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## PERSPECTIVE

# Challenges in the acceleration of sustainability transitions

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Grand sustainability challenges such as climate change, degradation of ecosystems, waste production and disposal, lack of clean water, poverty, or inequality pose extraordinary societal questions. The global initiative to target 17 sustainable development goals (SDGs) and the Paris climate agreement underline the urgency of these challenges. Widespread diffusion of technological innovations and new infrastructures is essential for the achievement of many SDGs (Thacker *et al* 2019). So far, however, progress has been rather limited (Sachs *et al* 2019), because existing systems of provision and consumption exhibit high degrees of inertia.

This inertia and the dynamics of radical innovations are at the center of a novel, interdisciplinary field of research on ‘sustainability transitions’ (Markard *et al* 2012). Sustainability transitions are fundamental changes in socio-technical systems such as energy, food or transport that aim to address grand challenges in a way that meets the needs of the present without compromising the ability of future generations to meet their own needs. Transition research investigates how radical innovations emerge, struggle with incumbent interests, and eventually lead to major system changes (Geels 2011).

Innovations include novel technologies such as wind or solar, but also alternative business models (e.g. around circular economy), or changes in social practices (e.g. sharing or consuming less). Technological change is viewed as an integral element of wider social, political and corporate transformation processes (Köhler *et al* 2019). While many sustainability challenges are global, transitions research often focuses at the national or local level, where situated innovations and interactions between policymakers, firms, consumers, and civil society organizations can be empirically analyzed.

To address the urgency of grand sustainability challenges, ongoing sustainability transitions such as

those in energy, transport or food have to enter a new phase, in which emerging innovations accelerate and contribute to broader system transformations (Markard 2018).

## 1. A new phase

In early transition stages, innovations emerge at the local level in tandem with closely associated developments such as the entry of new players and changes in businesses models, value chains, policies, or user practices. Much transitions research has focused on these early stages and on the emergence of innovations in small niches (Schot and Geels 2008).

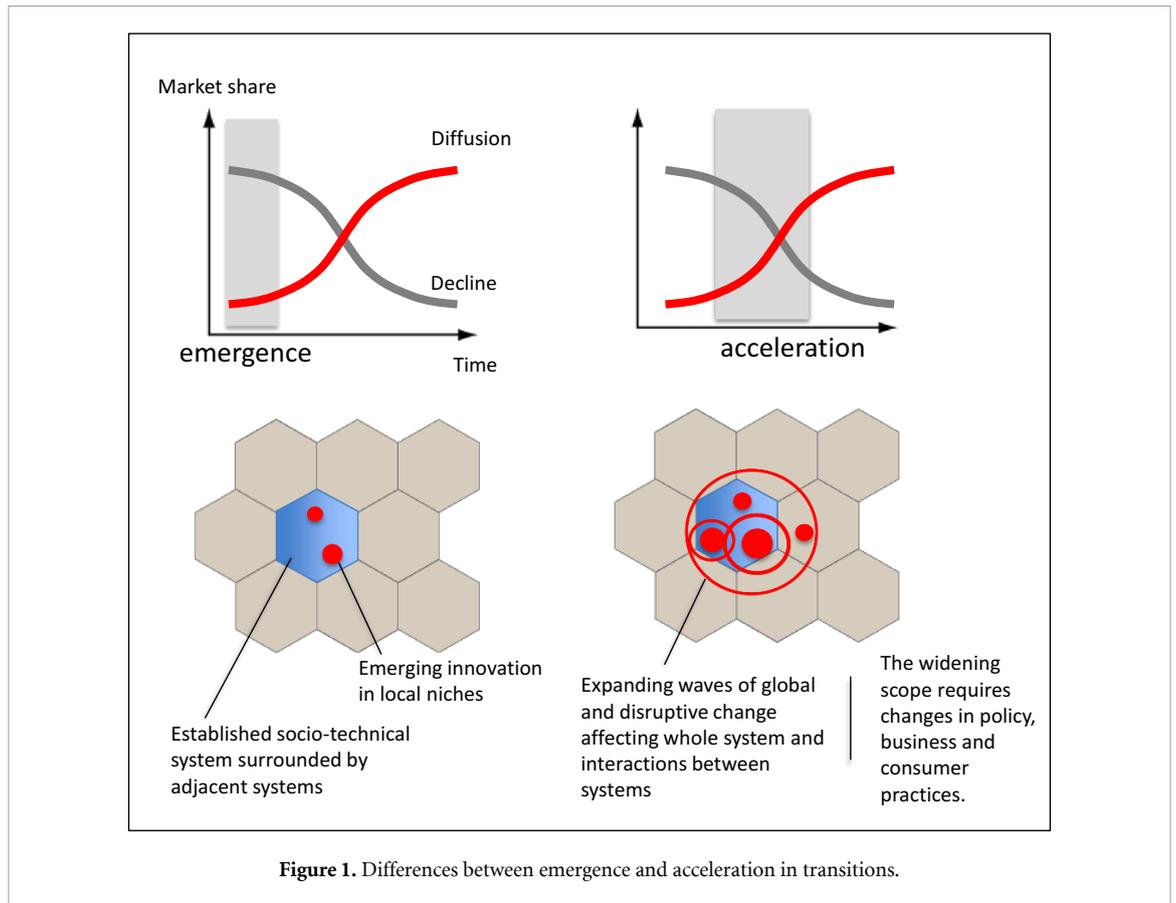
Some innovations such as solar-PV, wind, or electric vehicles have started to diffuse, moving to later transition stages. This is when transitions accelerate and widen in scope—both geographically and in terms of other systems (figure 1). So far, most studies have focused on the immediate technological and economic drivers of acceleration (e.g. R&D investment, upscaling, taxes and subsidies). While these drivers are crucial, we go further and discuss wider ‘acceleration challenges’, which currently prevent the acceleration of transitions and require substantial policy and research efforts.

