. It argues that intermediaries – in this case actors that facilitate the diffusion of innovations – have a key role in challenging the established paths and in creating alternative ones, especially when policy support and financial resources are scarce. The paper illustrates this argument with the case of community solar energy projects, which are grassroots initiatives that aim to reduce poverty, decarbonize energy systems and save energy costs. The paper studies the roles of four types of organisations as intermediaries: non-profit institutions, municipalities, new entrant companies with innovative business models, and the renewables arm of the incumbent. The findings show how non-commercial intermediaries, such as municipalities and non-profit organizations, help to upscale these projects by integrating different funding sources and interests, and by filling the gaps in the accountability regime. The article also analyses how the accountability regime influences the patterns and strategies of upscaling, and how some intermediaries may shape the legal-regulatory framework to enable the generalisation of community solar energy models.

The article by **Gong and Andersen** (2024) proposes a novel analytical framework to understand the role of material resources in technology diffusion and value chain upscaling in the context of net-zero transitions. The authors use the Technological Innovation System (TIS) approach as a diffusion framework and integrate it with a multisectoral value chain perspective, TIS phases, and the role of material resources in innovation. They apply their framework to a case study of the Electric Vehicle lithium-ion battery (EVLB) TIS in China, where material scarcities influenced technology diffusion. They identify the causes and effects of inter-sectoral imbalances related to material resource flows in the TIS value chain and analyse how actors perceive and respond to such imbalances. The article provides new insights on the importance of material resources and value chain dynamics for TIS and diffusion theory, and on how the urgency of a net-zero transition and geopolitics influence diffusion. The conceptual contribution of the article is the integration of material resources and value chain dynamics into the TIS framework and the analysis of how they influence diffusion in net-zero transitions.

The article by **Gulbrandsen and Osland Simensen** (2024) focusses on the research question of how pathways of industrial R&D and innovation translate into solutions that are relevant to society. They point towards a tension arising between the directionality integral to missions and transformative

innovation policy on one side, and the unpredictable, experimental, and whimsical nature of scientific and innovative endeavours on the other. Despite its significance in size and problem-solving orientation, industrial R&D is often overlooked in studies focused on grand challenges, even though it may play a crucial role in diffusion of innovation. They study this through a case study featuring a major international telecom firm, investigating how R&D and innovation processes (big data approaches and network algorithms) were tied to the scaling up of an innovation for a major societal challenge, specifically the Covid-19 pandemic. Their analysis illustrates that technology development can take the form of ‘exaptation’, wherein a technology finds utility in an unexpected area beyond its original purpose. As the technology takes shape throughout the innovation process, the direction for diffusion – important in transformative policy – can also only be substantiated midway through. They also highlight that for companies the relation with policies for grand challenges entails that inspiration for the direction to be taken should not solely come from researchers, yet should also involve users of research and innovation.

The article by **Haidar, Guimón and Alon** (2024) delves into the transformative potential of graphene in electrochemical energy storage technologies. It presents a comprehensive analysis of three scenarios: the current state, a projected state, and an ideal state. These scenarios are meticulously constructed to reflect the possible trajectories of graphene’s impact, from minor enhancements to groundbreaking changes. The study underscores the importance of foresight techniques like scenario building. These techniques allow us to anticipate future challenges and opportunities, enabling proactive and strategic decision-making in diffusion processes. By incorporating these techniques, we can foster a new approach to future-oriented diffusion policy-making. The approach can help us navigate the complexities of technological innovation and ensure that we are prepared for a range of potential futures. This is particularly crucial in the context of emerging technologies like graphene, where the path to large-scale adoption is fraught with uncertainties.

5. Discussion: an agenda for transformative diffusion studies

The articles that form this special issue, whilst each offering individual contributions, collectively further illustrate the eight building blocks outlined above. Focusing on transformative innovation, the stories and perspectives they bring, help fleshing out the real-life complexities and relevance of the diffusion of innovation, in ways that can contribute to broader transformative change.

We can start by mentioning that virtually all nine articles in this special issue see that diffusion concerns various forms of innovation, not only technology, but encompassing a wide diversity of innovation forms. For example, Hyysalo and Juntunen’s article, focusing on heat pump technology in Finland, shows that innovation diffusion extends beyond technological advancements, involving a number of social, organizational, and service innovations being diffused simultaneously. The article by Roysen and others about ecovillages provides a good case as well about the various mechanisms of diffusing organisational place-based innovation. This resonates with Building block 1 described in Section 3, and highlights that diffusion studies for transformative change may require the analysis

of bundles of innovations being diffused, and that the innovations within such ‘bundles’ may combine technological, social, organisational and other forms of innovation.

