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Sustainability transitions: policy and practice

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The EEA project manager was Mike Asquith.

Foreword

Based on a comprehensive review of the European environment, the EEA's last five-yearly report, *The European environment — state and outlook 2015* (SOER 2015), concluded that achieving the EU's long-term sustainability objectives will require the fundamental transformation of core societal systems (EEA, 2015b). Achieving such transitions will require profound changes in dominant practices, policies and thinking. Encouragingly, EU policy documents increasingly reflect this shift, for example in the language and logic of the EU's new long-term strategy for a climate-neutral Europe, and the European Commission's reflections on how to achieve the UN's 2030 Agenda for Sustainable Development (EC, 2018g, 2019b).

Translating these overall ambitions into concrete policies and actions will require new knowledge. The EEA and other knowledge institutions have compiled increasingly detailed and robust evidence about the systemic nature of the environmental challenges facing Europe and other regions. A knowledge gap exists on how governments and societies can respond to dynamically changing needs to ensure sustainability. The EEA requires a shift in emphasis — extending beyond a focus on monitoring and assessing existing environmental problems towards creating a more solutions-oriented knowledge base. This can be mobilised by governments and society to build a sustainable future (EEASC, 2015).

Following the publication of SOER 2015, the EEA invested in deepening its understanding of transitions research and its implications. This work resulted in a series of reports addressing different systems and themes (EEA, 2016a, 2016b, 2016c, 2017a, 2017b; EEA and Eionet, 2016). The most recent publication, *Perspectives on transitions to sustainability* (EEA, 2018d), provides a detailed overview of theoretical perspectives on transforming societal systems, with contributions from leading experts in the transitions community.

This report, *Sustainability transitions: policy and practice*, aims to build on the insights from these past assessments, going beyond theoretical discussions to explore the practical implications of transitions research for policy and practice. It highlights the growing links to established EU policy frameworks and identifies how transitions thinking is being operationalised at different scales across Europe. Co-authored by leading experts in transitions studies, the report has also benefited strongly from interactions with EEA partners in multiple policy areas, in particular, at a workshop co-hosted with the European Commission's European Political Strategy Centre in July 2018.

Sustainability transitions involve diverse social actors and policy areas. Therefore, an overview of the policy implications of transitions research in this report cannot explore any individual areas in great depth. Instead, it provides a framework that can help develop understanding and support sustainability assessments. For example, the analysis provides a key contribution to the EEA's next five-yearly assessment, SOER 2020, which will be published in December 2019. It also provides a foundation for potential future work by the EEA and its partners, focusing in more detail on particular policy areas or themes.

Executive summary

The emerging transitions discourse

During the last two decades, the concepts of 'sustainability transitions' and 'transformations' have emerged with steadily growing prominence in academic literature. Since 2010, this trend has been matched by increasing uptake of the language and logic of sustainability transitions in European policy and frameworks.

Behind these trends lies an evolving understanding of the scale and character of the sustainability challenges facing societies globally — and how those societies can respond. In the environmental domain, this has involved a move away from addressing individual issues, based on linear cause-effect principles, towards acknowledging multi-causality and systemic causes. In policy terms, this has meant a shift from targeted policies towards integrated and systemic policy frameworks. Similarly, in the area of science, technology and innovation (STI) policy, the emphasis has moved from state interventions aimed at overcoming market failures and promoting economic growth towards addressing grand challenges and achieving multidimensional sustainability objectives, such as those set out in the Sustainable Development Goals (SDGs).

Collectively, there is growing recognition that addressing the major societal challenges of our age and achieving sustainability objectives will require fundamental changes in lifestyles and patterns of consumption and production in all industrialised and industrialising countries. The European Commission's long-term vision for a climate-neutral Europe (EC, 2018g) expresses this clearly, affirming that achieving the transition to net-zero greenhouse gas (GHG) emissions by 2050 will require 'economic and societal transformations ..., engaging all sectors of the economy and society'. The Commission's recent 'reflection paper' on the 2030 Agenda for Sustainable Development likewise refers repeatedly to the need for a sustainability transition to achieve the SDGs (EC, 2019b).

The emergence of the sustainability transitions discourse in science and policy represents a significant reframing of Europe's sustainability challenges and response options. However, the implications of this shift for public policy and institutions are, as yet, largely unexplored. As noted in a recent European Commission report: 'It is now well understood how transitions arise. However, turning this understanding into sound advice on how to better manage present and future transitions is still a major challenge' (EC, 2018l). The present report represents a response to that knowledge gap.

Challenges for established governance approaches

The EEA's last five-yearly report, *The European environment — state and outlook 2015* (SOER 2015), presented a mixed picture of the European environment's past trends and future prospects. Although European environmental policy has achieved important successes during the last 40 years, SOER 2015 concluded that achieving the EU's 2050 vision of 'living well, within the limits of our planet', as defined in the 7th Environment Action Programme (EC, 2013a), will require fundamental transitions in core production-consumption systems such as those meeting European demand for food, energy, mobility and housing. Such transitions will necessarily entail 'profound changes in dominant institutions, practices, technologies, policies, lifestyles and thinking'.

SOER 2015's call for fundamental transitions was based on its analysis of both the scale and the systemic character of the sustainability challenges facing Europe. Environmental pressures are growing fast, as an ever greater proportion of the global population shifts towards the resource-intensive consumption patterns of developed regions, and planetary boundaries relating to climate change, biosphere integrity, land-system change and biogeochemical cycles (phosphorus and nitrogen) have been crossed (Steffen et al., 2015), implying risks of irreversible and abrupt environmental change.
For advanced economies in Europe and elsewhere, reconciling high levels of human development (living well) with environmental sustainability (living within the limits of our planet) is expected to require five-fold (factor 5) or even 10-fold (factor 10) improvements in environmental performance (EC, 2011a; UNEP, 2011a).

Recent history suggests, however, that this is very difficult to achieve, because the key socio-economic and environmental challenges facing society, including rising inequality, climate change and biodiversity loss, are systemic in nature. The systems that meet society's essential needs (e.g. food, energy, mobility) account for much of humanity's burden on the environment, in terms of both extracting resources and producing waste and emissions. These systems are also closely linked with a variety of socio-economic and institutional processes that co-evolve with the systems' technologies over long periods of time, creating lock-ins and making them resistant to fundamental and far-reaching change. Systemic challenges are complex and multi-dimensional. Linked to global developments, these are perceived differently by diverse groups in society and at varied geographical scales.

The systemic nature of Europe's environmental problems creates a significant governance challenge. The interlinkages in complex societal systems imply that government interventions to alter one part of the system are bound to produce costs and benefits elsewhere, generating an uncertain mixture of feedbacks and trade-offs. System transitions necessarily disrupt and challenge established investments, jobs, behaviours, knowledge and values. While these changes create new jobs, business models and opportunities for green growth, structural change inevitably provokes various forms of resistance, constraining governments in their ability to impose regulations and pricing instruments that are consistent with long-term environmental goals. In competitive, globalised markets, the capacity of the state to address externalities and act in the interests of future generations is further diminished.

Addressing increasingly globalised environmental challenges will require a functioning system of global governance with shared commitments. The EU's economic scale, diplomatic and trade links, and global leadership in environmental governance, confer significant influence in intergovernmental settings. Yet, decision-making processes at the global scale are frequently slow and produce disappointing outcomes, and enforcement mechanisms are often lacking. Collectively, these reflections suggest that a purely hierarchical, top-down approach to achieving sustainability objectives will not work. Intergovernmental agreements, regulations and economic instruments all have important roles to play. Indeed, the Paris Agreement acknowledges this reality with its endorsement of more bottom-up governance and strong support for non-state and subnational actors (Jordan et al., 2018a).

Insights from transitions research

Drawing on historical evidence and case studies, transitions researchers offer a rather different account of how systems change, with implications for the role of public policy and institutions. According to these new perspectives, transitions are non-linear, society-wide processes, with a central role for bottom-up processes of innovation, experimentation, learning and networking. Change occurs through interdependent adjustments in technologies, business models, behaviours, rules, values, and so on, producing non-linear and highly unpredictable results. Public policies and institutions are part of the regime structures, implying that they too need to be transformed.

Transitions emerge through interactions among multiple actors, including businesses, users, scientific communities, policymakers, social movements and interest groups. They are evolutionary processes, meaning that they are typically based on searching, experimenting, reflecting and learning. They also depend critically on interpretations and social acceptance. Transitions are therefore fundamentally uncertain and open-ended. Surprises and unintended outcomes are to be expected. Transitions are also conflictual and deeply political, producing trade-offs, winners and losers, and related struggles, as politically influential and well-resourced incumbents often resist change.

These findings have a variety of implications for governance. First, the perceived role of government shifts from acting as a 'pilot' with the knowledge and tools to steer society towards sustainability towards a role as an enabler of society-wide transformation processes. Environmental policy tools, such as regulations and market-based instruments, remain important as a means to drive efficiency improvements, stimulate innovation and steer the direction of change. Tackling the core drivers of environmental degradation requires a much broader policy mix, aimed at enabling innovation, experimentation, diffusion and networking, as well as facilitating structural economic change.

At the same time, the breadth of activities across policy areas and across scales of governance creates the need for coordination and directionality. Public institutions have a key role to play in ensuring horizontal coherence across policy areas, as well as vertical coherence between local, national and international levels. Sustainability transitions also imply normative choices between alternative visions of the future and how to get there, pointing to the importance of public engagement to foster consultation and deliberation. Meanwhile, the need to prepare for sudden shifts, unexpected consequences and new emerging issues implies a need for both exploratory, analytical approaches (e.g. horizon scanning), as well as adaptive governance grounded in horizon scanning, monitoring and learning, that enable reorientation of transition processes.

Key messages for policy

This report sets out 10 sets of messages for policy, explored in Chapters 3-12. The first five messages address the policy mixes and other actions needed to stimulate and enable system innovation. They focus on innovation, diffusion, and system reconfiguration, as well as on two important cross-cutting themes: cities and finance. The next five messages address how governments and other actors can coordinate systemic change processes and steer them towards long-term sustainability goals. The chapters focus on visions and pathways, horizontal and vertical coherence of governance, managing risks and unintended consequences, and knowledge and skills for transitions.

Message 1: Promote experimentation with diverse forms of sustainability innovation and build transformative coalitions

The emergence of new technologies, practices and business models requires a culture of experimentation. This implies supporting diverse innovative activities from publicly funded research and development (R&D) projects to local social movements, as well as creating new networks of actors.

- To support a wide range of sustainability innovations, innovation policy could be broadened beyond technology to also address infrastructural, social and business model innovation.
- Addressing the specificities of sustainability transitions means extending innovation policy's focus on R&D and innovation system support towards transformative innovation policy.
- Exploring uncertainties associated with radical innovation requires more real-world experimentation to assess technical performance, market uptake, social acceptance and environmental impacts.
- Radical innovation requires transformative coalitions and partnerships. Research and firms are crucial, but 'open innovation' policy should also target users, civil society, communities and other actors.
- More support for social and grassroots innovation can enable deeper and more transformative transition pathways.
- Innovation policy should also stimulate organisational innovations and new business models, which are important in determining the commercial feasibility of sustainability innovations.

Message 2: Stimulate the diffusion of green niche innovations

To achieve sustainability transitions, radical innovations need to move beyond experimentation and diffuse more widely. Novel technologies, social practices and infrastructure systems, pose different challenges and diffuse in varied ways, requiring different kinds of policy support.

- Governments can stimulate knowledge diffusion by replicating projects and stimulating the circulation of insights, for example, through standardisation and workshops organised by intermediary actors.
- Policy can stimulate adoption by users through financial and non-financial incentives, information provision and adjustments in economic framework conditions.
- Uptake of innovations in business can be supported using funding instruments, regulations and direct infrastructure investment.
- Governments can support societal adoption of innovations by developing positive narratives that promote social acceptance and by involving societal groups through public participation methods.
- Broad diffusion of innovations may require horizontal coordination with other policy areas (transport, energy, agriculture, environment, safety, education, etc.) and institutional adjustments.

Message 3: Support the reconfiguration of whole systems, phase out existing technologies and alleviate negative consequences

Sustainability transitions can involve disruption and conflict when the diffusion of new technologies and practices affects existing systems and businesses. Impacts on particular sectors or regions can be severe, implying a role for public policy in offsetting inequities and facilitating structural change.

- Reconfiguring entire systems should go beyond individual innovations or technological 'silver bullets' and promote synergies between multiple innovations.
- Sustainability transitions can be accelerated by deliberately phasing out unsustainable technologies and systems, for example using bans or targeted financial disincentives, or by removing implicit subsidies.
- Ensuring a just transition requires measures to alleviate negative consequences and help firms, employees and regions to reorient (e.g. compensation, retraining and regional adjustment).

Message 4: Leverage and strengthen the role of cities in sustainability transitions

Cities have a particularly important role in sustainability transitions because they are hubs for innovation and experimentation, providing great opportunities for learning and networks, and offering the potential for achieving whole system change at local scales.

- Cities are centres of innovation. Governments can support this transformative potential with more resources and local responsibilities and with clearer criteria for urban sustainability.
- Diffusion of urban sustainability innovations can be further supported by attending to learning, networking and replication of best practices. City networks may act as crucial vehicles for diffusion.
- Urban transitions are also about whole system reconfiguration at city levels. Governments can support system change by providing financial, technical and administrative support, and capacity-building.
- Monitoring and evaluation of local sustainability actions are often weak, undermining opportunities for learning. EU and national actors can help develop robust metrics and evaluation procedures.

Message 5: Reorient financial flows towards sustainable and transformative innovations

Finance is essential for the emergence and diffusion of innovations and enabling the transformation of production-consumption systems. Ensuring that society's investments promote sustainability goals is a major challenge because of wide-ranging barriers and market failures.

- There is a need for much greater investment in sustainability-oriented research and experimentation. Ambitious goals for public investments in climate solutions could be extended to other areas.
- Policy support is key to help innovations bridge the 'valley of death' between research funding and commercialisation, e.g. through co-funding, loan guarantees and market creation (e.g. feed-in tariffs, loans).
- Meeting the investment needs will depend on policies that correct market incentives, reduce risk and uncertainties, and incentivise private investment, as well as more fundamental financial reforms.

Message 6: Promote clear direction for change through ambitious visions, targets and missions

Sustainability transitions are purposeful and oriented towards defined sustainability outcomes, notably the SDGs. This creates a difficult governance challenge, as the complexity and uncertainty of societal change means that transitions cannot simply be planned and implemented from the outset.

- Developing ambitious long-term visions, targets and missions using collaborative and forward-looking approaches such as foresight is essential to guide transitions. Such instruments help in developing shared narratives and values, as well as conveying urgency and commitment.
- To make long-term visions concrete and to incentivise supporting actions, it is important to translate these visions and missions into sectoral and cross-sectoral policy strategies, programmes and instruments.
- Ambitious and consistent short-, medium- and long-term sectoral and cross-sectoral targets are needed to make the vision and related policy strategies credible and to measure progress.
- Progress towards visions and missions must be reviewed periodically to enable policy learning, and to improve and adapt actions to help achieve the overall vision.

Message 7: Align policies between different domains to improve policy coherence for transitions

The multidimensional nature of transition processes means that they are influenced — positively or negatively — by policies in diverse domains, including environment, innovation, sectoral and fiscal, and education policies. This creates significant risks of inconsistencies and incoherence.

- Governing sustainability transitions requires horizontal policy coordination, aligning both sectoral and cross-cutting policies. This means reconciling contrasting objectives across policy areas and actors.
- Policymakers should actively seek to identify and correct existing policy misalignments. This involves a political choice between patching of existing policy mixes and a more fundamental redesign.
- Policy coordination and policy integration are two key strategies for achieving coherence. They can be promoted using macro-level policy strategies, (policy) processes and organisational changes.

Message 8: Promote coherence of actions across EU, national, regional and local governance levels

Sustainability transitions necessarily involve actions at multiple levels of governance, as they are multi-actor processes that cannot be steered by any actor on any level of governance on its own. Again, this creates problems of inconsistency and incoherence across scales of activity.

- Transitions require policy action at all levels of governance. Ensuring that they reinforce each other requires vertical coordination and mapping of responsibilities, inconsistencies and barriers.
- Promoting both top-down and bottom-up processes of governance requires new mechanisms to promote dialogue between different levels and increased flows of information and resources.
- Thematic working groups crossing different governance levels and including industry and civil society actors could be used as a tool for facilitating coordination in polycentric systems of governance.

Message 9: Monitor risks and unintended consequences and adjust pathways as necessary

From a risk management perspective, transitions present a particularly difficult governance challenge. Transition processes are highly unpredictable, open-ended, complex and non-linear processes that often produce unintended consequences and surprises.

- Transitions have unintended consequences and trade-offs between social, economic and environmental sustainability outcomes. It is essential to continuously identify and evaluate risks associated with transitions using anticipatory governance approaches.
- Ex ante approaches must be complemented with adaptive governance approaches, based on iterative cycles of policymaking and planning, implementing, evaluating and learning.
- Governance of transitions requires a precautionary approach, as it has an important role in supporting decision-making in situations of uncertainty.

Message 10: Develop knowledge and skills for transitions governance and practice

The knowledge systems developed to support environmental governance in the 20th century were well adapted to the challenges and thinking of that time. They do not provide the evidence base needed for governance today because they fail to integrate many fundamental characteristics of transitions.

- Effectively supporting sustainability transitions requires fundamental changes in the knowledge system supporting governance, implying shifts in skills, methods, processes and cultures.
- Supporting radical innovations requires new knowledge that broadens the solution space and engages with the multiple dimensions of innovation and system change more systematically.
- Public authorities need to develop new skills and policymaking practices, embracing foresight, experimentation, evaluation and stakeholder interaction, as well as new organisational structures.

Part 1 Understanding sustainability transitions

1 The emergence of transitions research and policy

During the last two decades, concepts such as 'sustainability transitions' and 'transformations' have acquired growing prominence in academic literature (Köhler et al., 2019). Since 2010, this trend has been matched by an increasing uptake of the language and logic of sustainability transitions in European policy frameworks.

Behind this emerging discourse lies an evolving understanding of the scale and character of the sustainability challenges facing societies globally — and how those societies should respond. In part, this involves a recognition of the urgent need to achieve huge reductions in environmental pressures to avoid potentially catastrophic outcomes. In part, it reflects an acknowledgement that environmental goals are intimately connected with many other dimensions of sustainability, as embodied in the 17 globally agreed Sustainable Development Goals (SDGs) (UN, 2015b). In general, the emergence of this new policy discourse points to growing recognition that sustainability objectives cannot be achieved with technical fixes alone but necessitates a more fundamental transformation of societal systems (Steward, 2012).

In the EU context, recent policy developments have crystallised this shift in thinking. The EU's long-term strategy for a climate-neutral Europe, published in November 2018, outlines 'a vision of the economic and societal transformations required, engaging all sectors of the economy and society, to achieve the transition to net-zero greenhouse gas emissions by 2050' (EC, 2018g). The European Commission's reflection paper on the 2030 Agenda for Sustainable Development (EC, 2019b) likewise adopts the language of transitions systematically, affirming, for example, that it is 'of the utmost importance that all actors in the EU prioritise the sustainability transition'.

For policymakers and other actors, this shift presents challenges in relation to both understanding and operationalising the concept of sustainability transitions. Making sense of the rapidly growing body of knowledge on systemic change is difficult — in part because academic research on these themes is fragmented, comprising contributions from diverse scientific communities that explore the issues in overlapping but contrasting ways (as outlined in Section 2.1.1). Furthermore, these different research communities have only recently begun to explore the concrete implications of transitions thinking for policy and governance.

This report aims to respond to this knowledge gap, providing a broad overview of the policy implications of transitions research, reflecting on links to established policy frameworks, and using examples and case studies to illustrate concepts and themes. In doing so, it aims to provide a foundation for more detailed analysis, addressing specific policy areas and societal systems in coming years.

The analysis presented here builds on a series of EEA reports, starting with the EEA's last five-yearly assessment, The European environment — state and outlook 2015 (SOER 2015), which identified the need for sustainability transitions and was based on a comprehensive analysis of the *European environment's state and trends* (EEA, 2015b). Subsequent EEA assessments have explored sustainability transitions from a range of angles. This included addressing the different theoretical perspectives on transitions and transformations (EEA, 2018d), the food system (EEA, 2016c, 2017b), the energy system (EEA, 2016e), the mobility system (EEA, 2016f), products (EEA, 2017a) and local actions across Europe (EEA and Eionet, 2016).

1.1 New policy framings

1.1.1 Evolving environmental policy framings

The recent emergence of integrated policy frameworks with an increasingly systemic and transformational focus builds on decades of learning about the successes and limitations of established approaches, stretching back to the early 1970s. In the environmental domain, this process has involved a move away from addressing individual issues based on linear cause-effect principles,

Table 1.1 Changing understanding of environmental challenges, policies and assessment approaches

Characterisation of key challenges	Key features	In policy since	Policy approaches (examples)	Assessment approaches and tools (examples)
Specific	Linear cause-effect, point source, local	1970s	Targeted policies and single-use instruments	Data sets, indicators
Diffuse	Cumulative causes	1990s	Policy integration, market-based instruments, raising public awareness	Data sets, indicators, environmental accounts, outlooks
Systemic	Systemic causes	2010s	Policy coherence, systemic focus (e.g. mobility), multidimensional goals (e.g. SDGs)	Indicators, accounts, practice-based knowledge, systems assessment, stakeholder participation, foresight

towards acknowledging multi-causality and systemic causes (Table 1.1).

The EU's first two environment action programmes, running from 1972 to 1981, exemplify the first generation of environmental policy, with regulatory interventions used to tackle specific issues such as water quality, air quality, waste disposal and species protection. Instruments such as the Waste Framework Directive (EEC, 1975), Bathing Water Directive (EEC, 1976) and Birds Directive (EEC, 1979) sought to tackle environmental issues with direct, well-identified cause-effect relationships. Since the 1970s, this intervention model has culminated in a body of some 500 directives, regulations and decisions. It today represents the most comprehensive modern set of environmental standards in the world, commonly known as the 'environmental acquis'.

As detailed in EEA reports since the mid-1990s, the environmental acquis has led to measurable and substantial improvements in environmental protection. As a result, the local environment in many parts of Europe is arguably in as good a state today as at any time since the start of industrialisation (EEA, 2015b). Notable achievements include significant reduction of pollutant emissions to air, water and soil; the establishment of the world's largest network of protected areas under Natura 2000 (EEC, 1992); the recovery of many species previously on the brink of extinction; and reduced exposure to hazardous chemicals.

Despite these gains, it was increasingly clear by the 1980s that targeted policy approaches are insufficient to address environmental problems resulting from diffuse pressures, such as the unsustainable use of natural resources, environmental impacts on human health and biodiversity loss. As a result, a second generation of policies emerged that sought to integrate environmental concerns into sectoral policies. 'Environmental integration' was introduced as a key mechanism in the EU's 5th Environment Action Programme (1993-2000) and was formally established as a requirement under the Treaty of Amsterdam (EU, 1997) following an initiative of the European Council (the Cardiff process). The first five target sectors were those contributing most to environmental deterioration: industry, energy, transport, agriculture and tourism. This shift in approach was accompanied by an increasing use of non-regulatory instruments, such as financial instruments (e.g. investment funds), market-based instruments (to 'get the prices right'), horizontal approaches (e.g. information, education, research, etc.), and more coordination with stakeholders.

Environmental integration has been pursued through policy frameworks such as the common agricultural policy (CAP), the common fisheries policy (CFP) and cohesion policy. While it has achieved some progress (e.g. in the field of energy and climate policy), it has produced mixed results (Jordan and Lenschow, 2010; Nilsson and Persson, 2017). In some cases, environmental considerations have been insufficiently integrated into sectoral policies. In others, policy instruments have struggled with the interplay between social, economic and environmental factors, failing to deliver results at the scale and speed needed. For example in the agricultural sector, which is responsible for many environmental pressures, environmental considerations have been increasingly embedded within the CAP through cross-compliance conditions for obtaining full direct payments, as well as voluntary commitments by farmers to get additional payments under agri-environment schemes (EU, 2013b, 2013a) Such measures account for only a small proportion of the overall CAP budget, however, and there are no associated agri-environmental binding targets to ensure that associated measures lead systematically to reduced pressures on the environment.

> 'Fundamental transformations in the way the world lives, works, and does business are needed for building the low carbon, climate resilient, green and inclusive economies and societies of the future.' (UN, 2015a)
> Helen Clark, former Director of the United Nations Development Programme

1.1.2 *Long-term and systemic policy frameworks*

Recent years have witnessed the emergence of a third generation of policies with a markedly more integrated and long-term character. In the EU context, this new paradigm is evident in strategic frameworks such as the Circular Economy Action Plan, the Energy Union and the 'Europe on the move' agenda, as well as calls for a European 'common food policy' (EC, 2015a, 2015b, 2017a; EESC, 2017). These frameworks are characterised by:

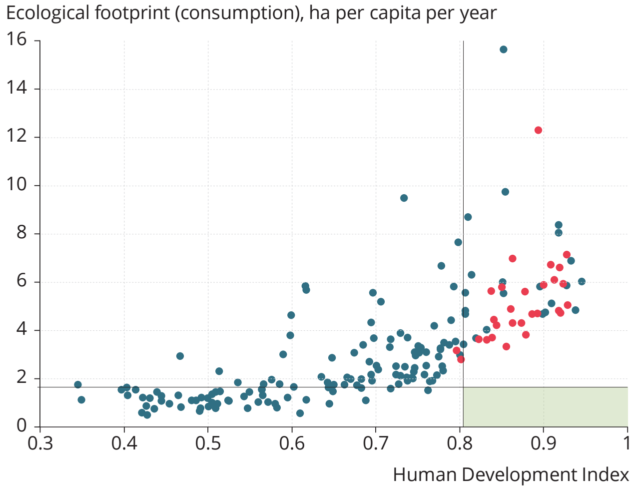
- a shift from sectoral to systemic focus (e.g. recognising interlinkages between environment, economy and society; seeking greater coherence and alignment of policy signals);
- an emphasis on transformation of the economy and society informed by new objectives (e.g. to become low-carbon, circular, etc.);
- the emergence of long-term framings and targets (e.g. 2030, 2050);
- multidimensional goals, addressing themes such as fair access, jobs, competitiveness, sustainability;
- a focus on diverse societal actors and creation of stakeholder platforms;
- increasing adoption of transitions thinking, including particular emphasis on the role of innovation in different policy areas.