We look into five non-exhaustive new challenges, which relate to the focal system, adjacent systems, and three essential social groups (firms, consumers, policymakers): (1) innovations in whole systems, (2) interactions with adjacent systems, (3) resistance from declining industries, (4) changes in consumer practices and routines, and (5) coordination challenges in policy and governance.

## 2. Whole systems change

Wide diffusion of radical innovations stalls if they fail to trigger or align with wider changes in whole systems. Two critical issues need to occur to overcome this challenge: (i) complementary interactions

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between multiple innovations, and (ii) changes in system architecture. Complementarities between different elements are central for the functioning of the system as a whole but also for the performance of individual elements (Markard and Hoffmann 2016). In electricity, the integration of renewable energies is a key issue in this regard. Variable renewables such as solar or wind require complementary storage technologies such as batteries or hydro-power to provide back-up capacity. From a transitions perspective, a lack of such complementarities becomes an acceleration challenge if system performance declines or bottlenecks occur. In Germany, for example, there is a lack of transmission grid capacity to transport electricity from wind parks in the North to the centers of consumption further south, hampering the acceleration of the renewable energy transition.

Second, acceleration may also stall if far-reaching changes in the architecture of socio-technical systems fail to happen (McMeekin *et al* 2019). Such changes in system architecture challenge acceleration if they disrupt existing business models or established roles of consumers. In electricity systems, for instance, we see disruptive architecture changes through decentralization, enabled by solar-PV, small-scale batteries or smart grids, which allow households and communities to self-generate power.

In the acceleration phase, policy thus has to shift from stimulating singular innovations towards

managing wider system transformation. Policy-makers will have to monitor progress in rapidly diffusing innovations and stimulate developments in complementary innovations such as infrastructure to prevent critical bottlenecks.

### 3. Interaction between multiple systems

A second acceleration challenge is to overcome tensions as interactions between different systems intensify (Papachristos *et al* 2013, Rosenbloom 2020). One aspect is about sustainability interdependencies. If one system becomes more sustainable it may attract attention from actors in other systems to solve ‘their’ sustainability challenges, thereby creating challenges in the focal system. For example Norway, a country with an abundance of hydropower, is pursuing a strategy to electrify transportation, heating and industrial production for deep decarbonization. This may create tensions, e.g. as different sectors compete for the same resource. Similar challenges have been observed in forestry and agriculture, where a more widespread use of biomass for biofuels or renewable electricity has created new sustainability challenges (e.g. threat of monocultures, competition with food production). Competition between systems can also apply to different geographies. Norwegian hydropower is exported as ‘clean energy’ to other countries, so there is competition between domestic use and export.

A related aspect is about potentially conflicting business cultures, values and institutional logics of different systems, or mismatches in organizational competences. Such conflicts have been observed in the past at the intersection of agriculture and energy (see above), or waste and energy (Raven 2007). Currently, we see mismatching time horizons for planning and project execution when it comes to grid expansion for high capacity charging stations, e.g. for electric ferries.

Furthermore, there will be competition by firms from different sectors, including the technologies or technological standards they promote. While such competitive dynamics can be productive, acceleration challenges occur when the existence of multiple standards creates uncertainty or even battles over standards. Such disruptions can be particularly far-reaching where generic technologies (e.g. ICT) or multi-purpose technologies (e.g. batteries) come into play.

For policy, interactions between multiple systems increase the complexity of transitions. A typical challenge is that policies are usually compartmentalized (e.g. energy policy versus transport policy) instead of integrated. Another challenge is that accelerated developments in one system may narrow down variation in another system. While electrification of transport currently seems an attractive way forward, it competes with alternative fuels such as hydrogen and it may postpone more comprehensive solutions (e.g. changes in urban planning, multi-modal transport).