Regarding the co-evolution of actor roles, innovation and diffusion, Finstad & Dahl Andersen’s article on carbon capture and storage technologies indicate that users’ roles evolve from adopters to co-creators, influencing the trajectory of innovation diffusion. On a less positive side, the article by Borrás, Gerli & Cenzato on technology transfer offices, finds that intermediary organizations like technology transfer offices find it difficult to perform the new roles in transformative innovation diffusion processes expected from them. Resonating with Building block 2, this indicates that capacities to undertake these changing roles in transformative innovation diffusion might not be easy for both traditional and non-traditional actors like users. As Finstad and Andersen (2023) and Hyysalo and Juntunen (2024) demonstrate, the diverse ecologies of actors are not easy to demarcate.

In a similar vein, not only do actors’ roles evolve during diffusion, but the innovations that are being diffused may co-evolve with the contexts in which they are diffused (Building block 3). This is exemplified by the article from Gong and Andersen, who studied electric vehicle lithium-ion battery technologies. Their findings shows that innovations are not static, but are adaptive as they respond to user feedback, market dynamics, and regulatory shifts, evolving as they diffuse.

Following Building block 4, innovations also diffuse at different paces depending on context. For the diffusion of innovations to tackle urgent challenges (pandemics, mitigating the effect of climate change, etc.) the pace and timeliness of diffusion is key for policy makers, and society as a whole, as became clear in the articles by Gong and Andersen, and Gulbrandsen and Osland Simensen. Notions like acceleration, which has recently gained traction in e.g. transition literature (Andersen et al., 2023), should be considered as a dimension of diffusion.

The motivations for diffusion can come from different starting points and follow different institutional logics (Building block 5). There is a clear role for established companies to drive diffusion, as they have both the capacities and networks to organize deployment on a larger scale. Traditionally, diffusion scholars have underlined their role, which has also been more visible: they are often central to ecosystems and embedded in well-organised advocacy coalitions. Yet, in sustainability transitions the role of incumbent firms has received a mixed response. Some would rather favour radically-new or bottom-up initiatives and e.g. warn against greenwashing, whereas others emphasise that incumbents are the only type of actor capable of accelerating transitions on a wider scale. Coehlo Rodrigues’ article concerns government-led initiatives spread across different regions, whereas Roysen’s ecovillages are more about bottom-up, user-led diffusion strategies. There are also mixes of top-down and organically initiated diffusion activities through market dynamics and business-driven diffusion leading to unexpected outcomes (cf. Gulbrandsen and Osland Simensen). Several articles also attribute a significant role to intermediary organisations, such as in the case of Scharnigg and Sareen’s community solar energy projects. Having a deeper understanding of different diffusion management approaches, as well as the key role of diffusion intermediaries is needed, and will also lead to different roles for organizations, as well as strategies of policymakers and diffusion stakeholders.

Studies need as well to introduce more decidedly normative, ethical, and democratic accountability considerations in diffusion studies. As pointed in Building block 6, diffusion brings forward a series of dilemmas and issues that require societal attention and ways of engaging stakeholders into the co-

development of collective solutions. Future-oriented tools in the form of foresight instruments and approaches are key in diffusion strategies, as shown in the article by Haidar, Guimón and Alon. We even go a step further in saying that only looking at diffusion in an ex-post way would re-iterate a technology push perspective. A more anticipatory view on diffusion is needed, also in order to envision possible ethical, legal and societal repercussions with an eye on steering to more responsible ways of diffusion. This is even more important in light of: 1) diffusion in transformative policy potentially leading to new path dependencies and related problematic lock-ins, and 2) accelerated diffusion often leaving little time to anticipate and deliberate in an inclusive and reflexive way. By foregrounding diffusion issues, one sidesteps the potential trade-off between acceleration and responsibility.

Diffusion of innovations often displace incumbents or disrupt the existing order (Building block 7). In this case, the diffusion of innovation goes hand in hand with the destabilization of existing socio-technical systems and practices and the discontinuation certain technologies or practices. Without understanding the discontinuation, or the intentional phase out, of incumbent technologies or practices, we are missing a large part of the picture, as often the two are explicitly entwined, see for example the challenge of diffusing bio-sourced and biodegradable plastics into industries where fossil-fuel based solutions dominate.