The emergence of these more systemic policy frameworks reflects an awareness of both the limitations of established approaches and the scale and character of the governance challenge ahead. As set out in the EEA's last five-yearly report, SOER 2015, successes in some areas of environmental policy are matched by persistent problems in other areas. In particular, issues such as climate change, resource use and biodiversity loss represent fundamental and growing threats to ecological resilience. These issues are particularly difficult to address because they are 'systemic' in nature, meaning that they are tied in complex ways to established lifestyles, technologies, infrastructures and cultures. As a result, producers and consumers alike may have strong interests in avoiding systemic change. This is likely to constrain governments from introducing sufficiently stringent policies.

At the same time, the changing global context means that Europe, like other economically advanced regions, must find ways to dramatically reduce its environmental impacts. As in other developed regions, Europe's success in increasing living standards during the 20th century was associated with disproportionate increases in environmental pressures. Today, the resource use of countries with very high levels of human development far exceeds global average biocapacity (Figure 1.1). Planetary boundaries relating to climate change, biosphere integrity, land-system change and biogeochemical cycles (phosphorus and nitrogen) have already been crossed ([1]), implying increased risks of irreversible and abrupt environmental change (Steffen et al., 2015).

For advanced economies in Europe and elsewhere, reconciling high levels of human development with environmental sustainability is expected to require five-fold (factor 5) or even ten-fold (factor 10) improvements in environmental performance (EC, 2011a; UNEP, 2011a). For example, the EU needs to achieve GHG reductions of 80-95 % by 2050 as part of global efforts to limit global warming to less than

Figure 1.1 High living standards are associated with escalating environmental pressures



Note: The dots in the figure represent countries, with red dots denoting EU Member States. The Human Development Index (HDI) is calculated based on indicators of education, life expectancy at birth and wealth. It is expressed as a value between 0 and 1, from least to most developed countries. HDI scores between 0.8 and 1.0 are categorised as 'high human development'. The Ecological Footprint measures how much land and water area a population requires to produce the resources it consumes and to absorb its waste. The horizontal line shows world biocapacity per capita. World biocapacity is the global productive area available to produce resources and absorb waste. The HDI and Ecological Footprint data are from 2014.

Source: Based on GFN, 2018 and UNDP, 2018b.

([1]) The concept of planetary boundaries (or limits) suggests tolerance levels for nine fundamental earth system processes, beyond which the risk of unacceptable and irreversible global environmental changes would increase substantially.

2 °C and avoid the most severe impacts of climate change. Realising change at the necessary pace and scale presents an unprecedented challenge, requiring more than simply optimising established systems of consumption and production. Instead, it will necessitate a more fundamental rethinking of how society meets its needs (Figure 1.2).

1.1.3 System transformation as a new policy rationale

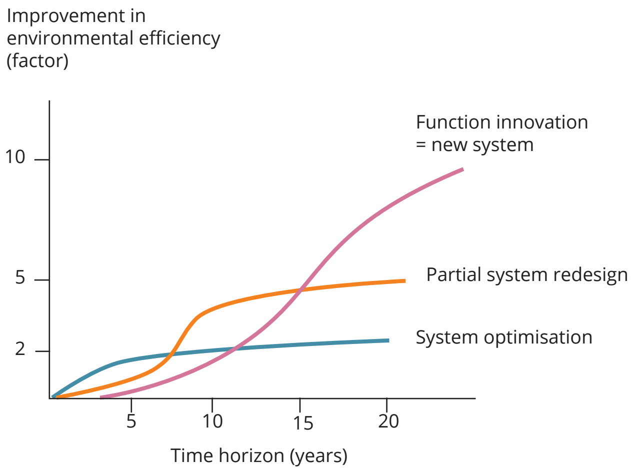
The evolution of environmental policy towards a more systemic framing is matched by a similar shift in other policy areas, such as sectoral policies. Indeed, the emergence of integrated frameworks that bring together social, economic and environmental dimensions points towards a converging understanding of the need for systemic change.

In the area of science, technology and innovation (STI) policy, for example, the logic of state intervention has shifted from measures to overcome market failure and promote economic growth towards a broader focus on promoting transformation (Schot and Steinmueller, 2018) through intervention mechanisms. This shift reflects increasing awareness of the need to orient innovation processes towards addressing societal challenges and achieving multidimensional sustainability objectives, as exemplified in the SDGs (Table 1.2). It also calls for a broadening of the actors involved in societal transformations, and the policy means to orchestrate such processes.

The SDGs themselves can be seen as an important step towards setting out a shared sense of long-term directionality for system innovation. Indeed, the need for societal transformation is arguably firmly embedded in the logic of the SDGs, which were adopted with UN Resolution 70/1, entitled *Transforming our world: the 2030 Agenda for Sustainable Development*. As reasoned by Schot et al. (2018):

> From an STI policy perspective, The UN Agenda 'Transform our World' can thus be interpreted as a call for a 'new form of innovation'. Such innovations provoke a broader system change not only in the technology used, but also in consumer practices and needs, skills and capabilities of all actors involved, infrastructures, governance, regulation, industry structure and cultural meaning of the system.

Figure 1.2 System optimisation and system innovation



Source: UNEP, 2011a, based on Weterings et al., 1997.

Table 1.2 Changing innovation policy framings

Overarching framing	Key features	Era	Policy rationale	Policy approaches (examples)
Innovation for growth	Science and technology for growth, promoting production and consumption.	Since the 1950s	**Responding to market failure:** public good character of innovation necessitates state action	State financing of basic R&D, incentives for business R&D (e.g. tax breaks, subsidies).
National systems of innovation	Importance of knowledge systems in development and uptake of innovations.	Since the 1980s	**Responding to system failure:** maintaining competitiveness, coordinating system actors.	Promoting science hubs; incentivising coordination; SMEs; education and training.
Transformative change	Alignment of social and environmental challenges with innovation objectives.	Since the 2010s	**Promoting transformation:** pathways, coordination domains, experimentation, learning.	Societal challenges (H2020), goal orientation (SDGs), mission-oriented innovation (FP9).

Note: FP9, Framework Programme 9; H2020, Horizon 2020; SMEs, small and medium-sized enterprises.

Source: Based on Schot and Steinmueller, 2018.

Effective governance of transitions requires the mobilisation of a broad range of policies and their coordination across governance scales and sectors. As the European Commission notes in its reflection paper on the 2030 Agenda for Sustainable Development (EC, 2019b), recent EU policy interventions geared towards achieving the SDGs span diverse themes. These range:

> from the European Pillar of Social Rights, the new European Consensus on Development to the values-based Trade for All Strategy, Strategic Engagement for Gender Equality and a European Education Area; from the Circular Economy package, 'Europe on the Move' packages and Energy Union to the Blue Growth Strategy and the Bioeconomy Strategy; and from the Investment Plan and Action Plan on Sustainable Finance to the Urban Agenda for the EU and Nature Action Plan, amongst others. (EC, 2019b)

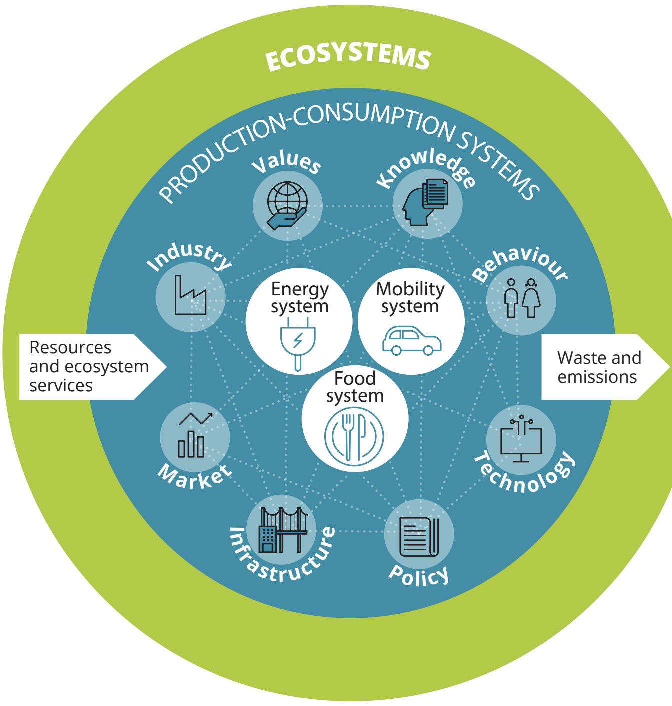
From a governance perspective, the need to ensure that this diverse mixture of policy areas works together to transform systems represents a significant challenge. As the reflection paper further emphasises (EC, 2019b), 'If we are to succeed, we must pull in the same direction at all levels. It is therefore of the utmost importance that all actors in the EU prioritise the sustainability transition. They must further develop the cross-cutting policy agendas that have been adopted at the EU level in recent years.' Directionality and coherence across policy areas and scales of governance are therefore prominent themes in this report (see Chapters 8-10).

1.2 Transforming the systems driving environmental degradation

While the need for societal transformation is increasingly recognised in sustainability science and policy, the question of which systems need to be addressed is less settled. As will be discussed in Chapter 2, different research communities address diverse mixtures of systems, emphasising society's interactions with ecosystems, technologies or economic processes, or sometimes examining the interplay of different systems in particular geographical settings (Røpke, 2016; EEA, 2018d).

Following the reasoning in SOER 2015, this report focuses primarily on the 'backbone systems of modern societies' that perform essential societal functions (Schot and Steinmueller, 2018). These transboundary systems provide for necessities such as food, energy, shelter and mobility, while also accounting for much of humanity's burden on the environment, in terms of both extracting resources and producing waste and emissions (Figure 1.3). Like SOER 2015, however,

Figure 1.3 Core production-consumption systems meet diverse human needs but also drive environmental pressures



Source: Based on EEA, 2014.

this report also acknowledges the need for a 'redesign of the systems that have steered these provisioning systems and have created unsustainable lock-ins: finance, fiscal, health, legal and education' (EEA, 2015b).

The examples presented across the report focus in particular on three key systems: those meeting European demand for energy, food and mobility. These are selected for attention because of their key role in supporting European societies, their substantial environmental impacts and their prominence in EU policy frameworks. The three systems also differ in character, illustrating contrasting challenges and varying degrees of progress in achieving transitions (see Section 2.1.4). Collectively, they offer valuable insights for understanding other important production-consumption systems, such as those relating to housing, clothing and consumer goods.

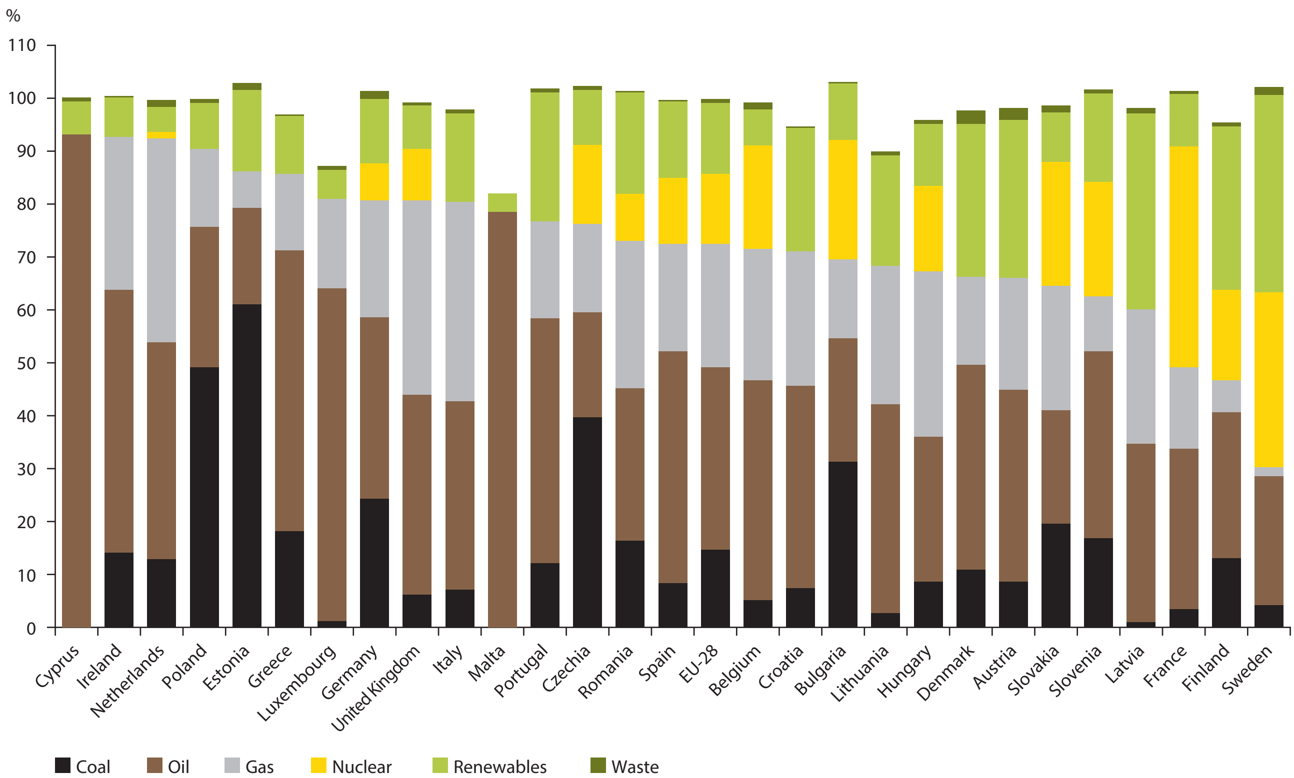
1.2.1 Energy system

Europe's energy system consists of a complex web of links between numerous sources, conversion technologies and end uses. The EU currently imports 55 % of all the energy that it consumes, with external trade providing for 87 % of oil products consumed in the EU, 70 % of natural gas and 40 % of coal (Eurostat, 2018b). This dependence on other countries and regions creates economic and political vulnerabilities, costing the EU a total of EUR 266 billion annually (EC, 2019a). Transitioning away from fossil fuels would thus be highly beneficial for the European balance of payments and for energy security.

Within the 28 EU Member States (EU-28), there is substantial variation in the mixture of fuels and technologies employed to generate energy (Figure 1.4). Although fossil fuels dominate in almost all countries, their contribution to national energy consumption varies between 93 % in Cyprus and 30 % in Sweden (Eurostat, 2019e). This continued reliance on fossil fuels imposes major burdens on the environment and human health. Impacts occur throughout the life cycle of a fossil fuel, beginning with the extraction of fuels (e.g. damage to landscapes) and also during transportation (e.g. oil spillage). However, the most significant and widespread effects result from the emissions released when they are burned. Fossil fuels are responsible for most GHG emissions and also account for a substantial proportion of EU emissions of a range of pollutants, including sulphur oxides (SO_X), nitrogen oxides (NO_X), non-methane volatile organic compounds and particulate matter (Figure 1.5).

The environmental impacts of such emissions are highly diverse. Some pollutants have direct effects on plants and animals (including humans), such as the lung damage caused by the release of particulate matter. Of even greater concern, however, are the second-order impacts that occur via the myriad linkages and interactions in ecological systems. For example, several different pollutants combine to form ozone, which causes harm to vegetation and human health. Other pollutants (e.g. SO_X, NO_X) cause air pollution, acidification and eutrophication in soil and water. The gravest impacts arise from GHGs such as CO_2, because climate change alters fundamental environmental conditions, with far-reaching implications for habitats and the diversity and distribution of species. It also causes more direct threats to human well-being and prosperity, for example as a result of extreme weather events, rising sea levels and changes in the spread of disease.

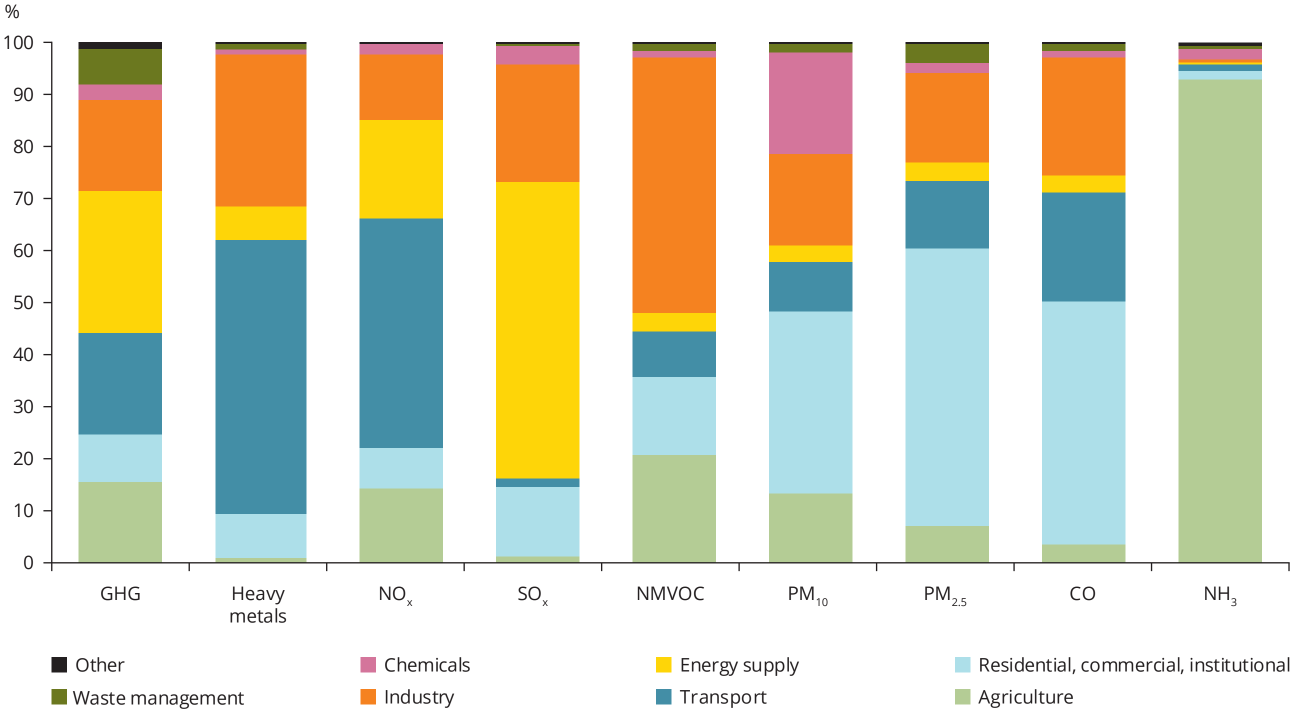
Figure 1.4 National energy consumption by fuel, 2016



Note: Countries are ordered from left to right according to the contribution that fossil fuels (oil, gas and coal) make to total energy consumption. Where national totals exceed 100 (e.g. Estonia), it is because those countries are net exporters of electricity. Conversely, where the totals are less than 100 (e.g. Luxembourg), it is because a portion of national consumption is met through imports of electricity. The 'waste' category comprises industrial wastes and non-renewable wastes (energy from other waste categories falls under 'renewables').

Source: Eurostat, 2019e.

Figure 1.5 Percentage of EU-28 pollutant and greenhouse gas emission by main sectors, 2017



Note: The sectoral definitions used for monitoring air pollutant emissions under the UN Convention on Long-range Transboundary Air Pollution differ in some respects from those used to monitor GHG emissions under the United Nations Framework Convention on Climate Change. NMVOC, non-methane volatile organic compounds; PM_{10}, particulate matter ≤ 10 µm diameter; $PM_{2.5}$, particulate matter ≤ 2.5 µm.

Sources: EEA, 2019a, 2019b.

The energy system has important links with the water and food systems. For example, Europe's largely carbon-based energy system accounts for 28 % of water abstraction in Europe (EEA, 2018h). Although much of the water used in energy generation is returned to local water systems, it can impact ecosystems because of the higher temperature or the rate at which it is released.

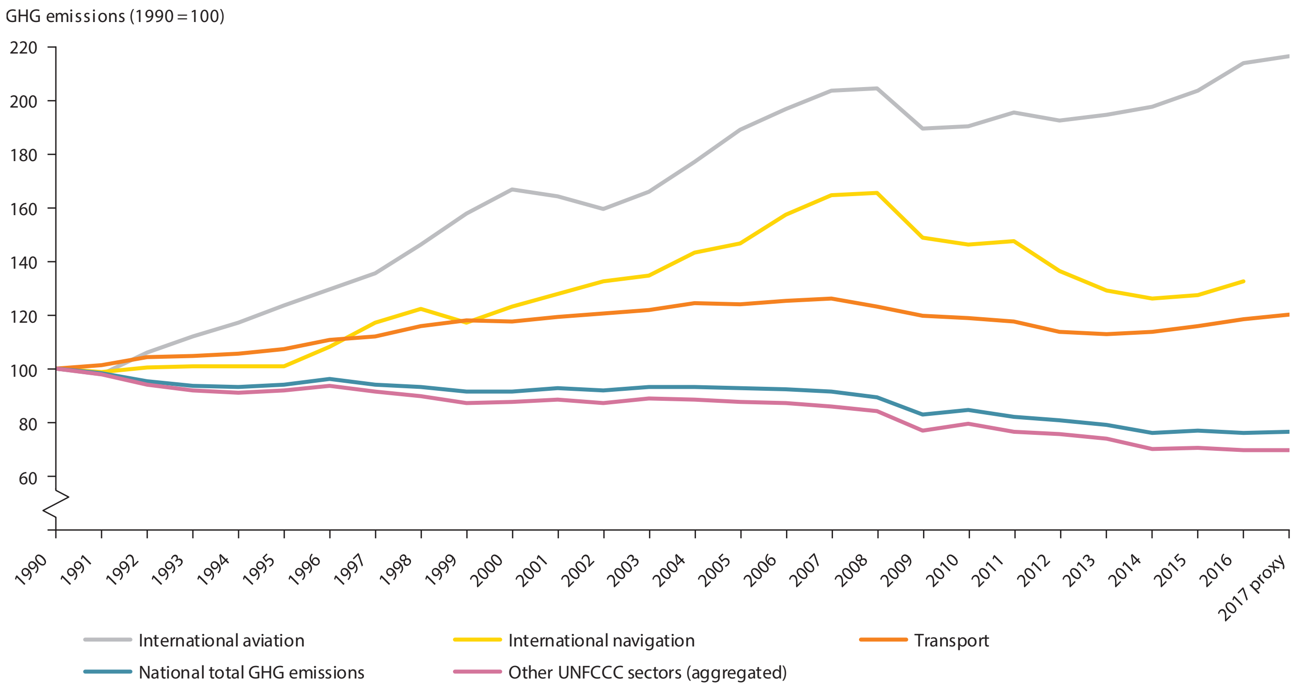
1.2.2 Mobility system

Transport is a key source of environmental pressures in the EU and contributes to climate change, air pollution and noise. It also contributes to urban sprawl, fragmentation of habitats and sealing of surfaces.

Today's European transport system accounts for one third of all final energy use in the EU, primarily from oil. While most other economic sectors, such as power production and industry, have reduced their GHG emissions since 1990, those from transport have risen (Figure 1.6), now accounting for more than one quarter of EU emissions. A reversal of this trend is currently not in sight. That makes the transport sector a major obstacle to realising the EU's climate protection goals. Cars, vans, trucks and buses produce more than 70 % of the overall GHG emissions from transport. The remainder comes mainly from shipping and aviation. GHG emissions from international aviation have more than doubled since 1990 and were almost 30 % higher in 2017 than in 2000. Emissions from the sector have increased over each of the last 5 years (2013-2017), at an average rate of over 2 % each year.

Transport is a significant source of air pollution, especially in cities. Air pollutants such as particulate matter, NO_X and SO_2 harm human health and the environment. Although air pollution from transport has decreased in the last decade because of the introduction of fuel quality standards, the Euro vehicle emission standards (Euro 1 to Euro 6) and the use of cleaner technologies, air pollutant concentrations are still too high. Road transport, in particular, continues to make a significant contribution to emissions of

Figure 1.6 EU greenhouse gas emission trends for transport



Note: UNFCCC, United Nations Framework Convention on Climate Change.

Source: EEA, 2018b.

NO_X (39 % in 2016), while non-road transport accounted for an additional 9 %. The contribution of road transport to harmful NO_2 concentrations, especially in urban areas, is considerably higher, because emissions occur close to the ground and mainly in densely populated areas.

Transport is also the dominant source of noise in the EU, with road traffic exposing more than 100 million Europeans to harmful noise levels (EEA, 2018f). Roads and tracks are also a main cause of landscape fragmentation, impacting ecosystem services and the stability and resilience of ecosystems. EU transport policies and funding programmes such as Cohesion Policy, the Connecting Europe Facility for Transport and its predecessor the Trans European Transport Network, are important drivers of landscape fragmentation. The construction of TEN-T infrastructure has been found to negatively impact land, as it enhances land take, soil sealing and land fragmentation (EEA, 2016d).

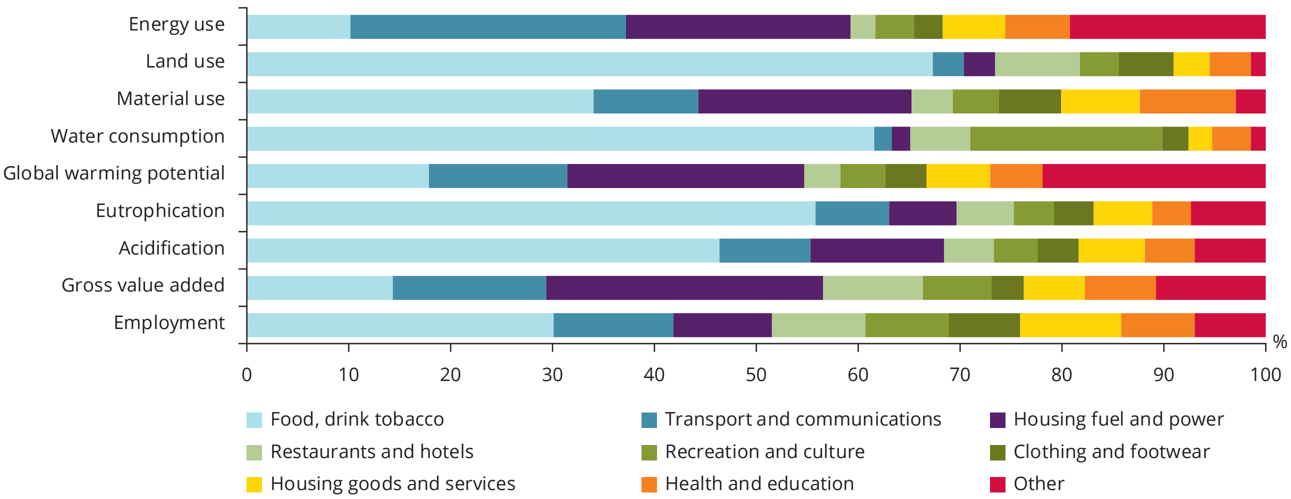
1.2.3 Food system

Food is one of the household consumption categories with the highest embedded environmental pressures, accounting for more than half of land and water use associated with final consumption, one third of acidifying emissions, and one sixth of GHG and ground ozone precursor emissions (Figure 1.7). These pressures originate throughout the life cycle of food, from agricultural production (via conversion of land, GHG emissions, eutrophication, etc.), through processing, packaging, distribution and storage (via use of water, energy and materials), to waste production and management (via GHG emissions and eutrophication). The embedded pressures vary greatly across food categories (Figure 1.8). Animal-based products, i.e. meat, dairy and eggs, contribute more than 50 % of most of the environmental impacts, despite being consumed in lower quantities than vegetable-based products.