#### 4. Decline and resistance

Acceleration of sustainability transitions will also involve the phase-out of unsustainable technologies. In the UK, coal-fired power generation, which provided 65% of the country's electricity in 1990, has fallen to 7% in 2017 and the remaining plants are expected to shut down in the coming years (Isoaho and Markard in 2020). Germany has decided to phase-out nuclear energy by 2022 and coal by 2038. Such industry decline is an important challenge to acceleration, because it may threaten existing business models and assets, which is why incumbent firms often try to slow down sustainability transitions (Hess 2014). Resistance also comes from unions and workers whose jobs are at stake and there might be particular regions or social groups that suffer more from decline and phase-out than others.

As a consequence, acceleration may be opposed. Incumbent firms often control critical resources (finances, ties to policymakers and unions) and deploy a broad range of strategies to resist and delegitimize emerging innovations and highlight the advantages of the established system. Such struggles over the course and pace of transformation are even more intense if

decline is accompanied by phase-out policies to end unsustainable technologies (Kivimaa and Kern 2016).

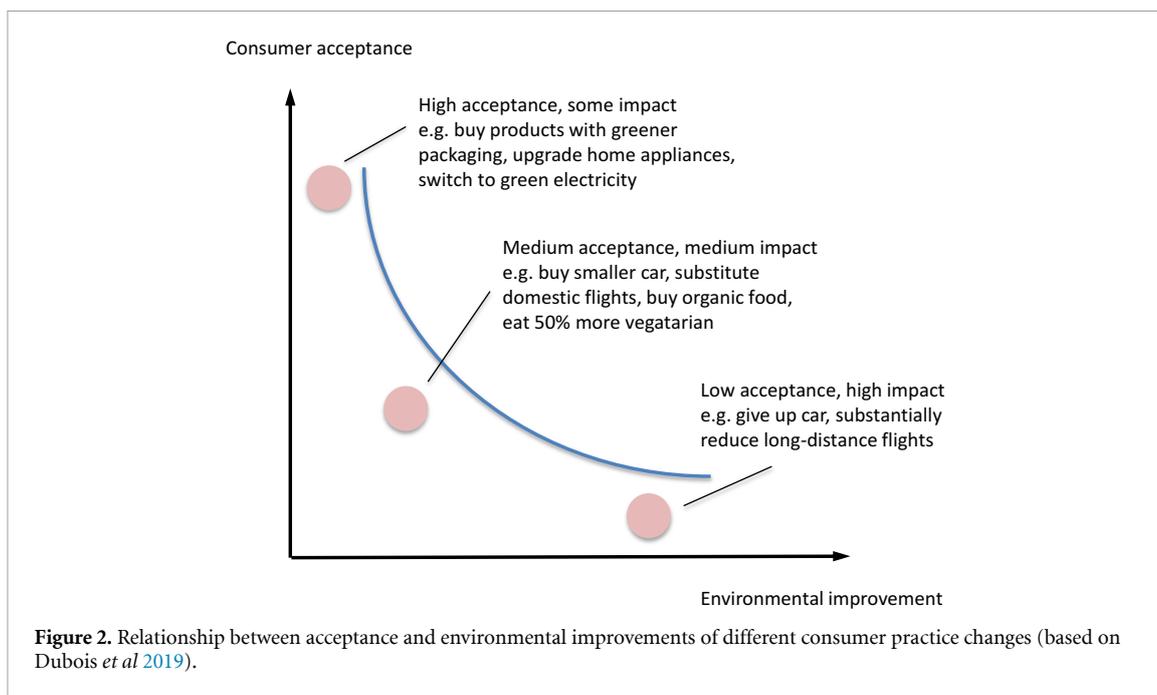
Political struggles and conflicts are therefore an inherent part of accelerating transitions. One policy strategy to deal with resistance is to accomplish wide societal support for long-term transition targets and to form broad constituencies of actors who are in favor of the transition, e.g. as they benefit from jobs in clean-tech industries (Meckling *et al* 2017). A complementary strategy is to assist 'losers' and to ease the unavoidable consequences of industry decline. In Germany, for example, policymakers are helping regions suffering from the decline of lignite mining by providing financial compensation, establishing innovation parks (e.g. on energy efficiency), and supporting new industries.

#### 5. Consumers and social practices

The consumer challenge relates to changes in social practices that may be required for the mainstreaming of sustainable technologies (Shove and Walker 2010). For instance, electric vehicles presently require changes in trip planning and refueling practices. Whilst early adopters may be willing to make such changes, the large majority of consumers may be more reluctant, which would hinder acceleration. Even more challenging are multi-modal transport systems, which require users to shift from car-dominated practices towards combining multiple modes of transportation.