There are clear gaps in the diffusion of innovation literature, for example many studies flip between very wide perspectives to very localized and specific perspectives (Hyysalo et al. 2024) to the study of individual uptake or implementation of a novelty (Coelho Rodrigues et al 2024). Introducing an organizational and inter-organizational perspective is a way forward, and there is also the need to bring innovation systemic perspectives into diffusion approaches, as a way of structuring the analysis of diffusion from bundles of innovations to systems, as suggested in the Building block 8 about investigating the diffusion of systems.

6. Conclusions: an agenda for transformative diffusion studies?

This special issue shines a light on the range of studies, frameworks and conceptual limitations of the diffusion of innovation. The seminal work of Everett Rogers, so dominant for five decades since its publication in 1962, is now being complemented by different, or further nuanced, concepts of diffusion – diffusion of product innovation following a market logic. Based on recent literature, we emphasized the heterogeneous nature of diffusion covering a variety of innovation types, systems, geographies and pathways.

The aim of the special issue is to demarcate and explore an approach to studying diffusion that is able to capture the heterogeneity under the term ‘generalisation’. To characterise main, cross-cutting elements of generalisation we first identified eight building blocks, capturing many of these broadenings, each opening up new avenues of research, whilst embracing the diversity in what we, the authors of this editorial, see as a renewal of our understanding of diffusion processes and outcomes.

What is clear is that there is a renewed interest in diffusion research which is flourishing in different academic communities, and the nine contributions of this special issue are a testament to the diversity

and complexity being opened up within this research domain. Yet, as we have shown in this editorial, there is a great deal of fragmentation with different research communities expanding and elaborating notions of diffusion in their own domains with limited reference to, or recognition of, explorations in other neighbouring research communities.

The eight building blocks could be seen as a pathway to new, or additional, foundations for a contemporary theory of diffusion. Whilst this may be a worthy goal, the authors of this editorial do not see the need for an all-encompassing theory of diffusion, rather, a connected community sharing new conceptualisations and empirical evidence of diffusion of innovations for transformative change, underpinned by a shared vocabulary. This would mitigate some of the fragmentation in diffusion research.

As a start, we call for further research on diffusion and sharing of findings across this disparate community. This special issue makes a start, but has shown that much more needs to be done. We have offered eight building blocks to help structure such a deepening of diffusion research and exchange. In discussing how these building blocks returned in the nine papers we also drew some lessons for diffusion, such as:

- Diffusion of innovation should be regarded as a set of heterogeneous activities involving different types of innovation, prime movers (companies, governments, users, intermediaries), and institutional logics. These prime movers are part of an ecology of actors, and one should pay attention to combinations (or bundles) of innovations to be diffused.
- Diffusion has a temporal aspect that can be steered on, e.g. by pushing for acceleration or slowing down.
- Repercussions of diffusion should be taken into account in terms of impact on user groups (including late adopters or non-users who might not benefit from transitions), on the creation of new lock-ins, and phase-out of innovation.
- A more anticipatory view on diffusion is needed, also in order to envision possible ethical, legal and societal repercussions with an eye on steering to more responsible ways of diffusion.

These lessons should also inform policymaking. There is also a demand from policy makers to improve our understanding of diffusion. With grand challenges being high on the policy agenda, we see that research and innovation policy makers acknowledge the need for a new policy approach, incorporating specific aspects of diffusion into policy-making. For example, in April 2024, the OECD launched its Agenda for Transformative STI Policies (OECD 2024a), which highlights the importance of a better understanding of diffusion and a stronger link of diffusion analyses to Science, Technology and Innovation (STI) policy making. Historically focused on early stages of emergence, STI policy is now challenged to engage in diffusion policies, particularly in areas for transformative change, i.e. the green transition, meeting grand societal challenges and achieving societal missions. Noteworthy is the inclusion of this in the Minister-level “*Declaration on Transformative Science, Technology and Innovation Policies for a Sustainable and Inclusive Future*”, signed by 44 countries and the European Union (OECD 2024b).

This increasing need for robust conceptual expansions and empirical evidence of diffusion poses challenges, but also provides opportunities for scholars of the diffusion of innovation: building and tailoring conceptual frameworks for contemporary innovation diffusion that provide useful strategic intelligence to decision makers.

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