Nutrients leak into the environment across all food system activities, including crop and livestock production, food processing and waste management. The growth in nitrogen (N) and phosphorus (P) flows impact environmental and human health, notably by leading to eutrophication and acidification of ecosystems. Over the last century, humans have altered the global nitrogen cycle substantially, and current levels already exceed planetary boundaries (Steffen et al., 2015).

Widespread use of pesticides in agriculture is another major concern. Pesticides are not only toxic for their

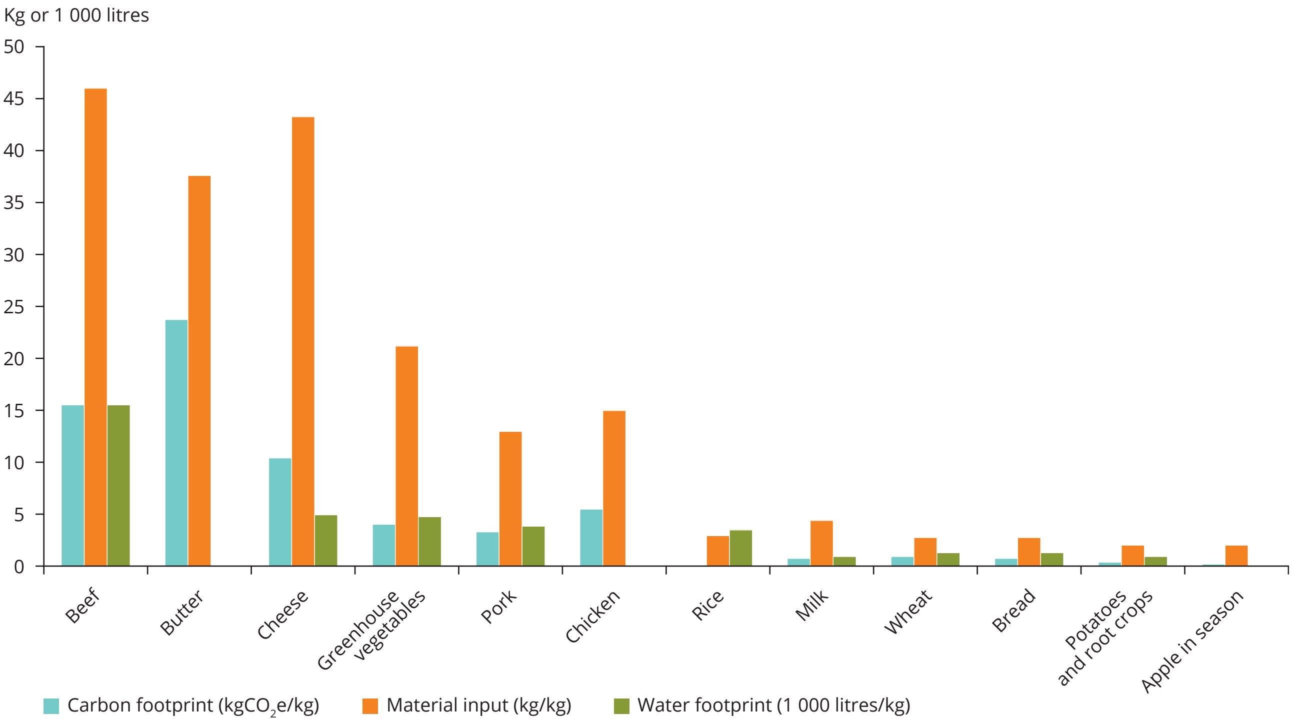
Figure 1.7 Percentages of the global environmental footprints caused by different household consumption categories in EEA countries, 2011



Note: The figure presents the contributions of different consumption expenditure categories to the EU's global footprint for energy use, land use, material use, etc. Some of the consumption expenditure clusters used here combine categories used in the UN's classification of individual consumption by purpose (COICOP), for example 'food, drink and tobacco' (COICOP 1 and 2), 'transport and communications' (COICOP 7 and 8), 'health and education' (COICOP 6 and 10).

Source: Tukker et al., 2013; Wood et al., 2014; Stadler et al., 2018.

Figure 1.8 Carbon, material and water footprint for selected food products



Note: Footprint calculations are based on aggregated product categories. In reality, footprints will depend significantly on production methods. For example, the environmental footprint of organically produced beef may differ in some respects from that of intensively farmed beef.

Source: EEA, 2013a (and references therein).

respective target species, but can also affect the wider environment, including aquatic organisms (EEA, 2018e). Chemicals with endocrine-disrupting properties, including several pesticides, have been shown to trigger feminising effects in fish in some polluted water systems (EEA, 2013b).

Although agricultural production is currently sufficient to meet global food demand, wealth inequalities, and patterns of distribution and trade, nevertheless lead to uneven access to food of sufficient quality, with recurring food crises in vulnerable regions. The situation may worsen in coming years, as the global human demand for agricultural produce is projected to grow by 50 % up to 2050 in a business-as-usual scenario (FAO, 2018b). In the context of expected climate change impacts on agriculture, this could put unprecedented stresses on ecosystems and their ability to continue delivering multiple services.

In addition to its impacts on water quality, agriculture also significantly affects water flows within ecosystems, primarily as a result of cultivation patterns that depend on drainage and irrigation. Agriculture is the largest water-abstracting sector in Europe (after energy), accounting for 46 % of total water use based on the annual average, and this can reach up to 80 % in some regions (EEA, 2018h). The irrigation need is highest in southern Europe, where it aggravates water stress on natural habitats. Again, climate change is expected to add to this problem (EEA, 2018h).

1.3 Report structure

Part 1 of the report sets out current transitions research and its broad implications for governance. Following this introductory chapter, Chapter 2 sets out a conceptual framework for understanding the dynamics of sustainability transitions, building on research in the last two decades. This framework accommodates both the stability of existing systems and the development of radical innovations that form the seeds of sustainability transitions. It also describes developments over time, distinguishing three ideal-type phases: emergence, diffusion and disruption. The core concepts are illustrated with brief descriptions from the energy, mobility and food systems, focusing on aggregate trends, lock-in mechanisms that stabilise existing systems and promising innovations. Chapter 2 also discusses the governance challenges inherent in sustainability transitions and indicates where these challenges are addressed in subsequent chapters.

Parts 2 and 3 of the report extend beyond this general discussion of governance challenges to identify more concrete messages for policy. Chapters 3 to 12 each has a hierarchical structure, which starts with a core policy message and several sub-messages. Each of these sub-messages is then elaborated in more detail in the subsequent chapter sections, drawing on scientific insights, policy implications and empirical illustrations from across energy, mobility and food systems.

Part 2 uses the conceptual framework elaborated in Chapter 2 to provide further insights into the change mechanisms and actors involved in transitions and implications for policy, using empirical examples to make the discussion more concrete. Chapters 3, 4 and 5 focus on the emergence, diffusion and disruption phases, and the roles of different actors and change mechanisms. Chapters 6 and 7 focus on the role of two key enablers for transitions — cities and finance — exploring their role in emergence, diffusion and disruption.

Part 3 discusses cross-cutting policy challenges for governing sustainability transitions. Chapter 8 addresses the role of visions, missions and targets in providing long-term directionality. Chapter 9 discusses the importance of horizontal policy coordination between different policy areas, which include not just environmental and innovation policies, but also a variety of other domains such as sectorial policies (energy, food, mobility), fiscal and finance policies, and regional, industrial and educational/skills policies. Chapter 10 then addresses vertical policy **coordination** across scales of governance, for example between local/urban, national and European levels. Chapter 11 highlights the importance of anticipatory governance (e.g. foresight, risk assessment) and adaptive governance (experimenting and adjustments) in dealing with risks and unintended consequences, which are highly likely because transitions are complex, non-linear processes. Finally, Chapter 12 discusses the new kinds of knowledge and competencies that policymakers need to manage sustainability transitions. These deviate in some respects from the established technically rational decision-making procedures, because transitions are open-ended, uncertain and contested processes.

2 Transitions research and its implications for governance

2.1 Understanding the dynamics of systemic change

2.1.1 Systemic framings of sustainability challenges

The emergence of transitions and transformations as prominent themes in sustainability science and policy is a comparatively recent development, stretching back only a decade or two. Yet this trend builds on a more mature body of research and knowledge, grounded in diverse scientific disciplines. To help make sense of these different approaches and how they relate to each other, the EEA (2018d) produced a report, *Perspectives on transitions to sustainability*, which contrasted mainstream understandings of sustainability transitions with the following four systemic framings ([2]):

- **Socio-technical transitions** research, which is grounded in the work of neo-Schumpeterian economists, such as Nelson and Winter (1982), who emphasise the role of innovation in economic change. It also employs insights from innovation studies, social movement theory, geography and institutional theory, as well as a rich body of historical case studies, to explain the dynamics of transitions in key production-consumption systems (Geels, 2018a).

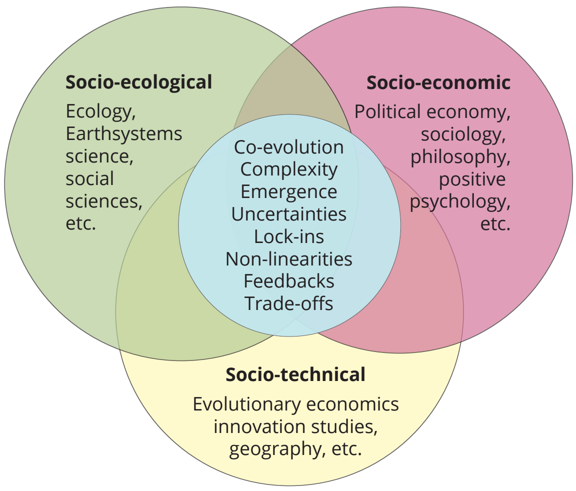
- **Socio-ecological transformations** research, which builds on several decades of work in the natural sciences (particularly ecology and earth systems science), addresses resilience and regime shift in complex environmental systems. It combines this knowledge with increasing contributions from the social sciences, which aim to explain deliberate transformations to sustainability through social change (O'Brien and Sygna, 2018).

- **Socio-economic transformations** research includes diverse disciplines, such as political economy, sociology, philosophy and positive psychology. Drawing on thinkers such as Polanyi (1944), it emphasises the way that the marketisation of society since the Industrial Revolution has shaped human identity, values and behaviours, contributing to destructive patterns of consumerism and materialism (Kemp et al., 2018).

- **Action-oriented perspectives,** which provide additional insights into the role of individuals, communities, cities, labour unions and other groups in achieving systemic change that complement the other systemic approaches, and increasingly contribute to socio-technical research. Key areas of research include Ostrom's work on governance of the commons and polycentricity (Ostrom, 1990, 2010), and social practice theory (Steward, 2018).

The report concluded that, despite employing sharply contrasting analytical approaches and addressing very different systems and scales, these four perspectives have a broadly shared understanding of the nature of sustainability challenges and the characteristics of systemic change. This shared logic embraces notions such as co-evolution, lock-in (of existing systems), complexity, uncertainties, trade-offs and non-linearities (Figure 2.1).

Figure 2.1 Three perspectives on systemic change



Source: Adapted from Loorbach, 2015.

([2]) The selection of analytical approaches included in the EEA report, *Perspectives on transitions to sustainability* illustrates the diversity of framings, rather than providing a comprehensive overview. Other relevant research into stability and change in complex societal systems spans a broad range of disciplines, ranging from the literature on technological revolutions and Kondratiev waves (e.g. Freeman and Louçã, 2001; Perez, 2003) to analysis of scientific and societal paradigms (Kuhn, 1962; Foucault, 1970).

This report primarily employs the socio-technical transitions framing to explore the dynamics of systemic change. The reasons for this selection are twofold. First, socio-technical research focuses on precisely the kinds of transboundary production-consumption systems, such as food, energy and mobility, that have been identified in research (and highlighted in Chapter 1) as key drivers of unsustainability. Second, it offers a clear framework for understanding the dynamics of change arising from the interactions of societal systems with drivers of change at the macro and micro levels. In doing so, it provides a foundation for mapping out the implications for policy and governance in this report.

As noted in EEA (2018d), however, there is increasing common ground between the different analytical approaches to understanding transitions. Moreover, the tools employed by socio-technical research — in particular the multilevel perspective on transitions — provide a simple framework for combining insights from different perspectives. Given this, the discussion draws on the different framings of systemic change, for example in highlighting themes such as interactions between systems, social practices, market-based instruments, and cultures and worldviews.

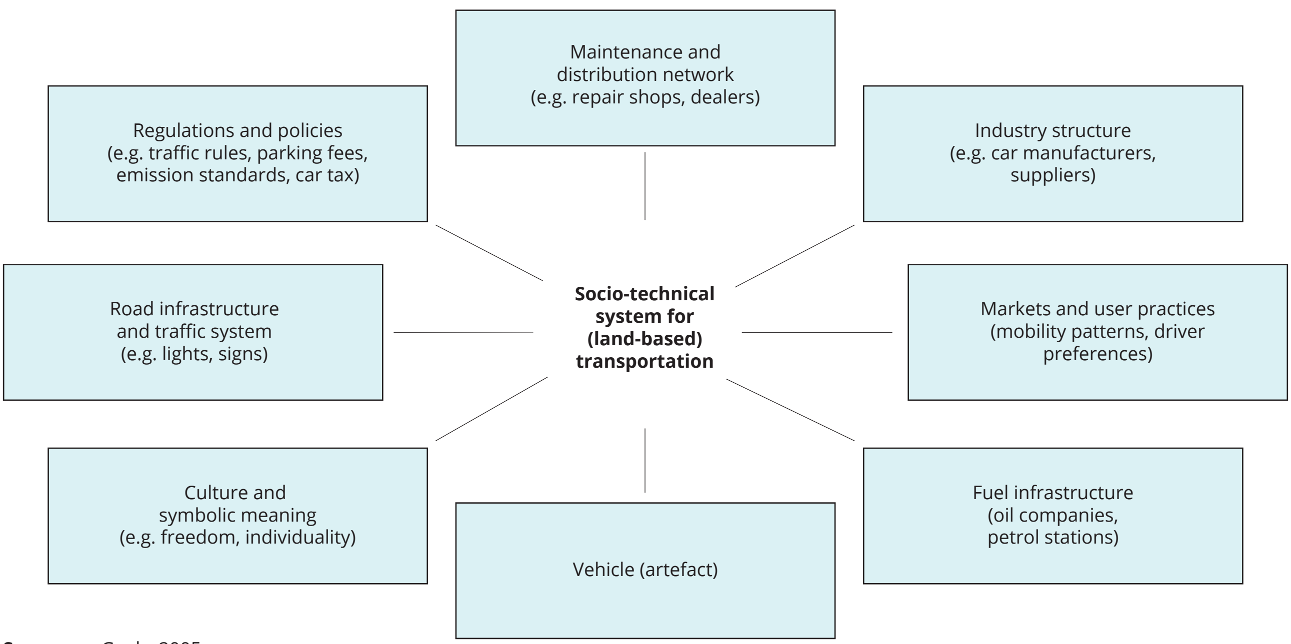
2.1.2 Socio-technical systems and barriers to change

Socio-technical transitions are about changes in the way societal functions, such as mobility, heating or sustenance, are performed. Societal functions of this sort are fulfilled through socio-technical systems, which comprise complex bundles of interacting material, social and institutional elements. This conceptualisation means that socio-technical systems extend beyond individual industries or sectors to embrace whole value chains, including production and consumption, resource extraction and waste management. They include not just techno-economic dimensions but also infrastructure, culture, knowledge and politics, as well as diverse actors and interests (Figure 2.2).

The diverse elements in socio-technical systems co-evolve over time, forming relatively stable configurations of technologies, regulations, user patterns, infrastructures, and cultural discourses and norms (Geels, 2004). For example, the emergence of the car as the dominant form of land-based transport during the 20th century was accompanied by major private investments in skills, knowledge and infrastructure for car production; public investments in road infrastructure; the emergence of complementary industries to manufacture and deliver fuel, tyres and other accessories; adaptation of urban design to the car; and changes in behaviour, expectations and cultural values linked to car ownership (Unruh, 2000).

The system elements are reproduced, maintained and incrementally improved by incumbent actors, such as firms, engineers, users, policymakers, special interest groups and civil society actors. The perceptions and actions of these social groups are shaped by socio-technical regimes, which include shared rules, practices

Figure 2.2 Example of socio-technical system for (land-based) transport



Source: Geels, 2005.

and institutions (e.g. technical knowledge paradigms, habits of use, prevailing normality, cultural discourses, established practices of professionals and regulatory regimes).

The essential idea is that the many interlinkages within and between complex systems mean that there are often strong economic, social and psychological incentives that lock society into particular ways of meeting its needs. Radically altering these systems is likely to disrupt established investments, jobs, consumption patterns and behaviours, knowledge and values, inevitably provoking resistance from affected industries, regions or consumers. Such resistance constrains governments in their ability to impose regulations and pricing instruments that are consistent with long-term environmental goals.

The interdependence of the different system elements therefore stabilises existing socio-technical systems, creating lock-ins and path dependence (Arthur, 1994; Sydow et al., 2009). Although change still occurs in path-dependent systems, it proceeds incrementally and relatively predictably in certain directions, giving rise to stable trajectories (Dosi, 1982).

Box 2.1 outlines some of the diverse lock-ins and systemic interactions that make it difficult to achieve rapid and transformative change in socio-technical systems.

Box 2.1 Lock-ins and barriers to change in socio-technical systems

Economic and social barriers

- **Increasing returns:** Production costs for new technologies often drop significantly as output grows due to economies of scale and learning-by-doing, as well as network effects (Arthur, 1994). As a result, established technologies can become the 'dominant design', enjoying significant price/performance advantages over newly emerging 'green' innovations (see also Section 4.2).

- **Sunk costs:** Public and private investments in long-lasting assets such as transport infrastructure or power plants are often very substantial. Businesses and employees likewise make major investments in manufacturing plants, knowledge and skills, which are geared towards particular modes of production.

- **Jobs and earnings:** Disruptive innovations threaten established businesses and can lead to structural economic change, leading to job losses and even impacting whole regional economies (e.g. in coal-mining areas). These effects are likely to create major resistance from workers, industry groups and unions.

- **Industry networks:** As a technology (e.g. the internal combustion engine) becomes established, supply chains and industry networks emerge to supply inputs, complementary technologies or infrastructure. This greatly increases the jobs, earnings and investments tied to and reliant on the dominant design.

- **Division of labour and specialisation:** These produce investments in specific skills and knowledge aimed at optimising aspects of the dominant design (rather than questioning the design as a whole). Cognitive routines and shared mindsets can blind actors to developments outside their focus (Nelson and Winter, 1982).

- **User practices and lifestyles:** These stabilise particular technologies. For example, the car has become embedded in mobility practices such as commuting to work, taking children to school, shopping and social visits. It is also embedded in cultural discourses and identity (e.g. prestige). Cognitive biases such as loss aversion, status quo bias and endowment effects can further deter lifestyle change.

Political barriers

- **Sectoral policies** (e.g. promoting standardisation or protecting human health): These tend to create lock-ins because producers and consumers will make choices and investments based on them. Partly for this reason, existing policies may favour incumbents, creating an uneven playing field.

- **Vested interests:** Changing policies is difficult because of active opposition to change from groups with vested interests (Geels, 2014), which use corporate political strategies to shape policies in their favour (Hillman and Hitt, 1999; Levy and Egan, 2003).

- **Distributional effects:** Policy changes impact different groups unevenly, creating political obstacles. For example, taxing necessities such as food, energy and mobility is likely to have regressive impacts and varying effects on urban and rural populations, young people and the elderly.

Box 2.1 Lock-ins and barriers to change in socio-technical systems (cont.)

- **Globalisation and jurisdiction:** The globalisation of value chains and financial flows places significant constraints on the efficacy of territorially based policy instruments in national jurisdictions, particularly as domestic measures may lead to offshoring of production (and burden shifting).
- **Short-termism:** Electoral incentives can discourage politicians from introducing measures that are likely to be unpopular in the short term but deliver long-term benefits for society.

Systemic interlinkages

- **Rebound effects:** Increasing returns to adoption and technological innovation can lower the costs of goods and services, incentivising increased consumption. As a result, the environmental improvements from green technological innovation may be (partly) counteracted by increased consumption (e.g. resource use and emissions).
- **Burden shifting:** In increasingly globalised systems, efforts to prevent an environmental or socio-economic problem in one location may result in substitution effects or relocation of production overseas.
- **Market failures:** The globalisation of production-consumption systems into often highly disintegrated value chains means that consumers and producers (at different stages) are unaware of the socio-economic and environmental impacts of their choices and have limited influence over them. Externalities substantially weaken incentives for systemic change.

2.1.3 The multilevel perspective on sustainability transitions

With diverse lock-in mechanisms at work within the socio-technical regime, there are major barriers to the emergence of new technologies, services and practices with the potential to reorganise how societal functions are performed. Based on historical evidence of past transitions, the multilevel perspective suggests that transitions involve interacting processes between three analytical levels (Geels, 2002, 2018a).

The first is the emergence of innovations within niches. These are protected spaces outside or on the fringe of the established regime, where new entrants or relative outsiders (such as inventors and entrepreneurs, start-up companies and small social networks) can experiment without direct exposure to mainstream market pressure and institutional forces. Such spaces include research and development (R&D) labs, subsidised demonstration projects, and small market niches where users have special demands and are willing to support emerging innovations (e.g. the military). Sometimes, such niche spaces are created by public policy interventions-markets created for environmental technologies and services by regulatory or public procurement demand, or experimental spaces enabled by R&D funding.

The second process is change at the landscape level, which can disrupt the established socio-technical system and regime. Such exogenous changes can include gradual, long-term trends such as demographics or political ideologies, or more sudden shocks such as military conflicts, recessions, accidents such as the Fukushima nuclear disaster or terrorist attacks (Van Driel and Schot, 2005). These processes can be combined in a single 'landscape' category, because they form an exogenous context that actors cannot influence in the short term. This does not mean that landscape developments occur without human agency. Urbanisation, globalisation, environmental problems, and macro-economic, macro-political and macro-cultural changes come about through the aggregation of a multitude of actions. The point, however, is that such landscape developments cannot be influenced at will by niche and regime actors in specific socio-technical systems.

Third, at the regime level, the existing system faces increasing problems (e.g. internal technical problems, increasing negative externalities, diminishing economic returns), which may make incumbent actors begin to doubt its future viability. This may weaken their resistance to change and lead to diversification efforts: incumbent firms start exploring alternative technologies; mainstream consumers may begin to change their preferences and purchase behaviour; policymakers support alternatives. Such regime destabilisation creates windows of opportunity for transitional change (Turnheim and Geels, 2012).

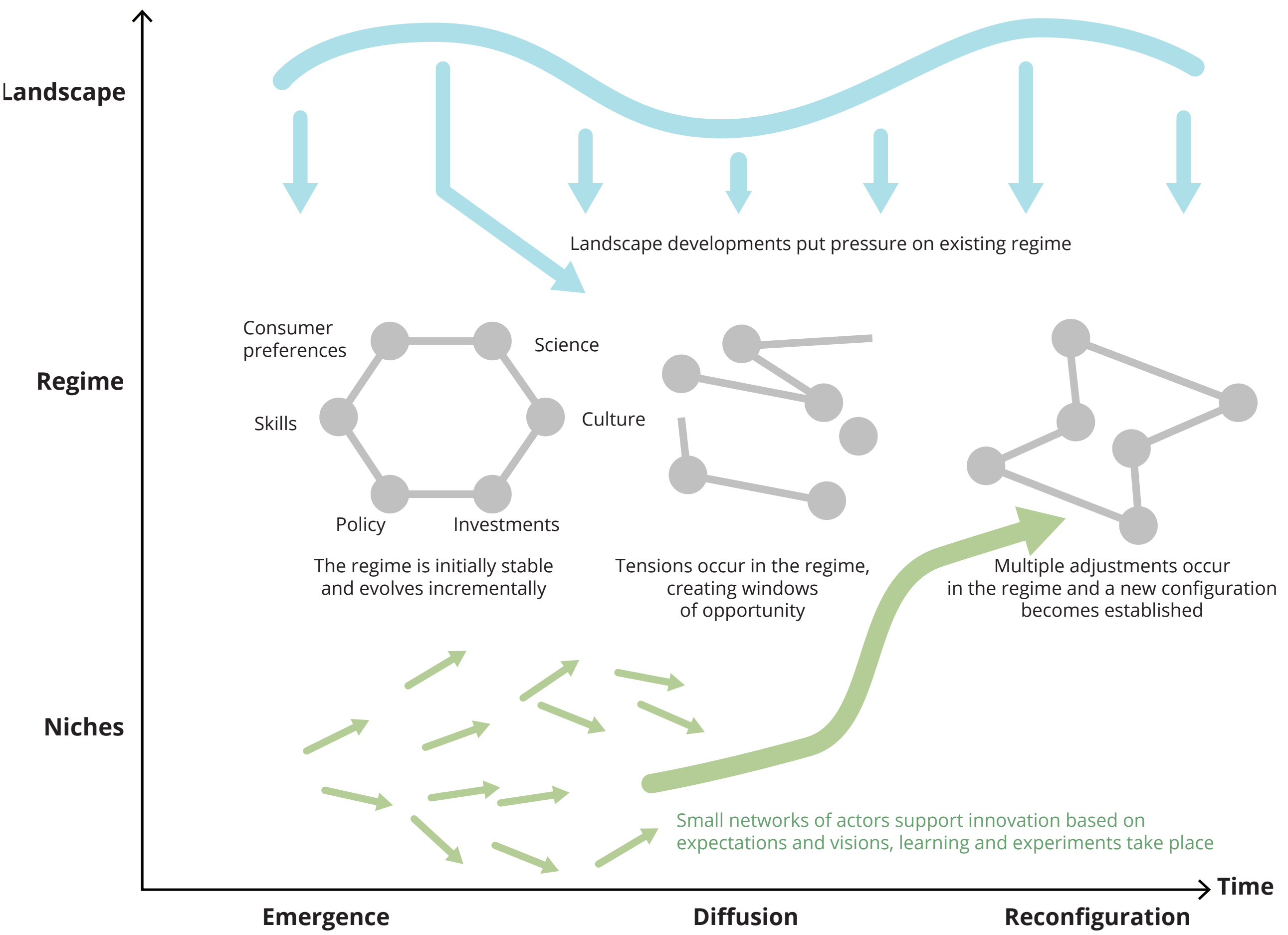
As presented in Figure 2.3, transitions are non-linear processes that arise through the interplay of developments at these three levels: increasing momentum of niche innovations creates bottom-up pressure on the regimes; landscape developments create exogenous pressure on the regime; incumbent actors initially defend the regime with incremental changes; but, if pressures continue, the regime will destabilise, which enables niche innovations to diffuse more widely (Rip and Kemp, 1998; Geels, 2002, 2005). This multilevel logic arises from more specific actions and interactions among multiple actors, including businesses, users, scientific communities, policymakers, social movements and interest groups. In the multilevel perspective, transitions are quasi-evolutionary processes, meaning that they are typically based on searching, experimenting, reflecting and learning. Transitions also depend critically on interpretations and social acceptance. Transitions are therefore fundamentally uncertain and open-ended; surprises and unintended outcomes are to be expected. Transitions are also conflictual and deeply political, producing trade-offs, winners and losers, and related struggles, as different social groups — including politically influential and well-resourced incumbents — often resist change.