An additional challenge is that reducing levels of consumption is desirable but difficult. For instance, reductions in demand for air travel, long-distance commuting, 'junk' food or fast fashion clothing are important for sustainability reasons. But such demand reductions are culturally and politically challenging because consumption is closely related to social norms (e.g. freedom) and established practices around work, family and identity. While some activists and social movements may voluntarily choose to reduce consumption, it is challenging to mainstream. A comparative household survey in Germany, France, Sweden and Norway (Dubois *et al* 2019) found that most consumers are willing to implement relatively simple changes, such as enhanced waste recycling or buying energy-efficient appliances, but unwilling to reduce consumption levels by abandoning private cars or flying. Unfortunately, these changes are inversely related to environmental impact (figure 2).

Policymakers presently mainly address consumer challenges by providing information (e.g. through energy labels), performance standards, taxes and subsidies (e.g. emission or consumption taxes, electric vehicle rebates) that aim to stimulate the adoption of sustainable technologies. The reduction of consumption levels is more challenging, because policymakers



**Table 1.** Overview of acceleration challenges.

Five challenges	Description	Example	Policy implication
Whole systems change	Major changes in system architecture	Decentralization of electricity supply	Focus on entire systems instead of singular innovations
Interaction between multiple systems	Increasing changes in the interaction of multiple systems	Electrification of transport, heating, industry etc.	Overarching missions; non compartmentalized policy making
Decline and resistance	Decline of existing industries and businesses	Traditional car industry, coal fired power generation	Create social acceptance; forge winning coalitions; compensate losers
Consumers and social practices	Major changes in consumer practices and demand patterns	Sharing economy	Stimulate technology adoption, behavioral change and learning-by-using processes
Governance	Increasing complexity of governance	Multi-level governance between European Commission and member states in Energy Union package	Context specific policy mixes; policy sequencing; stronger vertical and horizontal policy coordination

and environmentalists are wary about lecturing consumers about their lifestyles as this may evoke resistance, hinder economic growth, or threaten jobs.

### 6. Governance

The acceleration of sustainability transitions is not only associated with public policies that stimulate innovation or target decline, but also with broader governance challenges. One governance challenge relates to the need for horizontal and vertical policy coordination. Horizontal policy coordination is important for acceleration, because the diffusion of innovations often requires alignments between multiple policies, e.g. sectoral policies (e.g. transport, energy, agro-food) and cross-cutting policies (e.g. fiscal, education, industrial). But horizontal coordination between Ministries is often

hampered by political turf battles, which may impede acceleration. Vertical policy coordination is also challenging, because interests, political responsibilities, and financial resources vary between international, national and local policymakers. The European Commission, for instance, can formulate ambitious visions (e.g. Energy Union, Circular Economy), but has relatively limited financial resources (capped at 1% of European GDP) to realize them. National governments have many powers and substantial financial resources, but are often strongly lobbied by incumbent industries. These challenges in vertical coordination may delay acceleration.

Another governance challenge is that accelerated sustainability transitions require a shift from a neo-liberal policy paradigm and hands-off policy style towards a more interventionist approach with a stronger role for policymakers in shaping markets,

stimulating innovation, launching larger missions, building infrastructure, and regulating businesses (Roberts and Geels 2019). Such interventionist transition policies would aim to reorient big business and economic activities towards sustainability goals. This policy paradigm shift is challenging, because businesses have acquired substantial economic, cultural and political power, which enables them to influence or even capture policymaking.

## 7. Conclusion

To address the SDGs, we need fundamental transitions in socio-technical systems towards more sustainable modes of production and consumption. We are currently facing two transition phases, emergence and acceleration. For transitions to happen, various policies are required directed at both innovation and the destabilization of established systems (Kivimaa and Kern 2016, Rosenbloom *et al* 2020).

Once the first phase is in full swing, there are broader ‘acceleration’ challenges (table 1). These new challenges have important policy implications. First, policymaking has to become more integral, i.e. shift from singular innovations to changes in entire systems and from isolated policy domains to interactions across domains. Improvements in policy coordination require substantial governance changes such as overarching missions, policy ‘tsars’, stronger interaction between departments, or new ‘super ministries’, as well as increased global policy coordination. Second, policymaking should engage a broad range of actors to nurture social acceptance, stimulate learning-by-using, forge supportive industry coalitions in favor of transformation and compensate potential losers. Third, policymakers will have to work with a broad mix of policies (standards, incentives, subsidies, taxes) and apply them in a stepwise manner, e.g. continuously increasing sustainability requirements. Finally, sustainability transition policymaking will have to be context-specific to acknowledge the particularities of different sectors and places (Rosenbloom *et al* 2020).

Although many socio-technical systems are still characterized by inertia and resistance, there are promising signs in some sectors and places that acceleration is starting to happen. Future research should further investigate how actors navigate the acceleration challenges we described and if there are generalizable lessons that could facilitate acceleration more broadly.

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## Data availability statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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