Figure 2.3 also distinguishes three phases within complex transition processes, characterised by different processes, actors and barriers: emergence, diffusion and reconfiguration. These three phases provide the logical framework for exploring governance approaches in later chapters of this report, particularly in Part 2.

Emergence

The first phase involves the emergence of radical innovations in niches. Mokyr (1990) characterised radical innovations as 'hopeful monstrosities': monstrosities because early inventions have poor performance and high costs; yet hopeful because they offer a valued functionality, which may encourage certain actors to invest in further development. Markets are normally absent for radical innovations. Indeed, there may be considerable uncertainty about who the consumers are, their preferences and the crucial functionality of the new technology (Rosenberg, 1972). In this initial phase, niche innovations do not (yet) form a threat to the existing regime, which evolves incrementally along relatively predictable trajectories.

Figure 2.3 The multilevel perspective on sustainability transitions



Source: Based on Geels, 2006.

Various design options coexist, linked to different social networks with diverging views and visions. There is much uncertainty about user preferences, policy, infrastructure requirements and cultural meaning. The first phase is therefore characterised by experimentation, demonstration projects and trial-and-error learning, often over a long period of time (Wilson and Grübler, 2011; NESTA, 2013). Many pioneers and new entrants ultimately fail because of a lack of financial and organisational means (Olleros, 1986). This fluidity and uncertainty is represented by diverging arrows in the bottom left-hand corner of Figure 2.3.

Diffusion

In the second phase of transitions, innovations break out of protected niches and begin to diffuse more widely. Broad diffusion depends on concurrent activities at multiple levels. At the niche level, diffusion is driven by factors such as learning processes (which improve performance and stabilise the innovation into a dominant design, represented in Figure 2.3 by the convergence into a single green arrow), increasing investment (in development, deployment and manufacturing), scale economies (which reduce costs), political support, cultural acceptance and growing integration into people's lifestyles. As elaborated in Chapter 3, a variety of upscaling processes exist, with varying relevance to different forms of innovation (social, technological, business model, etc.).

As long as the regime remains stable, niche innovations often have little chance to diffuse more widely. Wider diffusion therefore depends on concurrent developments at the landscape level, leading to tensions that open up the regime and create 'windows of opportunity' for niche innovations. Such tensions include performance problems that cannot be met with the available technologies, practices or business models; changes in markets and user preferences; changing cultural discourses that delegitimise existing technologies or practices; and changes in policy agendas that lead to stricter regulations.

The breakthrough of niche innovations into broad diffusion is often characterised by head-on struggles between niche innovations and existing regimes on multiple socio-technical dimensions (Ingram et al., 2015; Bui et al., 2016; Mylan et al., 2018). For example:

- **Economically**, there is market competition between new and existing technologies or business models, linked to price/performance characteristics, economic frame conditions and the institutions that shape and constitute markets.
- **Commercially**, there are struggles between new entrants and incumbents, which may lead incumbents to collapse (Christensen, 1997), successfully defend themselves (e.g. by buying out the new firms) or reorient towards new technologies (Penna and Geels, 2015).
- **Politically**, governments, political actors and lobby groups engage in struggles over the setting of policy instruments that favour incumbents or new entrants (Levy and Egan, 2003; Hess, 2016; Meadowcroft, 2009; Geels, 2014).
- **Socially**, groups with professional, economic or cultural interests in the established modes of production and consumption (e.g. farmers, coal miners) lobby or campaign to resist change (Moe, 2016).
- **Culturally**, there are discursive struggles over the framing of challenges and innovations, which fundamentally influence social acceptance and uptake (Kern, 2012; Rosenbloom et al., 2016).

The outcome of these struggles shapes the speed of diffusion and how particular innovations are embedded in wider socio-technical systems.

Disruption and reconfiguration

Widespread diffusion of radical niche innovations tends to be accompanied by adjustments in user practices, infrastructures, regulations and cultural meanings, which together reconfigure entire systems. These changes become institutionalised and anchored in new rules, habits, mindsets, professional standards and technical capabilities.

Shifts to new socio-technical systems may also create unintended consequences that need to be monitored and addressed, e.g. rebound effects, unforeseen environmental effects, visual or noise effects for local residents, distributional effects and impacts on vulnerable social groups. Those affected may need to be helped or compensated to help ensure equitable and sustainable outcomes.

Transitions may also disrupt existing firms (Christensen, 1997). The potential downfall of incumbent firms may have negative economic and employment effects, particularly in regions dependent on particular industries (e.g. coal mining). This threat may lead to socio-political resistance and backlashes against transitions, which policymakers may want to address with mitigating measures. Such concerns are increasingly framed in terms of calls for a 'just transition', for example in the Paris Agreement on climate change (UNFCCC, 2015) and the European Commission's reflection paper on SDG (EC, 2019b).

2.1.4 Illustrations for the energy, mobility and food systems

Although rooted in research about the emergence and diffusion of technological innovations, the multilevel perspective can accommodate other kinds of niche innovation, including social, organisational and business model innovations. This also provides a useful framework for understanding the contributions of other perspectives on transitions (e.g. Smith, 2012; Göpel, 2016). These include insights into how social practices change; the role of communities and cities in enabling more polycentric forms of governance (see also Chapter 10, Section 10.3); the potential impacts of systemic change on society and the environment; and the importance of practices, values, worldviews and paradigms (EEA, 2018d).

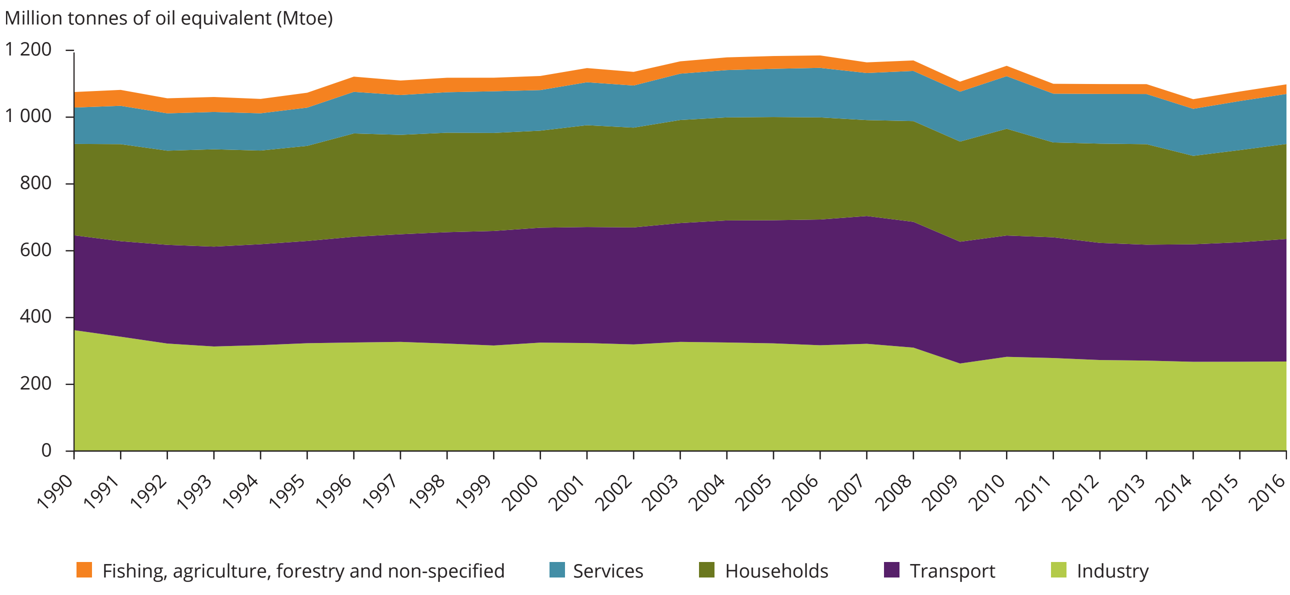
To illustrate the logic of the multilevel perspective, this section uses it to present the sustainability transition challenge in the three production-consumption systems identified in Chapter 1: energy, mobility and food. These three illustrative assessments provide an overview of system characteristics and dominant trends, discuss some of the lock-in mechanisms and barriers to change, and identify promising niche innovations that form the seeds for sustainability transitions.

The assessment shows that niche innovations (social, technological, organisational) have emerged in each system, challenging established configurations. Most of these niche innovations are still in the emergence phase but some have moved towards diffusion — e.g. wind energy, solar photovoltaics (solar-PV), electric vehicles — with variation between countries. Similarly, existing regimes in most domains are still relatively stable because of lock-in mechanisms and active resistance. However, the electricity regime is beginning to destabilise and incumbent actors are starting to reorient towards niche innovations. In general, sustainability transitions in these three systems are still in an early phase and future dynamics will depend on whether niche innovations increase their momentum and existing regimes lose their strength.

Energy system

The energy system includes the production, conversion, delivery and use of energy. Energy is vital for modern economies and societies to achieve end-use functions such as heating, cooking, mobility, industrial processes and electric appliances (washing machines, televisions, etc.). The three most important end-use domains are mobility, which accounted for 33 % of European final energy consumption in 2016; households, which accounted for 26 %; and industry, which accounted for 25 % (Figure 2.4). European energy consumption decreased after the financial crisis in 2008 but has started to increase again since 2014.

Figure 2.4 Final energy consumption by sector, EU-28, 1990-2016



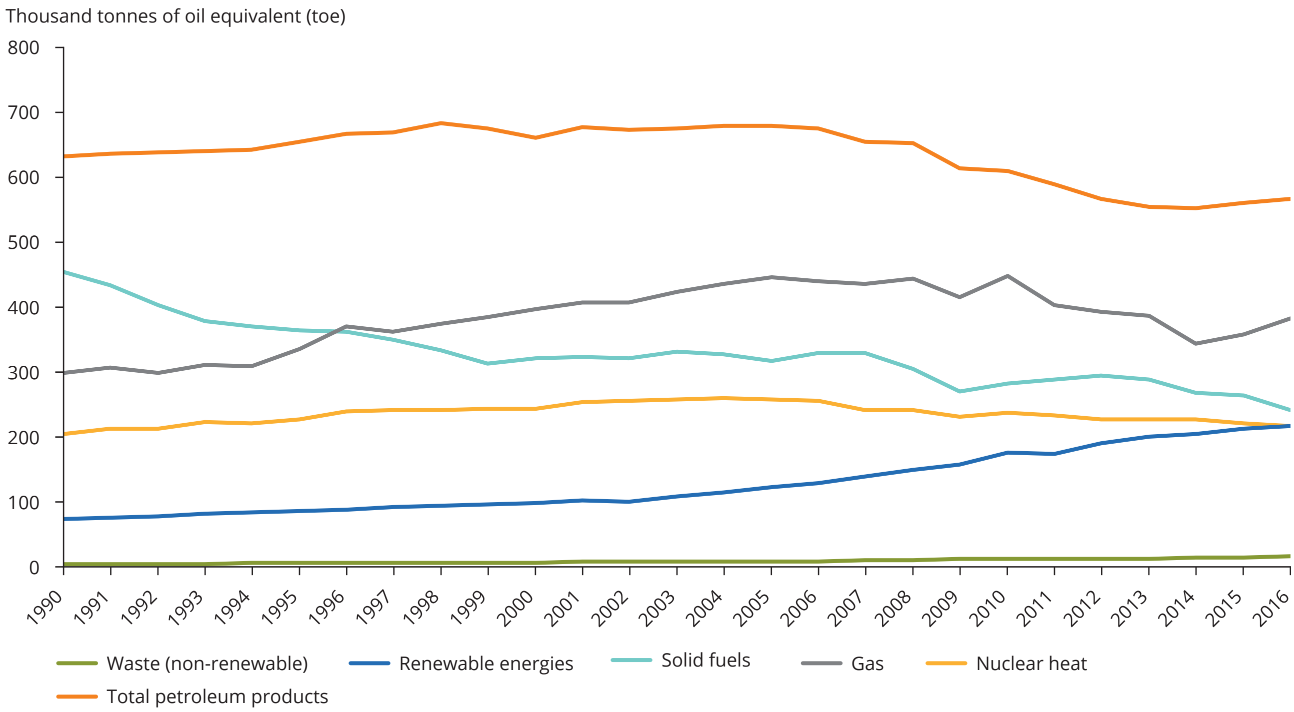
Source: Eurostat, 2019e.

In terms of fuel inputs, the European energy system is dominated by fossil fuels, with oil, natural gas and coal together providing 71 % of gross energy needs in 2016. Nuclear energy and renewables supplied the remainder in roughly equal shares, but the former is in long-term decline, whereas the latter has experienced steady growth since the early 2000s (Figure 2.5).

Lock-in mechanisms for the energy system are still strong in several dimensions but are beginning to weaken in other dimensions, creating windows of opportunity for transitional change, especially in the electricity system.

- **Sunk costs:** The investments in upstream extraction (oil and gas rigs, coal mines), conversion (power plants, oil and gas refineries) and infrastructure (oil and gas pipelines, electricity grids, gas grids) are huge, constituting deep sunk costs that incumbent industries are likely to protect. Lifetimes of these assets and infrastructures are in the order of decades, further locking in existing systems. Many European coal-fired power plants, however, are more than 40 years old and reaching the end of their planned lifespan (EEA, 2016e), which means that replacement decisions provide a window of opportunity for substantial change. In contrast, many gas-fired power plants in Europe are newer, perpetuating the lock-in to gas.
- **Jobs and earnings:** The energy sector in Europe employs close to 2.2 million people, spread over 90 000 enterprises across Europe and representing 2 % of total added value (EC, 2016d). Some regions are strongly dependent on particular forms of energy production. For instance, many of the 180 000 European jobs in coal mining and 60 000 jobs in coal-fired power plants are concentrated in eastern Europe, which creates resistance to transitions in those areas (see Section 5.3). In addition to facing political pressure from workers and businesses, governments are often more directly reliant on the coal industry as a source of tax revenues.
- **Vested interests:** Oil companies (e.g. Shell, BP, Total), utilities (e.g. E.ON, EDF, Iberdrola, Endesa) and other fossil fuel-related firms are very large and politically powerful organisations with often high degrees of access to policymakers that enables them to shape policies to suit their interests (Levy and Kolk, 2002; Mitchell, 2011). German utilities, for instance, have long resisted the energy transition by contesting feed-in tariffs in court and lobbying for weaker renewable energy policies (Geels et al., 2016), and have only recently begun to reorient themselves, as their traditional business models became unviable (Kungl and Geels, 2018).

Figure 2.5 Gross inland energy consumption by fuel, EU-28, 1990-2016



Source: Eurostat, 2019e.

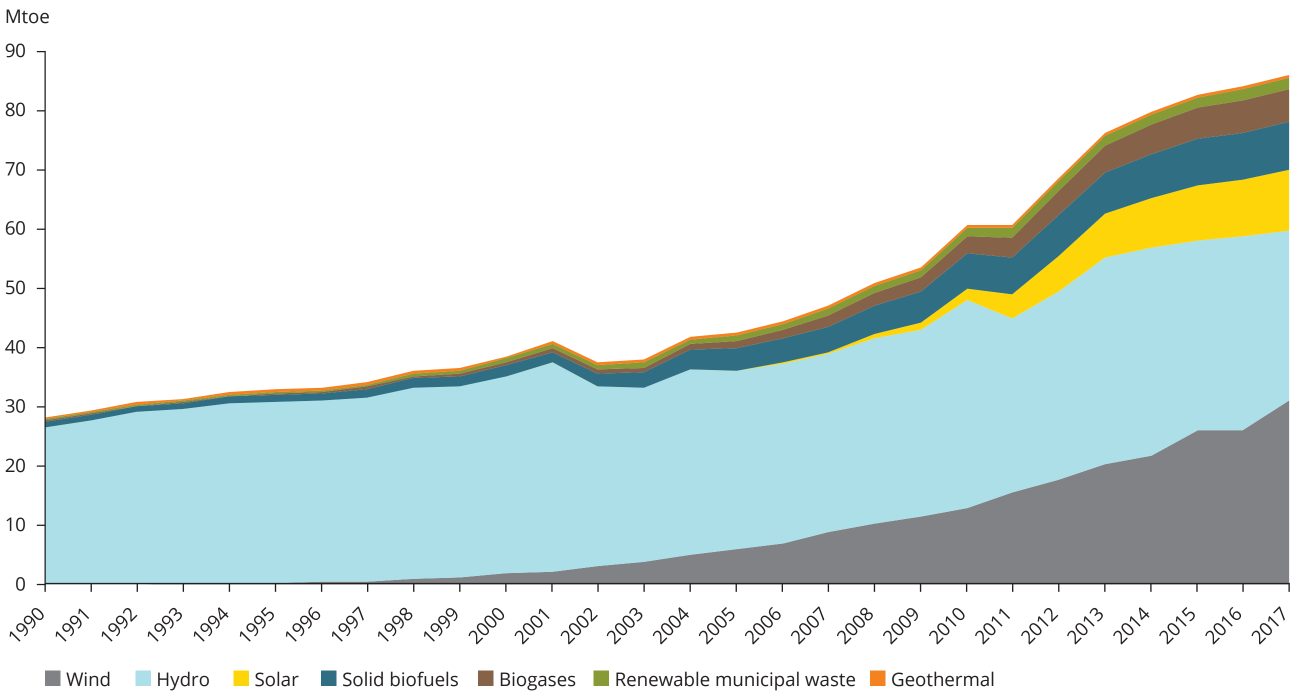
- **Sectoral policies:** While policymakers at national and European levels have long supported incumbent energy companies, they have also developed a suite of policies to address climate change, energy security, fuel poverty and the internal market, which in the last decade have become stronger and more comprehensive. The European 20-20-20 targets introduced in 2007, aimed for a 20 % reduction in GHG emissions, a 20 % share of renewables in energy consumption and a 20 % improvement in energy efficiency by 2020. The 2016 Clean Energy Package (EC, 2016d) strengthened these goals to 30 % energy efficiency improvements, 27 % renewable energy and a 40 % reduction in GHG emissions by 2030. Particularly in the electricity sector, these goals have been translated into more concrete national and European policies that have started to drive transitions towards renewable energy. In buildings, heating and cooling, and transport, the translation has been less comprehensive, resulting in less progress.

- **User practices and lifestyles:** Access to energy is widely recognised as an essential aspect of modern life. Increased appliance use is associated with progress and linked to broader cultural conventions such as convenience (e.g. heating food in microwaves), cleanliness (e.g. washing at high temperatures) and entertainment (e.g. television, radio, games) (Shove, 2003). Energy consumption in Europe has decreased since the mid-2000s (Figure 1.1), as a result of efficiency improvements, structural changes in the economy towards less energy-intensive sectors and the 2008 financial crisis (EEA, 2018a). Consumers have started to purchase more efficient refrigerators, light bulbs and gas boilers and have some degree of home insulation, but have not fundamentally changed their lifestyles (EPSC, 2019). Increased installation of rooftop solar-PV panels, however, is turning many households into 'prosumers' (Inderberg et al., 2018), who generate and consume their own electricity and sell some of it back to utilities.

There are many niche innovations in the energy system, some of which have moved from the emergence to the diffusion phase.

- Renewable electricity technologies, such as solar-PV, onshore and offshore wind, and various biomass configurations, have started to diffuse in many European countries since the mid-2000s (Figure 2.6). Including hydropower (which has remained fairly constant, depending on rainfall patterns), renewable electricity produced 29.6 % of total electricity in Europe in 2016 (Eurostat, 2018b). Box 4.6 provides further analysis of renewable electricity technologies in Germany, Spain and the United Kingdom.

Figure 2.6 Gross electricity generation from renewable sources, EU-28, 1990-2017



Source: Eurostat, 2019a.

- Other low-carbon electricity technologies, such as carbon capture and storage, have hardly developed, despite high ambitions, supportive regulations and co-funding opportunities. Europe currently has no operational large-scale commercial carbon capture and storage plants.

- Renewable energy technologies for heating and cooling have diffused less rapidly than renewables for electricity (Figure 2.7), reaching 19.1 % of gross final consumption in heating and cooling in 2016 (EEA, 2018g). Solid biomass is the largest category, burned in household stoves or as an input for biomass district heating systems (described in more detail for Austria in Box 4.1). Heat pumps, biogas, solar thermal, geothermal and bioliquids are much smaller and still mostly in the emergence phase, although diffusion rates vary between countries.

- On the demand side, niche innovations such as passive houses and whole-house retrofits have diffused in some countries (e.g. Austria, Finland and Germany), but has not yet gained traction in many others (Mueller and Berker, 2013; Kivimaa and Martiskainen, 2018a, 2018b). The same applies to energy cooperatives and community energy, which have developed well in some countries, but not in others (Wierling et al., 2018), depending on public policies and cultural contexts.

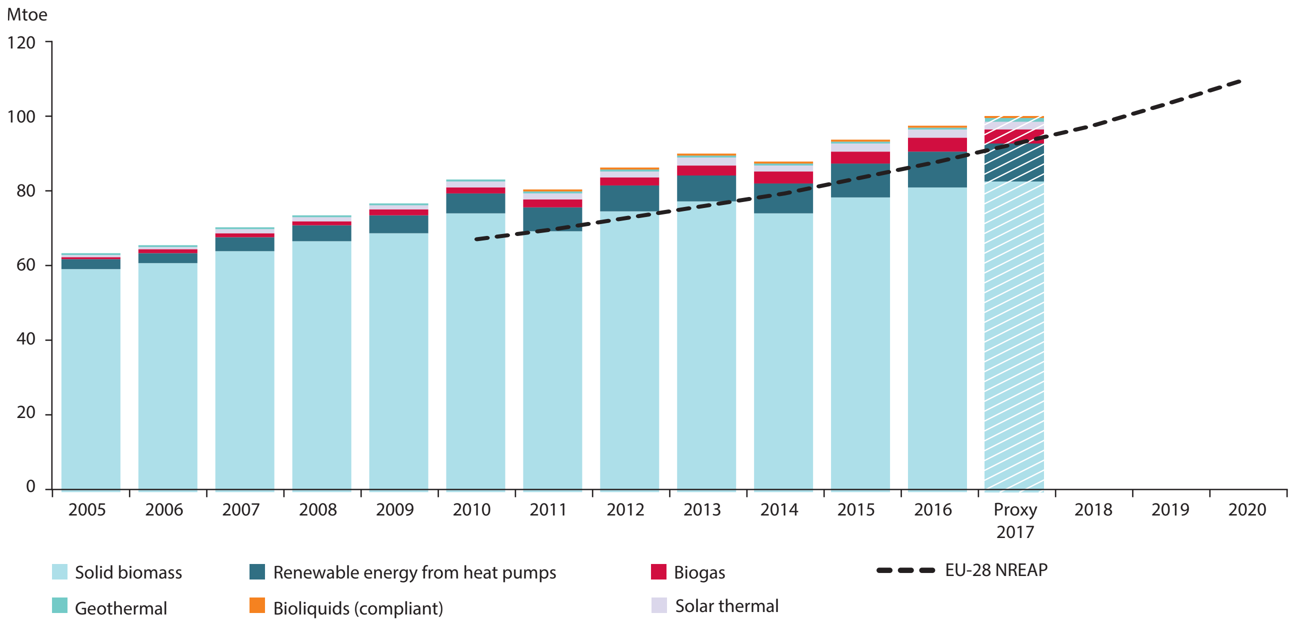
- For the whole energy system, renewable energy in Europe increased from 8.5 % in 2004 to 17.0 % in 2016 (Eurostat, 2018b), implying that the aggregate 20 % target for 2020 is within reach. Some countries have already reached their 2020 targets, while others are some way off (Figure 2.8).

Mobility system

The mobility system consists of multiple transport regimes. Aviation, cars, rail, bus, cycling and walking are the main regimes for passenger transport. Cars account for 83.1 % of inland passenger-kilometres in the EU in 2015. Motor coaches, buses and trolley buses accounted for 9.2 % and passenger trains for 7.7 % (Eurostat, 2018b). Shipping, railways, aviation and road are the main regimes in freight transport, with road transport accounting for 76.4 % of inland tonne-kilometres in the EU in 2016, railways accounting for 17.4 %, and inland waterways accounting for 6.2 %.

European passenger car transport has expanded substantially since the 1990s, decreased somewhat between 2010 and 2012, but then increased again in the following years, with growth of 2.6 % between 2014 and 2015, the largest annual growth rate since 1999 (Figure 2.9). Other passenger modes have remained relatively stable, although air transport demand grew by 19 % between 2012 and 2016, reaching a modal share of more than 10 %.

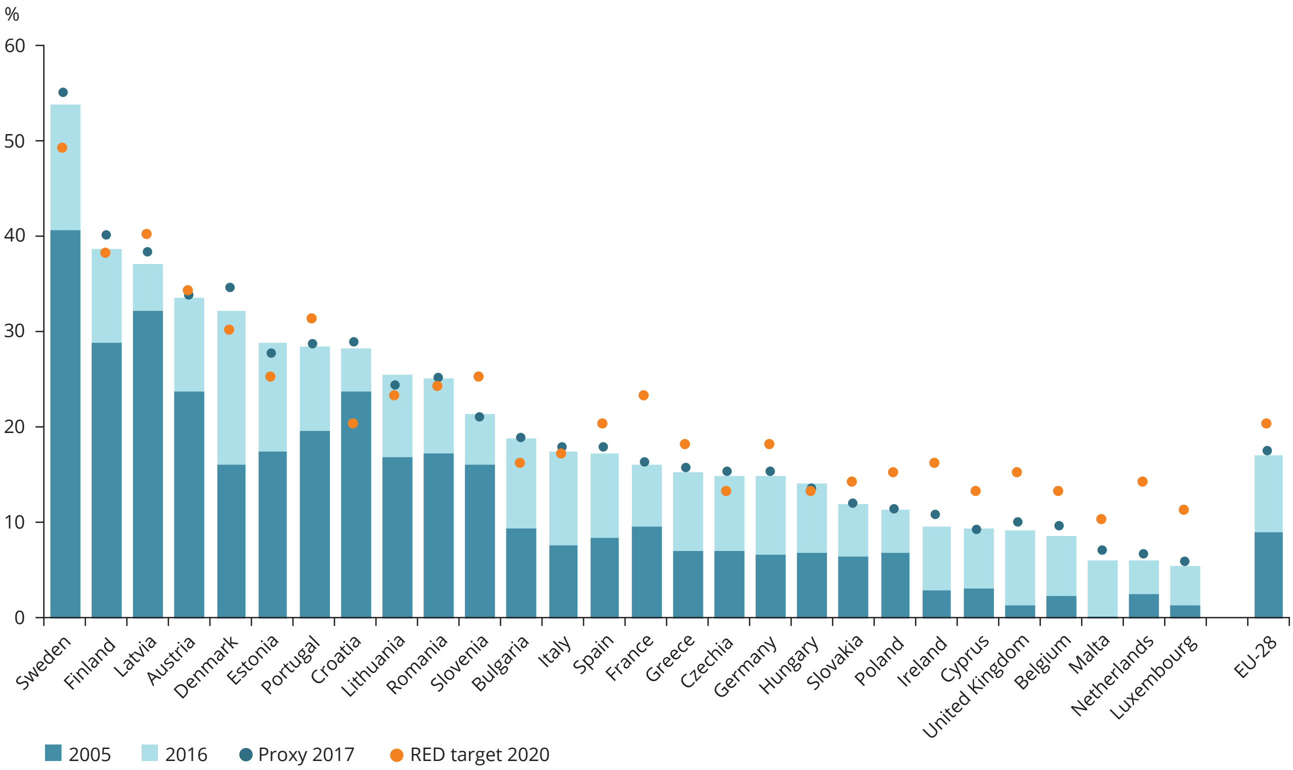
Figure 2.7 Renewable energies in heating and cooling in EU-28



Note: The line marked 'EU-28 NREAP' conveys the expected trajectory adopted by EU Member States in their national renewable energy action plans.

Source: EEA, 2018g.

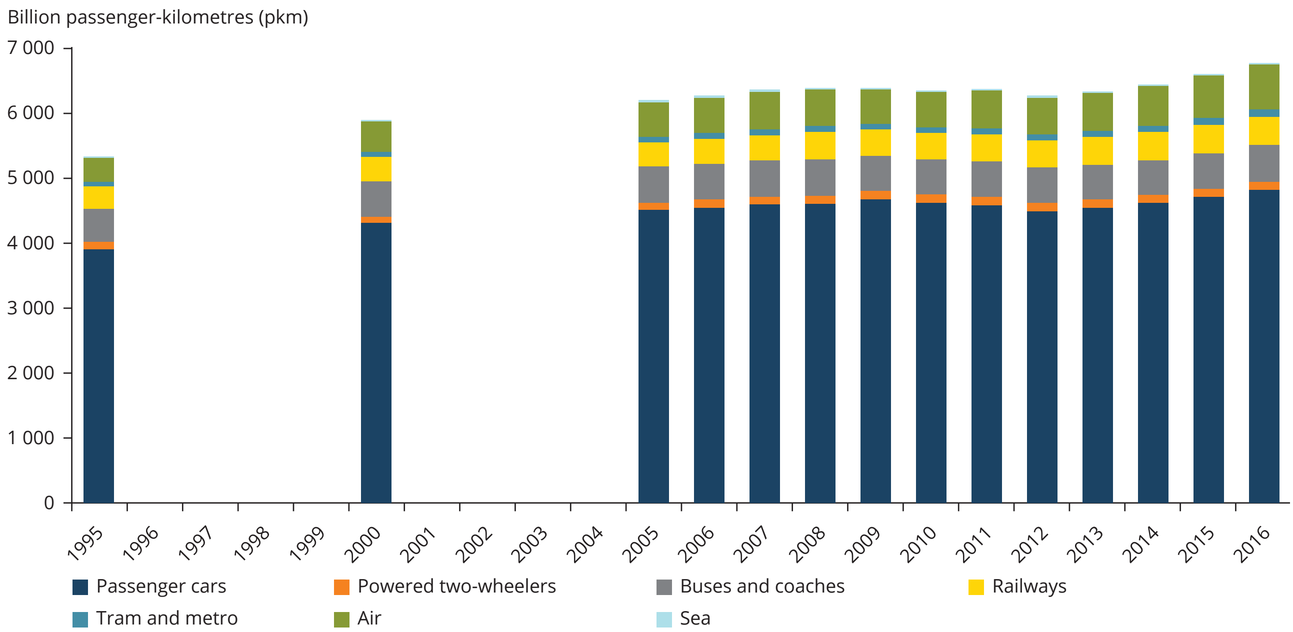
Figure 2.8 Proportions of energy from renewable sources in the EU Member States



Note: The dark blue bars show the percentages of energy derived from renewable energy sources in 2005. The tops of the light blue bars show the levels that they reached in 2016.

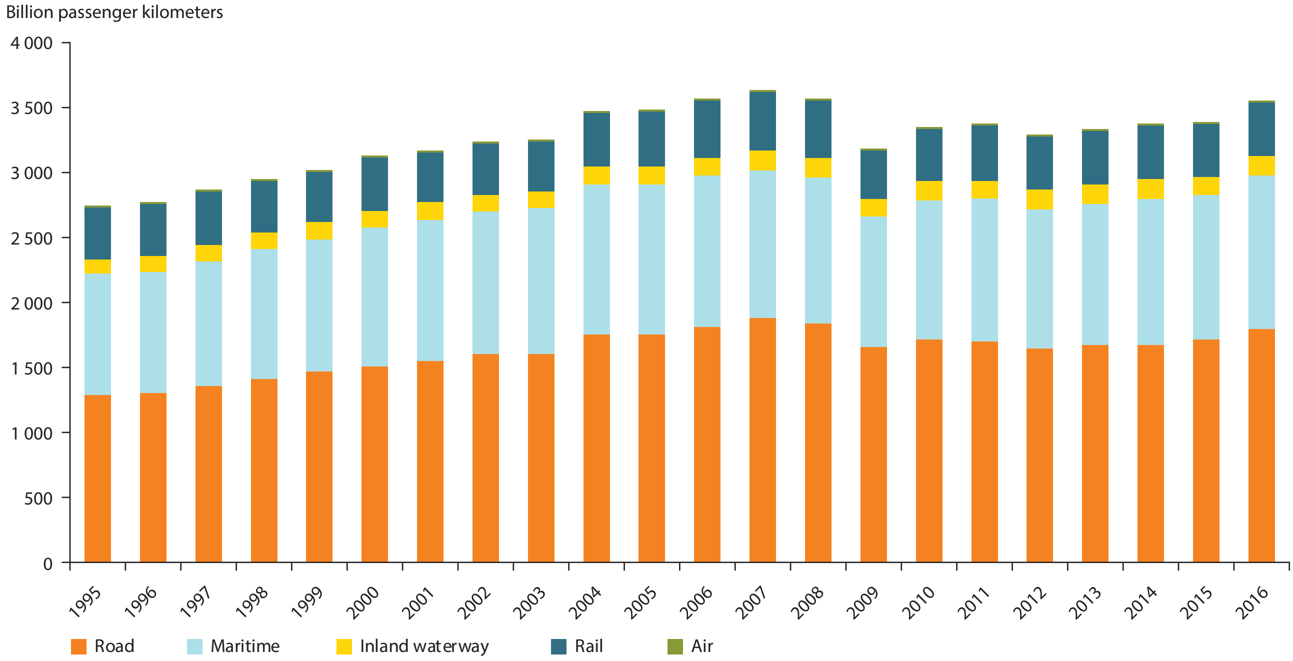
Source: EEA, 2018g.

Figure 2.9 Passenger transport volume and modal split, EU-28



Source: EEA, 2018c.

Figure 2.10 Freight transport volume and modal split, EU



Source: EEA, 2018c.

European freight transport also grew between 2000 and 2007, fell sharply after the financial crisis of 2008, and has recovered somewhat since then (EEA, 2018c) but has not yet reached pre-downturn levels. In 2016, total land freight transport increased by 2.8 % compared with 2015, whereas inland waterway transport was stable and rail freight volumes declined slightly (Figure 2.10).

Despite increasing concerns about problems such as climate change, air pollution, noise, congestion and traffic accidents, these developments suggest that the road transport system is still fairly stable, and even expanding. Strong lock-in mechanisms across various dimensions of the socio-technical system account for this relative stability:

- **Sunk costs:** Road transport infrastructures create strong lock-ins, because they are expensive to build and have lifetimes of multiple decades. In 2014, more than half of all infrastructure investment in Europe (53 %) was on roads (EEA, 2016b). Although the increases in road capacity were made in response to increasing demand, the creation of new infrastructure often generates new demand, which thus creates a self-reinforcing lock-in effect.

- **Jobs and earnings:** Mobility-related industries (manufacturing of cars, buses and railway carriages; road building; bus, train and taxi companies) are important for the European economy and employment. The production of motor vehicles, for instance, accounted for 2.4 million European jobs in 2015 (Eurostat, 2018a), and also generated large export revenues.

- **Vested interests:** Powerful mobility-related industries (particularly the car industry) have been quite effective in lobbying against stricter environmental regulations and exploiting loopholes in emission-testing procedures (Fontaras et al., 2017).

- **Sectoral policies:** Policymakers have long supported the increase in freight and passenger mobility, because smooth flows of goods and people are important for economic growth. For decades they invested in road and rail infrastructures, protected and stimulated industries, and promoted car use. Policymakers aim to address the negative consequences of mobility, but often pay more attention to congestion and traffic accidents (which are problems with immediate social and economic consequences) than to air pollution, noise, parking and climate change (Geels, 2012). Local environmental problems (particularly air pollution) have recently risen up policy agendas, leading to new initiatives such as clean air zones and diesel car bans.

- **User practices and lifestyles:** Mobility is a derived demand, which supports other social practices such as leisure, visiting friends, shopping, commuting to work, business travel and taking children to school. For many of these activities, cars are often, or are perceived to be, the most practical form of transport (in terms of travel time, carrying capacity, comfort), which is why many people choose this transport mode over others. Car use is also stabilised by long-standing positive cultural discourses, which associate cars with values such as freedom, individuality, power and success (Sheller, 2004).

Although these lock-in mechanisms stabilise existing transport regimes, there are multiple niche innovations that provides possible seeds for sustainability transitions.

- Battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), fuel cell and hydrogen vehicles, and biofuels are technological solutions that can reduce the GHG and NO_X emissions of car transport if their energy input is sustainably produced. Yet they do not address other problems such as congestion, parking and accidents. Moreover, although electric vehicles are likely to have disruptive impacts (e.g. for businesses that supply petrol and diesel), they do not threaten car mobility as such. For this reason, the car industry and many policymakers prefer this solution, even though the replacement (or modification) of internal combustion engines is demanding and expensive. Although the combined share of BEV and PHEV sales constitutes only 1.5 % of the European new car market (Eurostat, 2018c), BEVs and PHEVs have moved from emergence to diffusion phase in some countries (e.g. Iceland, Norway and Sweden). The use of supporting policies to promote the diffusion of electric vehicles is discussed further in Chapter 4 (especially Box 4.4).

- Car sharing, mobility phone apps and smart cards are business model and social innovations that could substantially reconfigure mobility systems by shifting from ownership to services (in the case of car sharing) or facilitating shifts between transport modes (apps or smart cards), which could enable intermodal transport systems (Lyons, 2015; Münzel et al., 2018). However, while mobility services and car sharing may be attractive for young professionals in dense urban areas, they tend to have less appeal for families with children and for residents in smaller cities and rural areas (Sprei, 2018).

- Teleworking, teleshopping and teleconferencing are social innovations in work and consumption patterns that could reduce mobility demand (Haddad et al., 2009; Hynes, 2016). But they could also generate new mobility because vans deliver packages at home and because homeworkers may visit more friends to compensate for a lack of social interaction. Therefore, the relative importance of mobility-substituting and mobility-inducing effects of teleworking is an on-going debate in transport studies (Cohen-Blankshtain and Rotem-Mindali, 2016).

- Infrastructural and spatial innovations such as compact cities and transit-oriented development (building mixed-use areas close to public transport facilities) could help to reduce travel distances and stimulate a switch away from cars (IEA, 2013). While offering great potential, such innovations are expensive, slow and disruptive (if implemented in existing cities).

Food system

The food system is inherently complex and heterogeneous. It comprises a large variety of products (e.g. grain, meat, fish, dairy, fruit and vegetables, processed food, beverages), which are configured in organisational chains that represent different subsystems: farming, food processing, distribution and retail, and consumption. Compared with other domains, food systems are further characterised by long (often global) supply chains with numerous actors (Figure 2.12), and an increasingly central role of the retail sector (Grin, 2012), particularly in countries that have taken a 'hands-off' regulation approach. In 2018, the 28 EU Member States (EU-28) imported 107 million tonnes of food from outside the EU, worth EUR 104 billion. Exports totalled 78 million tonnes, with a value of EUR 87 billion (Eurostat, 2019c).

Agricultural production relies on natural inputs, processes, environments and climatic conditions, but has developed an increasing dependence on artificial inputs and technologies in conventional agriculture (Friedmann and McMichael, 1989; Thompson and Scoones, 2009; Lamine, 2011): mechanical and infrastructural (tractors, harvesters, irrigation, farms, greenhouses), genetic (selective breeding, seed supply, genetically modified plants), chemical (fertiliser, pesticides) and pharmaceutical (antibiotics). Increased human control, homogenisation, industrialisation and intensified external inputs (Friedmann and McMichael, 1989) have oriented farming practices towards maximising yields and reducing natural variability, a drive towards monoculture and concentrating farming 'within the hands of a relatively few large, often corporately owned, farms' (EEA, 2017b). However, Europe also still retains large areas of farmland with high natural value and low-intensity agriculture (EEA, 2017b), notably in southern, eastern and mountainous areas, and the CAP increasingly recognises the value of rural land management services.

Agricultural products are increasingly transformed within a processing (or manufacturing) subsystem. Food processing enables the global transportation and increased shelf life of food (e.g. canning, freeze drying, curing, pasteurisation), the transformation of non-edible raw materials into edible produce (e.g. oil from seeds) and the production of specialty transformed products such as wine and cheese. Food processors are important actors in many chains (e.g. butchers and meat dealers in the food chain, milk processors in the dairy chain).

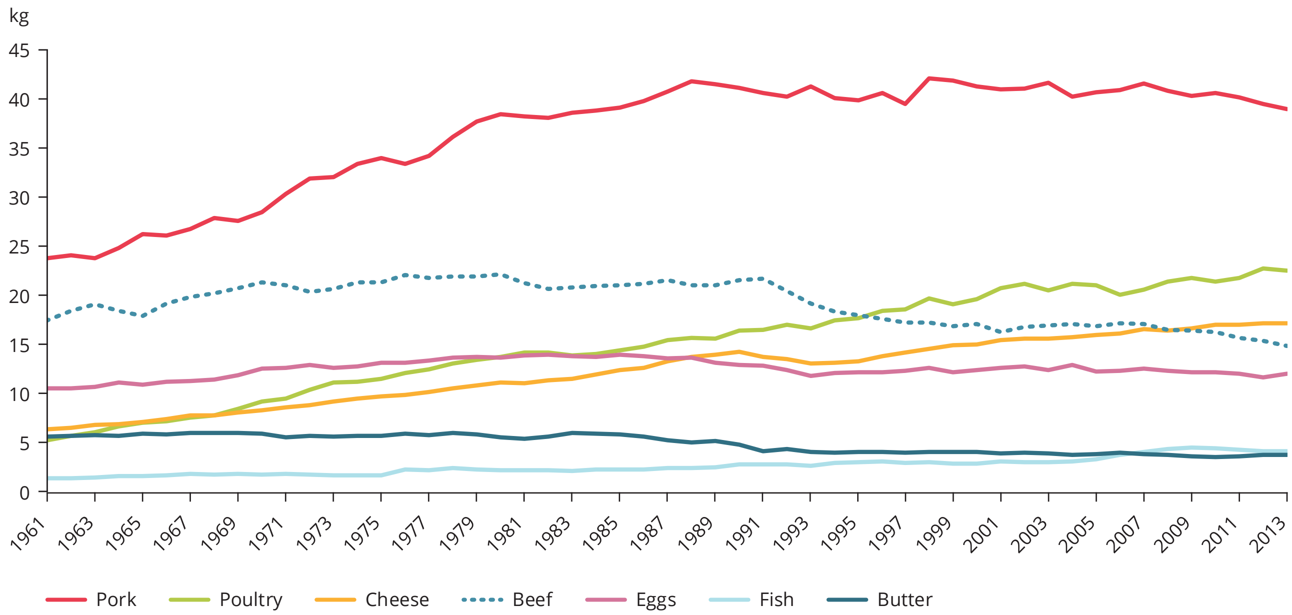
Supermarket chains dominate food retail activities in Europe and elsewhere, exerting considerable influence on the configuration of food systems (up- and downstream). This retail model, enabling the year-round availability of a considerable range of foods and food products, relies on complex global supply chains. It creates major logistical challenges to manage the purchase, stocking, display and sale of a large variety of goods, which have been met with innovations in logistics and standard-setting.

Food consumption is an inherently cultural practice, traditionally associated with positive meanings (e.g. joy, quality of life, sociability, pleasure, sharing). User engagement in activities such as shopping, cooking and eating practices is far greater than for the energy and mobility systems, where users are comparatively passive. The food system is also characterised by a relatively low degree of consumer knowledge (e.g. about food sources), because supply chains have become increasingly long and complex. Food consumption habits vary significantly across national and regional settings, but a number of trends can be observed, including the growing importance of animal protein intake in recent decades, notably pork and poultry (Figure 2.11), and the rapid development of convenience food markets (e.g. takeaways, ready meals, processed cooking ingredients).

So, while there is significant complexity and heterogeneity, the European food system is dominated by conventional farming, retail-led systems and the importance of food processing, which contribute to significant health and sustainability challenges. This system is stabilised by several lock-in mechanisms, including:

- **Jobs and earnings:** Although agricultural employment has steadily declined in recent decades, it employed approximately 22 million people in the EU in 2014 (including seasonal and part-time labourers), generating approximately EUR 200 billion in gross value added. The broader food system — also including food processing, retail and services — accounts for 44 million jobs and more than EUR 800 billion in gross value added (EC, 2017h). Given this, reconfiguration of the food

Figure 2.11 Per capita intake of animal products in EU-28



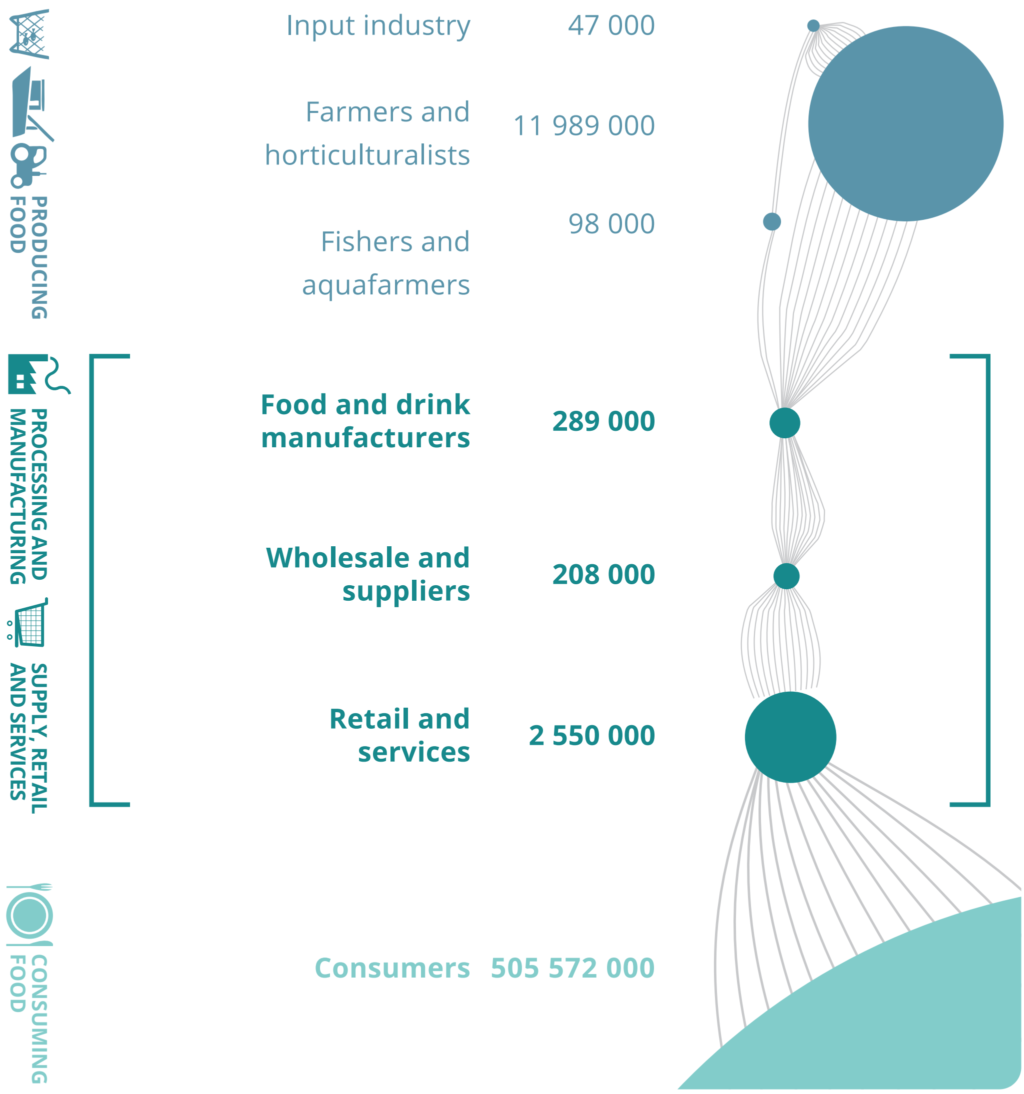
Source: FAO, 2018a.

system is likely to impact livelihoods, even if it also generates new opportunities.

- **Vested interests:** The food and drinks industry is one of the largest employers and productive sectors in the EU (EEA, 2017b), giving it significant lobbying power over regulation and policy changes. This power is particularly concentrated in a small number of corporations: the 10 biggest food retail companies in the EU have a combined market share of over 50 % (Heinrich Böll Stiftung et al., 2017; EEA, 2017b). This concentration of power increases their ability to resist major change but can also be interpreted as a potential leverage point for change.

- **Sectoral policies:** The CAP is a cornerstone of EU policy. With a budget of roughly EUR 59 billion (EEA, 2017b), it has helped to ensure stable access to affordable food for Europeans, supporting livelihoods in farming and fisheries, and modernising European agriculture. It is also criticised for its associated environmental outcomes (ECA, 2018). Attempts to radically reform it have proved difficult: the structural stability of the CAP policy framework encourages gradual adjustment of agricultural practices.

Figure 2.12 Actors in the food chain



Notes: There may be some double counting, as some actors operate across the value chain. The input industry also includes some wholesale of grain. Data used are the number of enterprises in 2012 (input industry, aquafarmers, manufacturers, wholesale and suppliers, and retail and services), number of holdings in 2012 (farmers and horticulturalists), number of vessels in 2013 (fishers) and population in 2013 (consumers).

Source: EEA, 2017b.

- **Distributional effects:** Food remains a substantial part of household expenditure in Europe, ranging from 10 % to 32 % depending on the country (EEA, 2017b), which means that policy interventions or innovations leading to increased food costs (e.g. sugar tax, organic produce) are likely to have regressive impacts on poorer and more vulnerable households.

- **User practices and lifestyles:** The increasing shift towards processed and convenience foods tends to reduce user engagement with, and knowledge of, food systems, food sourcing and food preparation. This disengagement has contributed to disempowerment and reduced consumer awareness of alternative behaviours.

A number of niche innovations and alternatives are emerging, linked to various societal, health and environmental motives (e.g. safety, quality, provenance, artificial inputs, animal welfare, fair trade, sustainability, climate) (Spaargaren et al., 2013).

- Low-input and organic farming are discussed in Sections 4.1 and 4.3, as examples of grassroots innovations, respectively focused on input reduction and input substitution, that have diffused widely in recent years. The total area under organic production grew by 21 % between 2010 and 2015 to 6.2 % of total utilised agricultural area (11.1 million hectares) and is expected to grow further in coming years (EEA, 2017b).

- Dietary change offers significant potential to support healthier and more sustainable consumption, e.g. towards less meat consumption and the use of more seasonal, local and fresh produce. Food policy aimed at behavioural change (e.g. nutritional guidelines and advice, awareness raising, cooking education) can be further demonstrated and supported by procurement (e.g. in schools, canteens). Vegetarianism, flexitarianism and other dietary shifts are gaining traction, for a variety of motives, and are supported by the increased availability of alternatives (e.g. meat and dairy substitutes). Although meat consumption has increased since 1960, Figure 2.11 shows a substantial decline in per capita beef consumption since the early 1990s. Portion adjustments or preferences for local and seasonal foods also offer ways forward that can be further supported through education and the introduction of new consumption practices.

- Waste reduction: Food waste is a significant problem, with an estimated 88 million tonnes of food wasted in the EU-28 in 2012 (i.e. 173 kg/person) (EEA, 2017b). However, numerous options for waste reduction exist throughout the value chain, including the recycling of agricultural by-products (e.g. manure, biomass) through composting or anaerobic digestion processes, and the reduction of processing and retail waste (e.g. discounts, improved inventories, donations, reduced packaging, valorisation), and of final consumption waste (e.g. food planning, consumption of by-products).

- Efficiency improvements: There are many options to reduce waste and increase efficiency throughout the food system. At farm level, this includes optimised input use in conventional farming (e.g. precision farming) and yield improvements (e.g. optimised breeding, integrated pest management). Such innovations offer potential avenues for development linked with digitalisation and robotisation.

- Food councils: Food councils are local-level stakeholder forums advocating change towards sustainable and fair food provision. Based on open and participatory processes, they seek to mobilise local actors to rethink and rewire local food chains through various initiatives. Relevant topics include promotion of urban agriculture, access to sustainably produced food for low-income households, strengthening local producers and developing diverse direct market structures. Such councils are mostly formed by civil society organisations and seek to establish dialogue between national and local administrations, farmers, retailers, restaurants and consumers. Local authorities and urban municipalities are increasingly embracing food councils as a means to set food targets, transform local food systems and introduce more deliberative forms of food governance (Marsden et al., 2018).

Food councils are active in cities in English-speaking countries (e.g. Canada, the United Kingdom, the United States) and beyond (Sonnino, 2019). A growing number of European cities are developing food strategies or action plans to improve local food security and nutrition, the livelihood of local food producers, the development of peri-urban agriculture and progress towards environmental objectives (ecosystem restoration, climate mitigation and adaption) (De Cunto et al., 2017). The Food and Agriculture Organization of the United Nations (FAO) has recognised the importance of territorial food system planning and local management (FAO, 2011). Transnational networks, such as the FAO Urban Food Actions Platform and the Milan Urban Food Policy Pact (which has been signed by 187 cities) are further supporting the development of local sustainable food governance.

2.2 Governance challenges for sustainability transitions

The multilevel perspective provides an analytical framework for describing and understanding transition processes, based on a substantial body of historical and contemporary evidence. Turning to the issue of transitions governance, however, the multilevel perspective leaves open major questions about if and how societies can initiate and steer deliberate processes of systemic change towards long-term environmental and socio-economic goals. Indeed, in exposing the complexity, uncertainty and no-linearity that arise from interactions between multiple actors and scales, transitions frameworks such as the multilevel perspective make it clear that transitions towards particular sustainability outcomes cannot simply be planned and implemented. As Hajer at al. (2015) argue in relation to the SDGs:

> The SDGs … risk falling short of expectations because of what we call 'cockpit-ism': the illusion that top-down steering by governments and intergovernmental organisations alone can address global problems. In view of the limited effectiveness of intergovernmental efforts and questions about the capacity of national governments to affect change, the SDGs need to additionally mobilise new agents of change such as businesses, cities and civil society.

This awareness is associated with a shift in emphasis from 'government' to the broader concept of 'governance', i.e. 'the totality of interactions in which government, other public bodies, private sector and civil society participate (in one way or another), aimed at solving public challenges or creating public opportunities' (Meuleman, 2008). Correspondingly, the different research perspectives on transitions and transformations (Section 2.1.1), all emphasise the need to mobilise a broad base of actors of change, and promote action and knowledge sharing across social networks.

As presented in Table 2.1, governance includes two long-recognised approaches to coordinating human activities: hierarchical governance, i.e. top-down planning and implementing by state authorities; and market governance, i.e. bottom-up processes that resolve complex questions (e.g. about resource allocation, supply and demand) through the operation of market forces. In recent years, a third approach has been increasingly recognised: network governance, arising from interactions between multiple societal groups. In contrast to the centralised and authoritative traits of hierarchies and the individualism and competitiveness of markets, network governance is characterised more by trust, partnership, diplomacy and lack of structure (Meuleman, 2019). Public authorities have special responsibilities and resources to enable and shape the operation of networks, but they cannot steer them at will.

While the multilevel perspective and other transition frameworks highlight the challenges of transitions governance, they also offer concrete insights into the

Table 2.1 Three styles of governance

	Hierarchies (top-down)	Markets (bottom-up)	Network governance
Social relationships	Hierarchical, command-and-control relations, with government responsible for steering markets and society.	Policymakers have arms-length (or hands-off) relations with firms and societal actors, which are assumed to be autonomous and relatively independent.	Mutually dependent interactions between policymakers, firms and societal actors.
Government roles	Government sets goals, selects solutions and shapes implementation through laws, regulations, standards and public investments.	Policymakers articulate goals and shape framework conditions (rules of the game, incentives), but let autonomous actors self-organise via markets and choose solutions.	Policymakers moderate, orchestrate and facilitate social interactions, discussions, learning processes and information exchange, aimed at defining problems and exploring solutions.
Scientific disciplines	Classic political science.	Neo-classical economics.	Sociology, innovation studies, neo-institutional theory.
Policy instruments	Formal rules, regulations, laws and standards.	Financial incentives (subsidies, taxes, fiscal incentives).	Network management, sector-level round tables, public-private partnerships, demonstration projects, experiments, scenario workshops, strategic foresight conferences and public debates.

Source: Roberts and Geels, 2019.

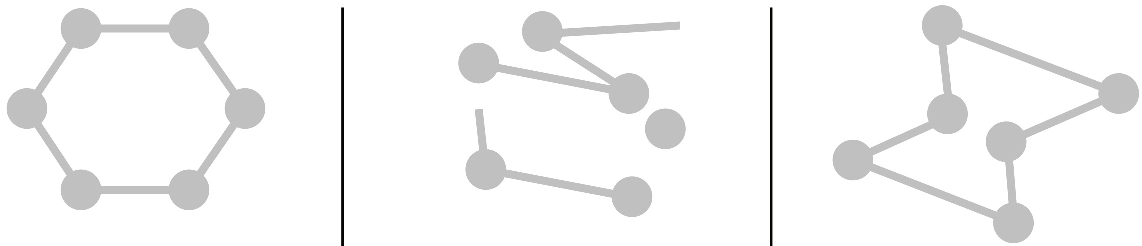
types of public policies and interventions that could contribute to sustainability transitions. While the remainder of this report will discuss and illustrate these policies for different transition phases and issues, it is important in advance to emphasise that no single policy instrument is sufficient. Instead, as illustrated in Figure 2.13, the multidimensional character of transitions necessitates a policy mix that extends far beyond the core tools of environmental policy. Stringent environmental regulations and pricing instruments retain an important role — for example as means to drive efficiency improvements, stimulate innovation, steer the direction of socio-technical change and sometimes destabilise existing regimes. But catalysing systemic change also requires policies that directly support innovation, experimentation, diffusion and networking; facilitate and drive structural economic change towards sustainability; and manage the inevitable disruption — for example by means of phase-out measures, and education and welfare policies.

The characteristics of sustainability transitions point to additional governance challenges, in particular relating to directionality, coordination and unexpected consequences.

Directionality is important because, in contrast to historical change in socio-technical systems, societies today need to achieve transitions towards specific sustainability objectives, such as those articulated in the SDGs. Increasing evidence of global environmental change together with the need to remain within planetary boundaries also implies the need for

Figure 2.13 Examples of the policy mix contributing to sustainability transitions

Emergence | **Diffusion** | **Reconfiguration**



Emergence

Directionality, credibility, e.g.

- Vision and pathways
- Long-term targets
- Scale and speed
- Foresight

Innovation policies, e.g.

- R&D
- Experiments
- Network building
- New entrant support

Diffusion

Environment and sectoral policies, e.g.

- Carbon pricing
- Strict regulation
- Removing barriers (e.g. harmful subsidies)

Industrial and fiscal policies, e.g.

- Specific vision
- Market creation
- Adoption subsidies
- Backing winners

Reconfiguration

Welfare, education, employment, regional policies, e.g.

- Compensating losers
- Offsetting inequities
- Retraining

Coordination across policy areas and levels of governance

Source: Based on EEA, 2018d.

urgency and speed. Governments have an important role to play in defining visions, pathways and targets to provide directionality for transitions. Articulating alternative visions of the future and how to get there inevitably involves normative choices, underlining the importance of public engagement and deliberation.

The breadth of activities and diversity of actors across sectors and across scales of governance creates the need for coordination. Public institutions have a key role to play in ensuring horizontal coherence across policy areas, as well as vertical coherence between local, national and international levels. Since transitions will depend in part on bottom-up activities and local initiatives, public policy and administrations should create the conditions for polycentric governance (discussed further in Section 10.3).

Finally, the likelihood of sudden shifts, unexpected consequences and new emerging issues, implies a need for both analytical approaches (e.g. horizon scanning) and adaptive governance approaches grounded in monitoring and learning that enable timely reorientation of transition processes.

While the sustainability transitions field has grown rapidly in recent years, analysis of the implications of transitions thinking for policy — particularly EU-level policy — remains limited or fragmented. The remainder of this report aims to create a more coherent picture of the governance challenges and implications for policy. Table 2.2 presents the main governance themes, how they relate to characteristics of sustainability transitions and where they are addressed in the report.

Table 2.2 Characteristics of sustainability transitions and their governance implications

Characteristics of sustainability transitions	Governance implications	Addressed in chapter
Multidimensional changes in socio-technical systems	Policy mix approach that spans environmental policies, innovation and industrial policies, sectoral policies (mobility, energy, food, housing), tax policies and educational policies. This is important to achieve horizontal policy coordination.	Chapters 3, 4, 5, 6, 7, 9
Multi-actor, multi-scalar processes	Multilevel governance allows for top-down guidance and funding as well as local policy experimentation and creativity. Such polycentric governance involves flexible and self-organising activities by non-state actors.	Chapters 6, 7, 10
Goal-oriented directionality	Indications about the general direction of travel (e.g. through financial incentives, regulation and broad goals, targets and visions) and more specific indications about innovations and pathways (through roadmaps and foresight exercises).	Chapter 8
Disruptive (involving winners and losers)	Stimulate sustainable innovations but also engage incumbents and potential losers (via compensation or reorientation policies).	Chapter 5
Open-ended and uncertain	Portfolio approaches, project-based learning and experimentation, especially with radical innovations (social, technical, business models) in early transition phases.	Chapter 3
Surprises, unintended consequences	Monitoring, reflexivity and adaptive governance, to ensure directional flexibility and address side-effects.	Chapter 11
Urgency and acceleration	Stronger innovation and diffusion policies. Phase-out and exnovation policies (through bans or stronger environmental regulations).	Chapters 3, 4, 5, 7

Part 2 Enabling innovation and system change

3 Promoting transformative innovation and experimentation

Message 1: Promote experimentation with diverse forms of sustainability innovation and build transformative coalitions

- To support a wide range of sustainability innovations, innovation policy could be broadened beyond technology to also address infrastructural, social and business model innovation.
- Addressing the specificities of sustainability transitions means extending innovation policy's focus on R&D and innovation system support towards transformative innovation policy.
- Exploring uncertainties associated with radical innovation requires more real-world experimentation to assess technical performance, market uptake, social acceptance and environmental impacts.
- Radical innovation requires transformative coalitions and partnerships. Research and firms are crucial but 'open innovation' policy should also target users, civil society, communities and other actors.
- More support for social and grassroots innovation can enable deeper and more transformative transition pathways.
- Innovation policy should also stimulate organisational innovations and new business models, which are important in determining the commercial feasibility of sustainability innovations.

3.1 More strongly supporting a wide range of sustainability innovations

As discussed in Section 2.1.4, in the energy, mobility and food systems there are many radical niche innovations that deviate in one or more dimensions from the existing socio-technical regime. Table 3.1 presents different forms of green niche innovations: technical, social, behavioural, business model and infrastructural. These dimensions often interact and are not mutually exclusive. Battery electric vehicles, for instance, also require changes in recharging infrastructure. Car sharing and bike sharing are not just about behavioural change, but also about new business models and new technology, e.g. electronic booking systems, global positioning systems (GPSs), smart cards. New information and communications technology (ICT) platforms play an important role in enabling new business models and social innovations linked to the sharing economy and the shift from products to services.

Table 3.1 also includes incremental technical innovations, which improve existing technologies and build on existing technical capabilities. These incremental innovations are relevant because they can increase environmental performance, but they do not enable sustainability transitions. Incumbent firms normally favour incremental innovation, as it is compatible with their established technologies, organisational structures, expertise, markets and business models. Policymakers have likewise tended to focus much of their efforts in recent decades in this area, 'picking the low-hanging fruit'. While this strategy has led to environmental improvements, it has been insufficient to address persistent environmental problems such as climate change and biodiversity loss (see Chapter 1).

'A massive research ... and innovation effort, built around a coherent strategic research and innovation and investment agenda is needed in the EU within the next two decades to make low and zero-carbon solutions economically viable and bring about new solutions not yet mature or even known to the market.'
EU long-term strategy for a climate neutral economy (EC, 2018g)

Table 3.1 Examples of radical niche innovations in energy, mobility and food systems

	Energy (electricity, heat)	Mobility	Food
Incremental technical innovation	Insulation (walls, lofts, double glazing), energy-efficient appliances (television, fridge, washing machine), gas or coal-fired power plants with higher thermal efficiency	Fuel-efficient petrol or diesel cars (e.g. engines with variable valve timing or direct fuel injection)	Precision farming, optimised breeding, integrated pest management, food waste valorisation
Radical technical innovation	Renewable electricity (wind, solar, biomass, hydro), heat pumps, passive house, whole-house retrofit, biomass stoves, smart meters	Battery electric vehicles, electric bikes, alternative fuels, autonomous vehicles.	Permaculture, no-till farming, plant-based meat, plant-based milk (soy, almond, rice), genetic modification, manure digestion (for biogas)
Social or grassroots innovation	Decentralised energy production ('prosumers'), community energy, energy cafés	Car sharing, bike clubs, modal shift to bicycles and buses, teleworking, teleconferencing	Alternative food networks, organic food, dietary change (e.g. less meat and dairy), urban farming, food waste reduction
Business model innovation	Energy service companies, back-up capacity for electricity provision, vehicle-to-grid electricity provision	Mobility services, car sharing, bike sharing	Alternative food networks, organic food
Infrastructural innovation	District heating system, smart grids, biomethane in reconfigured gas grid	Intermodal transport systems, compact cities, integrated transport and land use planning	Reforms to distribution systems, storage provision and better food waste management

Radical innovations, in contrast, offer the potential for larger environmental improvements and therefore form the seeds of sustainability transitions. However, such innovations face barriers that often hinder their emergence. For example:

- they face up-hill struggles against deeply entrenched systems that are stabilised by various lock-in mechanisms (see Section 2.1);
- they are more expensive than existing technologies because they do not yet benefit from economies of scale and decades of incremental improvements, which complicates market introduction;
- markets for radical innovations are not 'read-made' — there are often deep uncertainties about consumers and their preferences;
- radical innovations often suffer from the 'liability of newness' (Zhang and White, 2016), and may be perceived as strange, unreliable or unfamiliar, which reduces their legitimacy and makes it more difficult to attract external investment or support.

In the context of growing global environmental pressures and other sustainability challenges, policymakers have become more interested in transitioning to a green economy (UNEP, 2011b), green growth (OECD, 2011b), and low-carbon and circular economies (EC, 2015b).

While this strategic shift is important, most policy attention and support goes to innovative technologies (e.g. photovoltaics (solar-PV), wind energy, electric vehicles) rather than targeting the wider solution space, described in Table 3.1. To go beyond narrowly defined, technology-focused transitions, there is a need to explore a variety of transition pathways and engage more systematically with demand-side solutions, enabling infrastructural innovations (Wilson et al., 2012; Creutzig et al., 2016, 2018).

Alongside broader policy support for sustainability innovations, there is also a need to strengthen support to accelerate the development and diffusion of alternatives. With regard to climate mitigation, for example, the International Energy Agency's 2018 analysis (*Tracking clean energy progress*) shows that only 4 out of 38 energy technologies (solar-PV, light emitting diodes (LEDs), electric vehicles and data centres) are on track to meet long-term climate, energy access and air pollution goals (IEA, 2018b). All the other technologies and sectors analysed are considered to be 'not on track' (e.g. renewable heat, heating envelopes, carbon capture and storage, transport biofuels, aviation) or 'more efforts needed' (e.g. energy storage, smart grids, demand response, bioenergy, appliances, energy-intensive industries).

'It is important to define 'green growth' and the 'green good life' in a very broad sense, recognising the potential for innovation across every industry and activity. 'Green' not only includes all the trends in energy conservation, renewables and sustainable goods, but innovation in the productivity of resources; the shift from products to services and tangibles to intangibles; an increase in the use of bio-materials and bio-chemistry; a reorientation towards reuse and recycling; and so on.'
European Commission Expert Group 'Research and innovation policy for green growth and jobs (EC, 2016b)

3.2 Beyond R&D and innovation systems support to transformative innovation policy

As outlined in Chapter 1 (Table 1.2), innovation policy can be divided into different generations, which started in different periods but all remain relevant today (Weber and Rohracher, 2012; Schot and Steinmueller, 2018).

First-generation innovation policy started after the Second World War, with foundations in a linear understanding of innovation processes (Box 3.1 and Box 7.1). It focuses on upstream invention by stimulating R&D in public sector organisations (e.g. funding universities or research institutes) and private businesses (e.g. through R&D grants, strategic programmes for particular sectors, tax incentives for R&D workers, and corporation tax deductions for R&D spending).

Second-generation innovation policy (starting in the 1980s and 1990s) maintains the attention on knowledge but focuses more on the collaborations between actors (universities, research institutes, firms, standardisation agencies) that underpin the development and use of knowledge. National and sectoral innovation systems theories (Lundvall, 1992; Breschi and Malerba, 1997) led to more interactive instruments and focused on networks (e.g. grants for university-industry collaborations and industrial research students, promoting science hubs, cluster policies) or institutions (e.g. laws, property rights, regulations).

Whereas the first and second generations were inspired by concerns about economic growth and competitiveness, an emerging **third-generation innovation policy** is also interested in addressing societal and environmental problems (Steward, 2012; Weber and Rohracher, 2012) and is hence more explicitly concerned with the directionality of system innovation. Transformative change depends on contributions from both upstream actors (firms, universities) and downstream actors (civil society actors, cities, communities, users). Transformative innovation policy includes R&D and innovation system support, but also addresses other issues related to sustainability transitions. Specifically:

- It is concerned with long-term guidance and the direction of change to ensure that innovations contribute to solving particular problems. Transformative innovation policy therefore emphasises visions, targets and missions.

- It is concerned with radical innovations that deviate in one or more dimensions from existing socio-technical regimes (Table 3.1). Because of the many barriers that radical innovations face and the uncertainty about their environmental impacts and broader sustainability outcomes, transformative innovation policy emphasises the importance of real-world projects and experiments. Experimentation and piloting enable the search for initial market niches and learning about technical performance, consumer preferences and social acceptance (Kemp et al., 1998; Schot and Geels, 2008a).

Box 3.1 The linear model of innovation

The linear model of innovation distinguishes three phases in the emergence and spread of new technologies:

- **invention:** generating new ideas and knowledge, e.g. through technical and scientific research;
- **innovation:** development into concrete products and introduction into initial markets and application domains;
- **diffusion:** spread of innovations into mainstream markets and society, potentially contributing to systemic transitions.

Only a few of the green niche innovations listed in Table 3.1 have started to diffuse. Most are still in early innovation or invention stages (although social and business model innovations are rarely the object of dedicated R&D).

Subsequent research has highlighted the limitations of this linear representation. In reality, innovation processes are systemic in character, with a complex mixture of actors, interlinkages and feedbacks. Nevertheless, the linear model remains a useful simplification for highlighting and exploring the barriers that innovations face and how to respond. As a result, it continues to underpin many innovation policies.

- Because incumbent actors tend to favour innovations that are compatible with their existing business models, and preserve their competences and assets, transformative innovation policy aims to include a wider set of actors in innovation processes (Schot and Steinmueller, 2018). This resonates with the European Commission's open innovation policy. However, transformative innovation policy particularly emphasises the importance of including new entrants, entrepreneurs and peripheral actors, who often pioneer radical niche innovations (Van de Poel, 2000). Although such peripheral actors often have limited capacity and power to enact change under existing regime rules, they are important because they are willing to think 'outside the box'.

Transformative innovation policy aims to complement rather than replace traditional innovation policy. First- and second-generation innovation policy instruments remain important for sustainability transitions. Since they are well known, however, this report does not dwell on them, focusing instead on core elements of transformative innovation policy, such as missions, visions and directionality (addressed in Chapter 8), real-world experimentation and transformative coalitions (addressed in Sections 3.3 and 3.4).

Third-generation innovation policy may be particularly relevant for Europe, which faces challenges with regard to radical innovation. As the European Commission has noted, 'Europe is relatively strong in adding or sustaining value for existing products, services and processes, known as incremental innovation … But Europe needs to do better at generating disruptive and breakthrough innovations' (EC, 2018f).

3.3 Real-world experimentation for transformative innovation

Acknowledging the many uncertainties with radical niche innovations (price, performance, market demand, social acceptance, environmental performance), transition approaches such as Strategic Niche Management (Kemp et al., 1998; Schot and Geels, 2008a), Transition Management (Loorbach, 2010) and Technological Innovation Systems (Hekkert et al., 2007), all emphasise the importance of real-world experimentation. This includes exploring the viability and desirability of innovations at different stages (proof of concept, demonstration, prototyping, pilot) but also includes systemic and governance experiments.

In addressing radical innovations, the underlying logic does not involve controlled laboratory experiments in which individual parameters can be manipulated. Instead innovations are explored through learning-by-doing and trial-and-error processes. Ex ante analysis such as computer simulation or cost-benefit analysis is very difficult for radical innovations (Christensen et al., 2008). Therefore, analytical approaches should be complemented with open-ended learning approaches, which explore multiple configurations in relatively small, real-life settings (e.g. experimental or demonstration projects) and then adapt, maintain and upscale what works.

The innovation management literature describes such experimentations as 'probe and learn processes' (Lynn et al., 1996). Organisations:

> probe initial markets with early versions of the products, learn from the probes, and probe again. In effect, they run series of market experiments, introducing prototypes into a variety of market segments … Probing and learning is an iterative process. The firms enter an initial market with an early version of the product, learn from the experience, modify the product and marketing approach based on what they learned, and then try again. Development of a discontinuous innovation becomes a process of successive approximation, probing and learning again and again.

This open-ended experimentation logic applies not only to new technologies and markets, but also to grassroots innovations (Seyfang et al., 2013; Gernert et al., 2018), urban experiments (Bulkeley et al., 2014; Evans et al., 2016), living laboratories (Marvin et al., 2018) and business models (Bohnsack et al., 2014; van Waes et al., 2018). The European Commission's 'Lamy report' on maximising the impact of EU research and innovation programmes acknowledges the importance of real-world experimentation for society as a whole (EC, 2017e). The Commission's BOHEMIA foresight report also calls for experimentation in policy: 'Beyond the need for more experimentation, rapid prototyping and scaling of new solutions, there is a need for a more experimental approach to policymaking, involving R&I [research and innovation] as well as sectoral policies, in order to promote and support real-world purposeful innovation' (EC, 2018l).

Experiments, pilots and demonstration projects are important for radical innovations because they can fulfil several specific roles within an exploratory, bottom-up logic, as outlined in Table 3.2.

> 'Our society should increasingly become a living laboratory for innovative solutions to the many challenges we face in Europe — be they economic, environmental or social. Through broad-based, impact-focused research and innovation policy and investments, we can turn these challenges into innovation opportunities. This requires action and participation by many, if not all of us.' (EC, 2017e)

Table 3.2 Different functions of experiments, pilots and demonstration projects

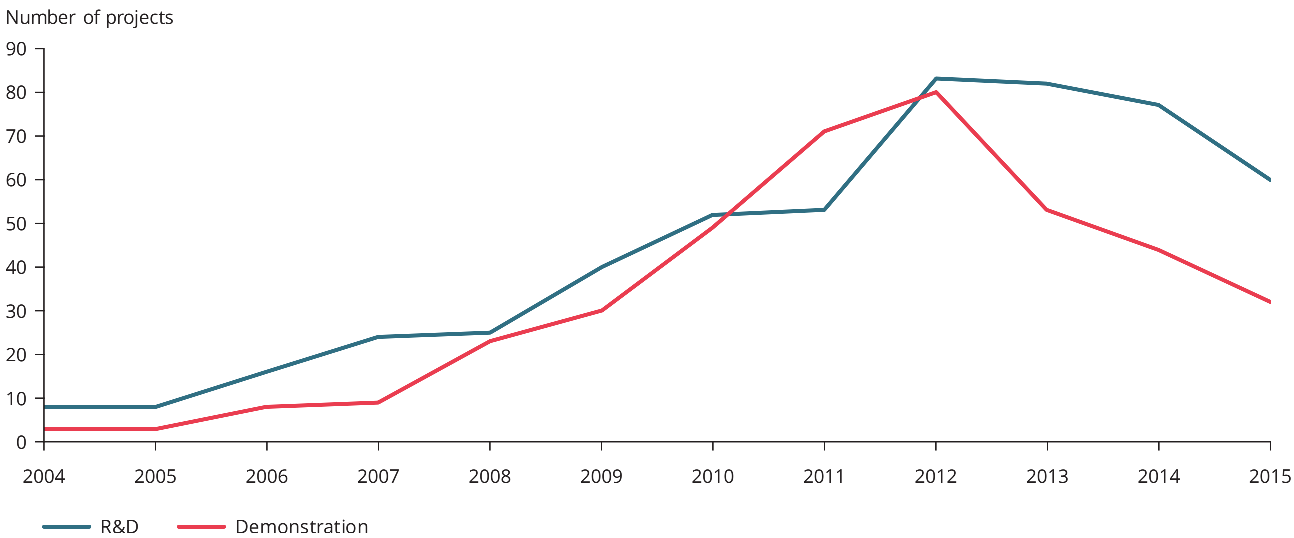
Function	Explanation
Technical testing	Testing the technical feasibility or workability of an innovation in the field (under real-world or large-scale operating conditions); the results can be fed back to guide further R&D.
Market testing	Learning about consumer experience with the product (which may feed back into R&D) and consumer interest in the product (which may reduce commercialisation risks and guide marketing efforts).
Behavioural change	Open-ended experiments may enable users to engage in 'second-order learning', which questions established user practices and may lead to behaviour change and new functionalities that designers had not foreseen.
Social acceptance and institutional change	Projects can help explore the social acceptance of innovations and the need for wider institutional change (e.g. new organisations or agencies with particular roles).
Raising awareness and visibility	Using demonstration projects to showcase and communicate the practical viability or functional appeal to wider audiences (e.g. policymakers, investors, opinion leaders); positive outcomes can be used to underpin wider visions.
Coalition building	Real-world projects involve close interactions between multiple actors, which may build trust and familiarity, leading to follow-up projects, and develop into advocacy coalitions that help champion and legitimise the innovation.

Sources: Compiled from Brown and Hendry, 2009; Hellsmark et al., 2016; Laakso et al., 2017; Sengers et al., 2018.

There are currently many technical, grassroots, social and business model experiments in Europe, which generate the seeds for possible sustainability transitions. For example:

- The EUR 106 million Second joint initiative for hydrogen vehicles across Europe (2017-2022) will deploy 152 fuel cell electric buses across 14 European cities to learn more about technical reliability, economic performance and hydrogen-refuelling infrastructure (FCH, 2018).
- All European countries (but particularly France, Germany and the United Kingdom) have supported dozens of smart grid demonstration projects in the last decade (Figure 3.1), worth hundreds of millions of euros per year (Gangale et al., 2017). These projects aimed to help prepare electricity infrastructures for higher contributions from intermittent renewables, and to explore technical issues such as bidirectional power flow management, sensors, automatic switches, power electronics devices, and voltage and thermal constraints (Jenkins et al., 2015).

Figure 3.1 Time distribution of smart grid R&D and demonstration projects in Europe



Source: Gangale et al., 2017.

- There are thousands of community energy initiatives in Europe (Hossain, 2018), although their prominence varies between countries. There are more than 700 community energy initiatives in Germany (de Vries et al., 2016), which account for about 40 % of renewable energy capacity, mostly in the form of citizens participating in energy cooperatives (DECC, 2014).

- There are several hundred transition town initiatives in Europe, especially in Belgium and the United Kingdom, which are registered by the Transition Network (TN, 2018).

- There are about one thousand cities with bike-sharing schemes, mostly in Europe (van Waes et al., 2018). While most schemes use docking stations, free-floating bike-sharing schemes (which can be parked anywhere) have also recently appeared in European cities. Several of these projects face economic problems because of unforeseen problems with theft, vandalism and reduced public subsidies (Yang et al., 2018), showing that experiments do not always succeed and may also involve learning from what does not work.

Policy support for real-world experimentation

Innovation policy at European and national levels has traditionally focused strongly on funding technical R&D projects. These remain important to generate new upstream knowledge and improve the performance of green innovations such as wind turbines or solar cells. Although innovation policy has in recent years shifted from R&D to emphasising research, development and demonstration (RD&D), there could be benefits from a further shift towards supporting real-world demonstrations and experiments. This aligns with the EU's 'open innovation agenda' and the European Commission's Research, Innovation and Science Policy Experts (RISE) group, which calls for 'openness for experimentation, for innovation deals, for green deals, for testing, for local co-creation, in experimental areas in cities; for market creation combining new sorts of opportunities for exchanging and extraction value, is part of such openness.' It further notes that 'For an old continent such as Europe, with its complex institutional set-up ..., this is of course a formidable, if not the most formidable challenge' (EC, 2017d).

Governments can stimulate real-world experimentation in various ways. First, they can allocate more financial resources for pilots, experiments and demonstration projects. These projects are normally co-funded with stakeholders to help prevent nurturing 'white elephants' that never become economically viable. Since more financial support (and stakeholder co-funding) tends to be available for technical projects (e.g. hydrogen buses or smart grids), care should be taken to also increase financial support for social and grassroots innovations.

Second, governments can provide exemptions from regulations that hinder particular innovations or entrepreneurship. For example, the European Commission has introduced 'Innovation deals', which help innovators who face regulatory obstacles by setting up agreements with stakeholders and public authorities. Third, governments can assist ongoing local projects by facilitating networking and knowledge exchange (e.g. through workshops or innovation or implementation agencies).

3.4 Transformative coalitions and partnerships

In the real world, innovation often emerges through the interaction of multiple actors in 'innovation ecosystems' (Lundvall, 1992; Breschi and Malerba, 1997). These bring together coalitions and partnerships of multiple actors with different kinds of resources, such as knowledge, organisational skills, money, supply and distribution channels, and political connections. Innovation depends on knowledge flows between universities, firms, policymakers, consultancies and professional societies. Realising innovations also requires the involvement of investors, suppliers, distributors, regulators (often from several ministries), users and citizens.

The need to involve a broader array of actors in innovation processes is increasingly recognised in EU policy discussions — for example, in the EU's concept of Responsible Research and Innovation (EC, 2014c). The European Commission's RISE group likewise notes the limitations of traditional innovation policy approaches in responding to grand challenges such as sustainability transitions, arguing that:

> Traditionally, addressing societal challenges has been a primarily 'supply-pushed' concern with the research community playing a central role ... Implementation in terms of innovation has, however, often been disappointing. Typically, users and more broadly the demand side, has been insufficiently involved in the design and development of innovative ways to address those societal, global challenges. (EC, 2017d)

The RISE group therefore recommends that 'It will be crucial to break open the current supply-side research dominance in addressing societal challenges, which has sometimes cornered the discussion and debates to technical debates about measurement, evidence and methodologies' (EC, 2017d).

The European Commission's 'Lamy report' similarly calls for wider stakeholder engagement:

> Fully mobilising and involving stakeholders, end-users and citizens in the post-2020 EU R&I programme, for instance in defining its missions, will not only increase the degree of co-creation, it will also maximise its impact and stimulate a stronger demand for innovative products and services as well as a better grasp of social changes. This will bring open science and open innovation to the next level and turn Europe into a continental living innovation lab. (EC, 2017e)

Because incumbent actors tend to be locked in to existing regimes (by their core competencies, established routines and taken-for-granted belief systems), radical innovations often depend on the involvement of new entrants, outsiders, entrepreneurs, users or communities (Van de Poel, 2000; Hockerts and Wüstenhagen, 2010; Schot et al., 2016). Box 3.2 describes how the entry of new actors was crucial to drive the early phases of the German electricity transition.

Box 3.2 Transformative actor coalitions in early phases of the German energy transition (1990-2010)

The German energy transition is a prime example of new entrants pioneering and driving radical innovations. Stimulated by positive public perceptions and strong anti-nuclear sentiments, small wind turbines were deployed in the late 1980s by relative outsiders such as farmers, environmentally motivated citizen groups and small utilities. Proposals for financial support were defeated in Parliament in 1987, 1988 and 1989, but succeeded in 1990 when the government was more concerned with German reunification (Geels et al., 2016). The 1990 feed-in tariff made onshore wind deployment economically feasible, which stimulated further deployment, especially by citizen groups and anti-nuclear activists (Jacobsson and Lauber, 2006). Many wind turbines were manufactured by German firms (e.g. Enercon, Husumer Schiffswerft, Tacke), which expanded the support coalition and attracted industrial policy support in northern German regions. Solar-PV remained small, because the feed-in tariff was too low to make it economically viable. However, in response to positive public views, the government introduced a 1 000-roof solar-PV programme in 1991, which subsidised solar-PV installations by individuals, and allowed learning and experimentation (Fuchs and Wasserman, 2008).

By the mid-1990s, green non-governmental organisations (NGOs) and solar-PV manufacturers lobbied for stronger policy support, which would make Germany a first mover (Fuchs and Wasserman, 2008). The newly formed (1998-2005) government coalition between the Social Democratic Party and the Green Party provided such support in the context of a wider ecological modernisation strategy that aimed to nurture and develop green industries (Geels et al., 2016). The 2000 Renewable Energy Sources Act (EEG) guaranteed consistent minimum payment for renewable electricity for 20 years and adjusted financial support to the maturity of different technologies. The EEG was supported by a broad advocacy coalition, which included environmentally oriented organisations (e.g. Eurosolar, Förderverein Solarenergie, Greenpeace and solar-PV companies), as well as organisations from the metal and machine building sectors (Jacobsson and Lauber, 2006).

The EEG stimulated the expansion of renewable energy technologies and further enabled the entry of new actors, creating the transformative coalitions that galvanised the German energy transition. By 2010, 16.6 % of German electricity was renewable, most of which was generated by new entrants rather than the 'big four' established utility companies (Table 3.3).

Although energy cooperatives played a key role in the early phase of Germany's energy transition, the number of newly founded cooperatives has shrunk in recent years. This shift has been attributed to revised rules on feed-in tariffs since 2014, namely the introduction of a cap, and a shift towards tendering systems (with exceptions for the smallest scale systems) (Wierling et al., 2018). More acute trends have been observed in Denmark (see Box 4.3).

Table 3.3 German ownership structure (percentage) of installed capacity of different renewable electricity technologies in 2010

	Households	Farmers	Banks, funds	Project developers	Municipal utilities	Industry	The four major utility companies	Others
Wind	51.5	1.8	15.5	21.3	3.4	2.3	2.1	2.2
Biogas	0.1	71.5	6.2	13.1	3.1	0.1	0.1	5.7
Biomass	2.0	0	3.0	6.9	24.3	41.5	9.6	12.7
Solar-PV	39.3	21.2	8.1	8.3	2.6	19.2	0.2	1.1

Source: Geels et al., 2016.

Because new entrants may be more likely to think out of the box and explore uncertain opportunities, innovation policy should include them in transformative coalitions, when designing experiments and demonstration projects. In practice, however, empirical research suggests that innovation and transition policies often favour incumbents (e.g. Verbong et al., 2008; Strachan et al., 2015; Geels et al., 2016). European electric vehicle projects in the 1990s, for example, had limited user involvement, focused primarily on technical learning, were dominated by incumbents and were overly self-contained (Hoogma et al., 2002).

The creation of transformative coalitions thus requires dedicated policy actions to open up the dominant 'working with incumbents' pattern. Specifically:

- The framing of grand challenges and solutions should be broadened to avoid a narrow focus on R&D and new technologies. This could be done through stakeholder dialogues or participatory foresight methods that include new entrants, NGOs and citizens in the definition of missions, besides technical experts and incumbents (see Sections 11.1 and 12.3).

- Parts of innovation budgets could be reserved for new entrants or require incumbents to collaborate with new entrants.

- New entrants or other outsiders could be given more access to policymaking networks and advisory bodies. This should go beyond passive consultation, for instance by providing new actors with seats at relevant tables.

- More generally, the role of policymakers could expand beyond regulator and funder (of R&D and experiments) to also include those of convenor, orchestrator and moderator. Policymakers can actively create new networks by inviting firms, NGOs and other stakeholders into public-private platforms, innovation partnerships or mission-oriented initiatives. Strategically selecting the right mix of actors can improve the transformative potential of such coalitions.

3.5 Social and grassroots innovations

Social innovations and grassroots innovations are important for sustainability transitions, because they aim at deeper and more radical transformations, including different ways of living. They are also typically enacted by new entrants such as volunteers and activists (Seyfang and Smith, 2007; Hargreaves et al., 2013), who often develop 'bottom-up solutions ... that respond to the local situation and the interests and values of the communities involved' (Seyfang and Smith, 2007). Social and grassroots innovations differ from mainstream innovations because they prioritise societal purpose, moral values and collective aspirations over market logics and profit motives (Table 3.4). They are also highly contextual, and often developed in response to concrete local problems.

Social and grassroots innovations are linked to different visions and pathways for sustainability transitions, which tend to be more radical than business-driven greening efforts, for example questioning conventional consumerism and advocating change in user practices and lifestyles. They are also more oriented towards local communities, social justice or alternative economic rationales, such as community ownership, shortening of supply chains, self-sufficiency and de-growth.

Over the last 10 years, many European countries have experienced a groundswell of bottom-up social and grassroots innovations, which aim to promote sustainability transitions by developing new social practices, changing consumer behaviour and using technologies in novel ways. Table 3.5 provides a range of examples from the energy, food and mobility domains.

Table 3.4 Key differences between mainstream and grassroots innovation

	Mainstream innovation	Grassroots innovation
Driving force	Rent seeking, profit seeking	Social need, ideological commitment
Forms of protection	Market niches	Value and cultural niches
Ownership	Private, public-private	Communal, collective
Main inputs	Capital, intellectual property, paid labour, market transactions	Voluntary labour, public grants, mutual exchange
Primary context	Market context	Social context

Table 3.5 Examples of social and grassroots innovations

Domain	Examples	Description
Energy	Community energy (CE)	CE refers to decentralised, small-scale, locally owned and operated forms of energy production (often solar-PV or wind turbines) with a high degree of community ownership and control. Projects can operate as cooperatives, charities, informal associations or development trusts (Hossain, 2018), which may involve a range of civil society groups such as social enterprises, schools, businesses, faith groups, local government or utility companies (Seyfang et al., 2014).
	Transition Towns	Transition Towns are community projects that aim to increase self-sufficiency, to reduce the potential effects of peak oil, climate change and economic instability. They seek to reduce their dependence on fossil fuels by stimulating renewable energy production and reducing energy use through lifestyle changes. Transition towns also stimulate community housing, alternative local currencies, repair cafes and community cafes using food that would otherwise go to waste.
	Energy cafes	Energy cafes aim to provide information and advice about energy bills, energy efficiency, renewable energy, behaviour change and how to switch to a cheaper tariff or supplier. They are run by volunteers (but often with grant money support) in a 'pop-up shop' format, which aims to lower the entry threshold (Martiskainen et al., 2018).
Food	Urban farming, community gardening	Citizens use relatively small plots of land within or close to cities to grow food with less inputs (pesticides, chemical fertilisers) than in established agriculture, raising awareness about the provenance of food and involving local citizens (White and Stirling, 2013).
	'Less meat' initiatives	Less meat initiatives are not as radical as vegetarianism but encourage consumers to become 'flexitarians' who once a week (or more) do not eat meat. 'Meat free Monday' is a concrete initiative in the United Kingdom, which is promoted by animal rights organisations, environmental organisations, health organisations and celebrities (e.g. Paul McCartney). It is being adopted by catering outlets in the House of Commons, schools, colleges and various universities (Morris et al., 2014).
	Organic food	Organically farmed food was pioneered by activists and initially disseminated via small cooperative shops. The organic food community subsequently professionalised, leading to standards and certification. Supermarkets were involved in wider diffusion, but this mainstreaming also watered down some of the initial values (Smith, 2006). This example is discussed in more detail in Box 4.5.
Mobility	Ride sharing	Initiatives that use websites and mobile phones to connect people offering a ride to a particular destination and people searching for a ride.
	Car-sharing clubs	Car sharing started as a citizen initiative, with friends borrowing each other's cars. In the mid-1980s, organised car sharing emerged in the form of cooperatives or clubs (which enabled sharing with relative strangers). Some cooperatives wanted to maintain the value-based sharing ethos, while others developed commercial for-profit business models that subsequently diffused widely in many countries (Truffer, 2003).
	Bike clubs (repair, cycling routes)	Volunteer organisations that promote cycling, offer training to novices, provide cheap repair services and advocate for cycling infrastructure improvement (e.g. organising 'bike trains' or 'critical mass' demonstrations along commuting routes).

The reach and spread of grassroots innovations are often difficult to assess (see Chapter 12) because local initiatives are inherently diverse, which can make it hard to categorise them, and often informal and volunteer-driven, which means they have no formal reporting responsibilities. Their number and importance for sustainability transitions also vary substantially between countries, depending on cultural and institutional contexts.

Although social and grassroots innovations tend to emerge outside mainstream policy networks, they sometimes receive some short-term seed money. However, they are rarely the focus of dedicated policy attention and sustained support. To stimulate broad sustainability transitions (including lifestyle changes), policymakers could offer more support for civil society innovations, for example by funding citizens' groups and projects; providing privileged access to public infrastructure (e.g. vacant land or offices); facilitating the circulation of knowledge about grassroots projects; stimulating experimental partnerships with public services (e.g. schools, hospitals); and more publicly displaying support for citizen-led sustainability projects and their positive contribution to public life locally. This may also require some institutional change to overcome the potential mismatch between informal grassroots innovations and formal procedures for policy support, e.g. proposal writing, organisational structures and accountability, and substantive and budgetary reporting.

3.6 Organisational innovation and new business models

Since radical innovations are often enacted by new entrants, start-ups, pioneers and entrepreneurs (Hockerts and Wüstenhagen, 2010), they may entail organisational innovation and new business models (Bolton and Hannon, 2016; van Waes et al., 2018), implying changes in the ways that firms appropriate value from their activities. Box 3.3 presents some examples of recent business model innovations, often with a focus on services. It also highlights some of the challenges that have arisen, demonstrating that business model innovation can be risky and challenging.

The European Commission acknowledges the importance of innovation and entrepreneurship but notes that Europe does not perform very well in these areas: 'Disruptive and breakthrough innovations are still too rare in Europe ... Too few European start-ups survive beyond the critical initial phase of 2-3 years. Of those that make it beyond that point, too few end up growing into larger firms and scaling up globally' (EC, 2018f). The

Box 3.3 Examples of business models for sustainability transitions in mobility, energy and food

- Car sharing, car pooling, bike sharing and mobile app-based mobility for hire services, such as France's BlaBlaCar, are new business models that challenge the established principle of owning your own car or bicycle. There is tremendous variety among emerging mobility-oriented services, and significant differences in terms of social and environmental sustainability as well as economic viability.
- To deal with the intermittency of variable renewables (wind, solar-PV), many grid operators are introducing technical options such as storage and back-up capacity, which would be used infrequently. There are ongoing debates, however, about suitable business models and payment options (e.g. capacity markets).
- Batteries in electric vehicles could also be used to provide extra capacity for electricity grids in the form of vehicle-to-grid configurations (Sovacool et al., 2017a). This would require new business models that make it easy for consumers to plug in to the grid and receive payment, including compensation for battery deterioration.
- Companies such as Philips are exploring the possibility of providing lighting services to entire cities, based around the installation, operation and maintenance of LEDs (Philips, 2018).
- Decentralised energy production (e.g. by rooftop solar-PV) is a new business model in which consumers become producers. There are ongoing struggles, however, about financing models, for example about whether 'prosumers' receive production or consumption tariffs, and whether or not they should be charged for use of the grid (Hess, 2016).
- Energy service companies operate energy service contracts in which customers (e.g. hotels, housing associations, universities) pay a monthly rate for the provision of heat (or electricity), leaving the construction and operation of plants to the energy service companies. These may be located on the client's premises or elsewhere, as in the case of district heating.
- The company Better Place (2007-2013) pioneered a battery swapping model for electric vehicles, which aimed to overcome short-range problems. The basic idea was that users would own the vehicle but lease the battery. When the battery ran empty, drivers could go to a battery switch station, where they could swap it for a fully charged battery. The company was backed by USD 700 million of venture capital financing and was trialled in small countries or states (Denmark, Hawaii and Israel) but ultimately failed.
- Alternative Food Networks (AFNs) are new food-provisioning practices based on shorter supply chains and direct producer-consumer interactions, e.g. farmers' markets, direct farm sale, weekly box schemes (see also Box 4.2). AFNs also pay more attention to environmental sustainability, quality, seasonality, proximity (localism and mutual commitments) and health. AFNs are social and business innovations, because they entail new forms of actor interactions that deviate from mainstream practice (i.e. consumers buying food in supermarkets without any contact with food producers).

European Commission's RISE expert group further notes that:

> Typical for Europe is the fact that new firms fail to play a significant role in the innovation dynamics of European industry, especially in the new growth sectors. This is illustrated by their inability to enter, and more importantly, for the most efficient innovative entrants, to grow to world leadership in new sectors. The churning that characterises the creative destruction process in a knowledge-based economy encounters significant obstacles in the EU, suggesting barriers to growth for new innovating firms that ultimately weaken Europe's growth potential. (EC, 2017d)

There may be opportunities to stimulate business model innovation and entrepreneurship by alleviating regulatory barriers (EC, 2016f). EU competition rules likewise hinder the ability of states to support entrepreneurs: 'The current State Aid rules are perceived as insufficiently innovation-friendly. While designed to avoid unfair competition within the single market, they should not act as a barrier to strategic investments' (EC, 2017e). Both examples highlight the importance of horizontal coordination between innovation policy and other regulatory policies (discussed in Chapter 9).

The European Commission also links limited entrepreneurship and breakthrough innovation to a 'deep-rooted aversion to risk' (EC, 2018f). As outlined above, this could be addressed with more innovation policy support for real-world experimentation and the creation of transformative coalitions. As discussed in Chapter 7, access to finance is another significant challenge and an important focus for policy interventions.

4 Diffusion and upscaling of innovation

Message 2: Stimulate the diffusion of green niche innovations

- Governments can stimulate knowledge diffusion by replicating projects and stimulating the circulation of insights, for example through standardisation and workshops organised by intermediary actors.
- Policy can stimulate adoption by users through financial and non-financial incentives, information provision and adjustments in economic framework conditions.
- Uptake of innovations in business can be supported using funding instruments, regulations and direct infrastructure investment.
- Governments can support societal adoption of innovations by developing positive narratives that promote social acceptance and by involving societal groups through public participation methods.
- Broad diffusion of innovations may require horizontal coordination with other policy areas (transport, energy, agriculture, environment, safety, education, etc.) and institutional adjustments.

To achieve sustainability transitions, radical niche innovations need to move beyond the experimentation phase and diffuse more widely into markets and wider society. As described in Chapter 2, diffusion results from internal drivers, such as knowledge circulation, learning processes, stabilising rules, expanding support coalitions and price/performance improvements. It can also occur as a result of contextual influences such as adoption and adjustment in wider markets, businesses, and societal and policy environments, as well as external landscape pressures.

The diffusion of technologies and other innovations 'is an active process, with elements of innovation in itself … Behaviours, organisation and society have to rearrange themselves to adopt, and adapt to, the novelty. Both the technology and social context change in a process that can be seen as co-evolution' (Rip and Kemp, 1998). This also means that diffusion may entail struggles and conflicts, which can create non-linearities and setbacks.

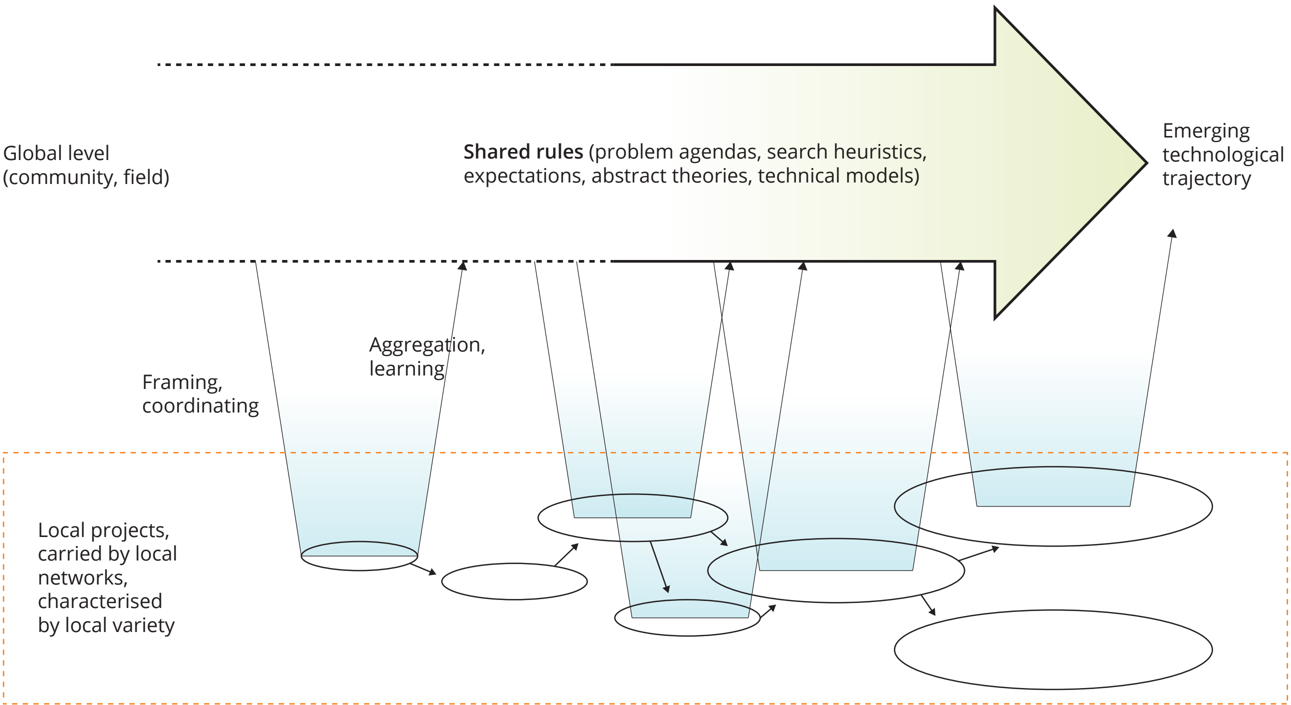
4.1 Stimulating knowledge diffusion through project replication and circulation

Section 3.1 describes how many experiments and local sustainability projects currently exist. However, an important challenge for sustainability transitions is to 'overcome the current fragmentation of initiatives, and their tendency to remain isolated or short-lived, which ultimately reduces their potential for lasting and wide-ranging change' (Turnheim et al., 2018c). Lessons and insights from experiments and projects often remain local and are not shared more widely, which may lead local innovators to reinvent the wheel. To diffuse more widely, it is therefore important that sequences of projects and experiments build on each other and that experiences and knowledge circulate between them.

4.1.1 Replication and adaptation of technical innovations

For technological niche innovations, knowledge (in the form of technical models and theories) is initially vague and not well articulated. Sharing experiences and dedicated comparisons between local projects can enable aggregation activities such as codification, standardisation, model building, writing of handbooks and formulation of best practices (Geels and Deuten, 2006). Collectively, such activities can gradually stabilise into an innovation trajectory (Figure 4.1). Such stabilisation of an innovation enables further diffusion, because it provides greater clarity, which reduces risks and makes actors more willing to commit and invest (Bolton et al., 2016).

Figure 4.1 Innovation trajectory emerging from sequences of local projects



Source: Geels and Raven, 2006.

For technical innovations, knowledge circulation and aggregation is often done by existing or newly created engineering communities, standardisation committees or industry associations. Implementation agencies (energy agencies or innovation agencies) can also act as intermediary actors (Kivimaa, 2014) in circulation and aggregation processes because they engage with multiple projects. They can compare projects, extract and categorise general lessons, and provide these as inputs for new projects (Geels and Deuten, 2006) or for policymaking more broadly (Kivimaa, 2014). Box 4.1 provides an example of the role of intermediaries in knowledge circulation and aggregation in the diffusion of biomass district heating systems in Austria.

4.1.2 Scaling up social and grassroots innovations

Similar processes of replication and circulation of knowledge are also important in enabling the diffusion of social innovations and grassroots initiatives (Moore et al., 2015; Durrant et al., 2018). Moore et al. (2015) distinguish three scaling mechanisms for social innovations: replicating and adapting social innovations in new settings; influencing cultural values, narratives and beliefs; and changing broader laws and policies. Box 4.2 describes these different aspects of scaling in the French Agri Court initiative, an Alternative Food Network, which started out as a grassroots project aimed at improving the sourcing of school meals.

While replication of social and grassroots innovations in different locations does occur, aggregation and cumulative learning between projects are difficult. This is because the local variability and specific contexts of individual projects often make it hard to articulate best practice lessons. In addition, grassroots activists may resist professionalisation, standardisation and codification because of conflicts with deeply held values, and commitments to the localised nature of action, in close connection to local sustainability needs. This means that learning is often informal, with knowledge retention occurring through individual participants.

In a state-of-the-art review, Hossain (2018) concludes that grassroots movements (GMs) 'leverage a tightly-knit network of local actors and engage in informal learning, mainly due to a lack of intermediary actors. Most GMs do not document their tacit knowledge, such as the institutional learning, skills, and training that their members possess.'

Box 4.1 Circulation and aggregation in the diffusion of Austrian biomass district heating systems

Biomass district heating (BMDH) systems, which use pellets and waste wood from Austria's abundant forests as input for generating and disseminating heat, emerged in the late 1970s in rural villages. They were pioneered by new entrants (sawmill owners, carpenters, monasteries), who used wood residues to provide and sell heat services to nearby houses. Early plant operators did not share information and were secretive about operational problems. From the mid-1980s, these small- to medium-scale village heat-only systems (400 kWth to 1 MWth) started diffusing more widely as more local municipalities adopted BMDH to heat public buildings, such as schools, town halls, hospitals and swimming pools. In the early 2000s, diffusion accelerated as another configuration also gained momentum: large-scale BMDH systems (between 10-65 MWth), which produced combined heat and power (CHP). By 2010, Austria had approximately 3 100 BMDH systems, of which the majority (about 2 500) were village heating systems.

From the mid-1980s, dedicated intermediary organisations such as the Austrian Biomass Association stimulated knowledge diffusion between local projects by comparing experiences between local BMDH systems, formulating generic lessons and disseminating insights to new entrepreneurs. Pioneering provinces (Styria, Lower Austria) also launched energy agencies that provided training and organised workshops to disseminate the findings from benchmarking and quality control exercises. These intermediary organisations also provided financial support for BMDH developers and dedicated technical advice via 'technology introduction managers' (Rakos, 1998). These support activities substantially improved technical and economic performance in the 1980s and early 1990s, which prepared the ground for further diffusion.

In 1995, the federal Environmental Promotion Fund streamlined the increasingly complex policy environment by harmonising eligibility, application and payment procedures for BMDH capital grants (Madlener, 2007). In 2000, technical performance guidelines were introduced as de facto standards, with the aim of further improving technical efficiency and economic viability (Madlener, 2007). These technical guidelines, standards and design rules were disseminated through seminars and training courses for BMDH planners and operators (Rakos, 1998). This stabilised set of rules enabled more reliable cost-benefit calculations, which in the early 2000s stimulated the involvement of powerful incumbent actors (energy utilities, National Forestry Agency), who constructed large-scale BMDH systems.

Source: Drawing on Geels and Johnson (2018).

Social and grassroots innovations may also experience other barriers that hinder diffusion:

- Reliance on non-market mechanisms (voluntary commitments, scattered expertise, grants) makes grassroots innovations fragile and difficult to sustain over time (Hargreaves et al., 2013). Their dependence on the commitment and energy of a small group of dedicated champions makes them vulnerable to the departure of key people and high turnovers of volunteers (Hossain, 2016).

- Some grassroots innovations do not aspire to scale up and grow (Seyfang et al., 2014; Hossain, 2016) because advocated solutions may be inherently small-scale (e.g. micro-renewables), favour proximity transaction (e.g. direct sales of agricultural products), cater exclusively to a local community, or because of commitments to radical values (e.g. 'small is beautiful', degrowth, radical ecology).

- Grassroots activists may resist mainstreaming if this involves the loss of particular values that inspired initial initiatives (Smith, 2012). *Agri Court*'s focus on professionalisation and logistics while upholding strong commitments to various aspects of social, economic and environmental sustainability (Box 4.2), however, illustrates a constructive handling of such trade-offs.

Box 4.2 Alternative Food Networks in France

AFNs have emerged in a number of European countries as bottom-up, transformative networks aimed at reconfiguring food provisioning and consumption practices to ensure environmental sustainability, quality, seasonality, proximity and health (Goodman et al., 2011). There is significant diversity among AFNs (Goodman et al., 2011), which include the support of local and organic farming supply chains, initiatives for consumer education, alternative forms of trade that are oriented towards direct producer-consumer interactions (e.g. farmers' markets, direct farm sale, weekly box schemes) and reducing intermediaries.

The *Agri Court* ('short-circuit agriculture') food hub in the Drôme valley (in south-east France) provides an illustration of the development and transformative potential of AFNs (Bui et al., 2016). The initiative started with a precursor project, *Court-circuit* ('short-circuit'), developed in 2009 by a group of parents seeking to raise awareness in support of fresh and seasonal food procurement in local schools. Realising the logistical challenges involved, the organisation developed ties with an organic food procurement project (within the wider local sustainable development programme *Biovallée*) and obtained financial support from local and regional authorities. *Court-circuit* raised its ambition around the dual objectives of creating demand (through awareness raising) and structuring supply (by linking producers with prospective customers), identifying procurement as the missing link (Bui et al., 2016). *Agri Court* was created in 2011 specifically to develop and implement an innovative procurement platform. The organisation clarified its vision and principles in a charter enabling more consistent and transparent decision-making, focusing on issues such as fair remuneration, sourcing principles, raising awareness about high-quality food, and education on food waste and economic recipes.

Agri Court subsequently professionalised and grew rapidly. By 2015, it supplied 60 % of local school meals, and developed links with a local farm incubator for organic produce (Les Compagnons de la Terre). Between 2017 and 2018, it doubled its sales to reach EUR 1 million. Even though the *Agri Court* initiative remains a relatively small local initiative, it provides evidence of:

- **Replication and adapting to new setting:** By 2016, *Agri Court* worked with 37 local producers and 40 local purchase groups (nurseries and primary and secondary schools) (Bui et al., 2016), supplied a growing proportion of school meals, started diversifying towards individual consumers and became an inspiring exemplar for similar initiatives.

- **Influencing cultural values, narratives and beliefs:** *Agri Court* aligned with the wider *Biovallée* programme, by further specifying a vision for the development of local sustainable food through the 're-definition of technical, economic and institutional aspects of the local agrifood system, including those related to farmland management' (Rossi et al., 2019). It also contributed to changes in consumer and farmer practices by offering an alternative for collective food provision, generating awareness among local families and residents, and contributing to the organic conversion of farmers (Bui et al., 2016).

- **Changing broader laws and policies:** It exerted pressure on local policies (e.g. local canteen procurement), raised the importance of food issues in local development and signalled the feasibility of new forms of public action. In France, the recognition in national legislation of territorial food projects since 2014 provides fertile ground for the generalisation of such developments (Lamine et al., 2018). *Agri Court* had a significant influence on the local political project of *Biovallée*, which became much more attuned to the involvement of alternative actors (as opposed to the original reliance on public procurement of agri-industrial organic produce) (Bui et al., 2016).

- Difficulties in securing funding and other resources (e.g. voluntary contributions, commitment, access to infrastructure, changing policy support) may prevent upscaling (Hossain, 2018). Banks and other commercial investors may be unwilling to lend because grassroots projects are too small or lack viable business plans or commercial ambitions. Policymakers or philanthropic organisations may provide some seed funding (e.g. grants) but grassroots activists may lack either the professional skills to apply for such funding (e.g. proposal writing, reporting, financial accountability) or the desire to deal with bureaucratic procedures. Changes in funding support can negatively influence upscaling and diffusion of grassroots initiatives, as discussed in Box 4.3.

Policy can support knowledge circulation and aggregation in various ways. First, governments can increase funding for project replication, paying special attention to social and grassroots projects (e.g. dedicated resources and simplified application procedures). Project funding rules can include an obligation to emulate proven innovation solutions that support the project's objectives in the region, and an obligation to share experiences and knowledge with others.

Second, governments could instruct implementation agencies (e.g. energy agencies or innovation agencies) (i) to apply a portfolio approach, with several projects addressing the same wider challenge but following different approaches; (ii) to promote moderated experience sharing and beneficiary-driven project assessments or evaluations among the portfolio projects; and (iii) to act more systematically as intermediary actors that collect, aggregate and disseminate information between projects (e.g. through workshops, codification, and training activities).

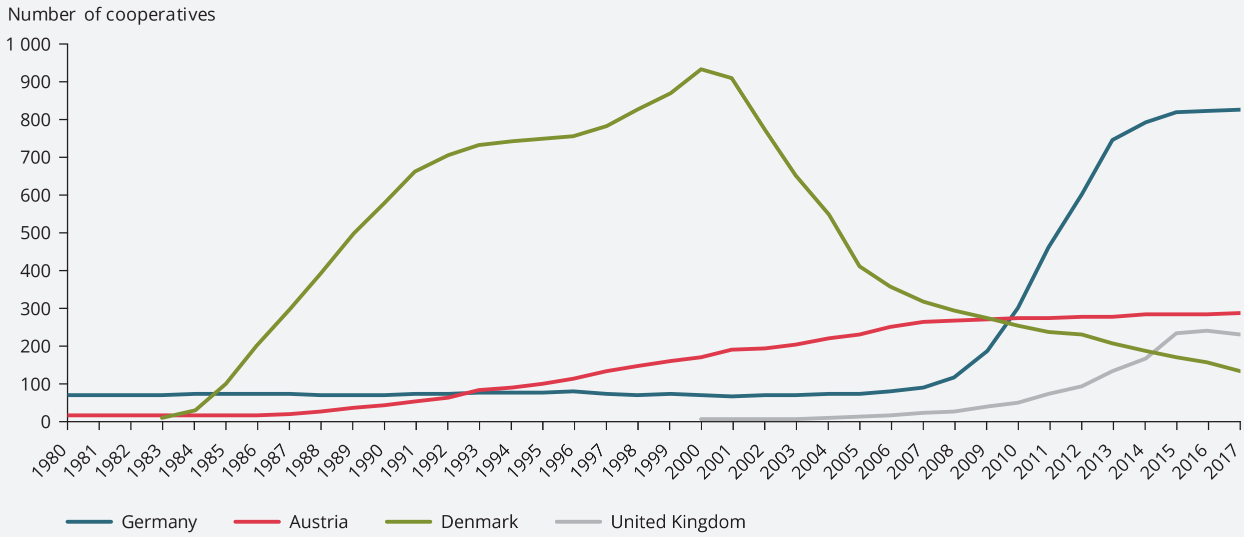
Box 4.3 The influence of policy on energy cooperatives in Denmark, Germany and the United Kingdom

Danish energy cooperatives expanded rapidly after the 1979 oil shock, when the government stimulated a shift away from oil, using feed-in tariffs and distributed innovation policies (Garud and Karnøe, 2003). In 2002, the newly elected centre-right government phased out feed-in tariffs and shifted towards tendering systems for renewables. This favoured larger companies but was ill suited to cooperatives, which rapidly declined.

The diffusion of German energy cooperatives was stimulated by feed-in tariffs established through the Renewable Energy Resources Act, declining technology costs and the 2011 Fukushima accident (Wierling et al., 2018). Downwards adjustments of feed-in tariffs since 2014 and a shift towards auction systems halted further diffusion and discouraged the founding of new energy cooperatives (Wierling et al., 2018).

The United Kingdom introduced a feed-in tariff for small-scale renewable energy in 2010 but substantially downscaled this in 2015, which created problems for many community energy initiatives.

Figure 4.2 Number of energy cooperatives in Austria, Denmark, Germany and the United Kingdom



Source: Wierling et al., 2018.

Third, project evaluation procedures could focus not only on financial reporting and immediate project results but also on assessing whether or not projects contributed to wider learning and knowledge circulation (see the discussion of developmental evaluation practices in Chapter 12).

4.2 Diffusion through market adoption

The diffusion of innovation into markets is driven by their purchase and adoption by users. Different adopters can be categorised along many dimensions, e.g. age, gender, income, value orientation, class and lifestyle. Rogers (1962) categorised adopters in terms of their degree of innovativeness (desire for novelty, distinction, risk) and provided rough estimates of their representation in the wider population (Figure 4.3). Diffusion often follows an s-shaped curve, starting slowly (in small market niches of 'innovators'), then accelerating (as the innovation is purchased by 'early adopters'), reaching high speed (as it enters mass markets, comprising 'early' and 'late majorities') and then slowing down again ('laggards').

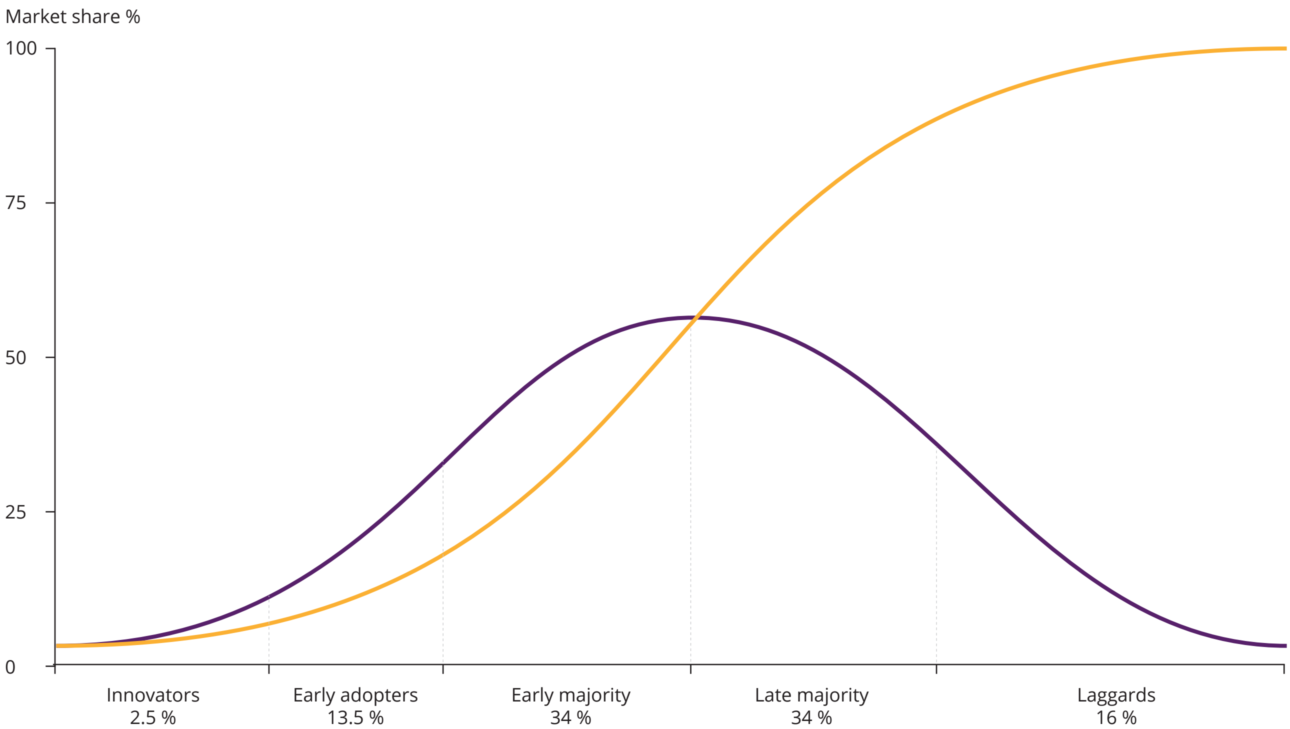
Diffusion may also be internally accelerated by self-reinforcing positive feedbacks that improve the performance and lower the price of an innovation.

These mechanisms mostly apply to new technologies rather than social or grassroots innovations, which is another reason for varying diffusion patterns for different kinds of innovation. Arthur (1988) highlights five different internal mechanisms:

- **Learning by using:** The more a technology is used, the more is learned about it and the more it is improved. For example, the more the United Kingdom utilities have used offshore wind turbines, the more they have learned about performance under various conditions (wind, waves) and how best to use them (Kern et al., 2014).

- **Network externalities:** The more an infrastructure-related technology is used by other users, the more attractive it becomes. For example, the value of networks such as telephone systems or the internet increases as they expand to include more users. Post-war diffusion of cars and highways is another example: more cars created congestion problems on roads, which generated more road building, which in turn made driving more attractive, stimulating further car purchases (Vigar, 2001). The same positive feedback is yet to happen with electric vehicles, which currently lack widespread systems of battery-charging facilities in most countries.

Figure 4.3 Adopter categories on the basis of innovativeness



Source: Rogers, 1962.

- **Informational increasing returns:** The more a technology is used, the more it becomes known among other users. For example, when one household installs photovoltaics (solar-PV) on its rooftop, others in the street may learn more about its performance, which can stimulate further adoption.

- **Technological interrelatedness:** The more a technology is used, the more complementary technologies become available, which further improve its performance. For example, the diffusion of Austrian BMDH stimulated further innovations in biomass collection and processing, pre-fabricated heat pipes (which reduced infrastructure installation costs and increased system efficiencies) and pellet boilers (which became easier to handle and more fuel-efficient). Whereas Austria imported biomass boilers from Sweden in the 1980s, the creation of specialised clusters and supply chains made them world-leading exporters of pellet boilers by the 2000s.

- **Scale economies:** As manufacturers produce more of a product, the costs per unit goes down because of learning-by-doing effects and because fixed costs are spread over larger numbers. Solar-PV and wind turbines have strongly benefited from this effect, as their costs decreased very substantially as they were deployed more widely.

For different technologies, analysts have tried to assess the 'learning rates', which refer to the relative cost reduction (%) for a doubling of production volume or installed capacity. Addressing renewable energy technologies, for example, IRENA (2018, 2019) estimates learning rates of 14 % for offshore wind, 21 % for onshore wind, 30 % for concentrated solar power and 37 % for solar PV in the period 2010-2020. In areas, such as renewable energy, where capacity is growing rapidly, these learning rates translate into major cost reductions. For example, the cost of electricity from solar-PV fell by more than three quarters in the period 2010-2018.

4.2.1 Policies to influence market adoption

Numerous barriers hinder the diffusion of innovations in markets. To help overcome these barriers, policymakers can intervene in various ways to influence adoption decisions. For example, marketing and communication scholars emphasise the importance of information provision: users need to know about an innovation before they can adopt it. Information spreads through a population through face-to-face contacts, the media or opinion leaders (Bass, 1969). Governments can therefore stimulate adoption through information provision, for example using media campaigns, labels or by involving celebrities.

Economists emphasise the role of price and performance: consumers are more likely to buy innovations if these are cheaper or offer higher performance than existing technologies (Geroski, 2000). Available budget and preferences explain why members of a population adopt technologies at different times. Using these rational mechanisms, policy can stimulate adoption using funding instruments such as purchase subsidies, low-interest loans and feed-in tariffs.

Social psychologists underline the importance of attitudes, beliefs and norms: purchase decisions are shaped by attitudes and beliefs (e.g. desire for novelty, expectations of particular products) and norms (e.g. concerns for nature) (Ajzen, 1991). Using this mechanism, policy can stimulate adoption by social marketing and nudging, which tailors the framing of information to different population segments. Indeed, insights from behavioural sciences are increasingly applied to policy initiatives across Europe (EC, 2016a).

In some instances, companies may lack the knowledge and abilities to manage innovation activities or subsequent growth processes. As a result, wider market adoption of innovation may fail from a lack of skills and competences in the innovating enterprise. Governments and innovation agencies can seek to strengthen these capabilities by making specialised training and consulting services accessible.

Box 4.4 describes how policies have employed these different mechanisms to promote the diffusion of electric vehicles. This development is likely to play an important role in decarbonising road transport in coming decades, although it is important to note that it is only part of the solution. The climate benefits of electric vehicles depend in part on changes in the energy system (Figure 5.1). Moreover, shifting to electric vehicles can create additional environmental pressures, for example by leading to around 50 % more metal consumption than petrol vehicles (Ekins et al., 2017).

4.2.2 Advantages and limitations of general economic instruments

Economists also emphasise the importance of generic, economy-wide financial instruments, such as environmental taxes or cap-and-trade policies. Such tools aim to make green niche innovations more attractive than unsustainable practices or technologies, which become more expensive (Baranzini et al., 2017). Changing relative prices may thus influence market adoption processes. Economic models suggest that such generic technology-neutral instruments are cost-effective (Tietenberg, 2013) because they avoid mistakes when policymakers seek to pick winners and instead enable market forces to direct investments towards the most efficient technologies.

While generic economic instruments have an important role to play in sustainability transitions, they also have limitations. First, empirical studies suggest that purportedly neutral instruments inevitably involve an element of selection, since they channel resources to technologies that are currently cheapest but not necessarily those that are most promising or potentially disruptive. As a result, general instruments mostly encourage the diffusion of incremental and close-to-market innovations, rather than radical innovations (Bergek and Berggren, 2014).

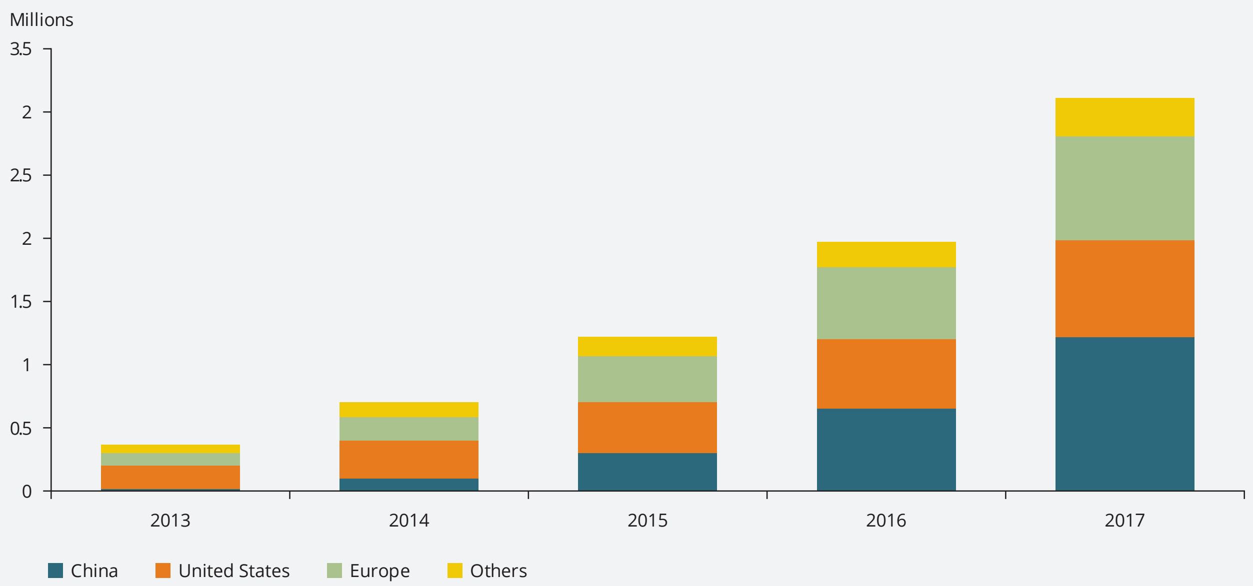
Second, the introduction of effective general economic instruments (such as a high-carbon tax) face major

Box 4.4 Electric vehicle diffusion

Electric vehicles have started to diffuse, with the total global stock passing 3 million in 2017 (Figure 4.4). Annual sales in 2017 surpassed 1 million units, which was an increase of 54 % compared with 2016. More than half of these global sales were in China, where electric vehicles had a market share of 2.2 % of all car sales in 2017 (IEA, 2018a).

Only a few countries have fairly high market shares: Iceland (12 %), Norway (39.2 %) and Sweden (6.3 %). Eight more countries have market shares of between 1 % and 3 % (Finland, France, Germany, Japan, Korea, the Netherlands, the United Kingdom and the United States). In 2017, members of the Electric Vehicles Initiative (EVI) signed up to the EV30@30 campaign, which set the collective aspirational goal for all EVI members of a 30 % market share for electric vehicles by 2030. The EVI members are Canada, China, Finland, France, Germany, India, Japan, Mexico, the Netherlands, Norway, Sweden, the United Kingdom and the United States.

Figure 4.4 Cumulative global fleet of battery electric vehicles and plug-in hybrid electric vehicles in different parts of the world



Source: IEA, 2018a.

In all of the countries that are pioneering electric vehicle diffusion, public policies at national and local levels are playing a major role. The most prominent are direct consumer incentives such as vehicle purchase subsidies or tax exemptions. There is a clear correlation between the strength of financial incentives and diffusion speed (Wesseling, 2016). Even with grants, however, up-front costs of electric vehicles remain higher than for normal cars. Early adopters are often middle-aged, well-educated, affluent, urban men, who are motivated by pro-environmental attitudes, a desire to save money on fuel costs and an active interest in new technology (Nilsson and Nykvist, 2016). These factors point to the importance of complementary measures that can shift public perceptions and drive changes in business practices. Measures that have been used include (EEA, 2016a):

- **Financial support to the electric vehicle (EV) industry.** For example, Finland's Electric Vehicle Systems Programme

Box 4.4 Electric vehicle diffusion (cont.)

provided around EUR 100 million to support and grow the electric mobility technology and service sector, in particular focusing on pilot, test and demonstration projects.

- **Public investments in charging infrastructures** or subsidies for home chargers. For example, Estonia has financed the construction of the world's first nationwide network of charging stations, with 165 chargers, each separated from the next by no more than 60 km.
- **Public procurement** of EVs (e.g. for municipal vehicle fleets). For example, in Czechia, municipalities, regions and local government agencies receive a 20-30 % subsidy when purchasing low-emission technology vehicles.
- **Indirect consumer incentives** such as preferential access to bus lanes (e.g. Estonia, Germany, Latvia), free or preferential parking (e.g. Bulgaria, Cyprus), access to low-emission zones (e.g. Greece, Italy), free charging at public stations (e.g. Czechia, Denmark) and road toll exemptions (e.g. Norway, Spain).
- **Consumer outreach and education policies.** For example, the Belgium Platform on Electric Vehicles promotes and disseminates information about EVs, involving all stakeholders involved in electric transport.
- **Regulatory incentives** such as EV sales targets for car manufacturers or sales bans on internal combustion engine vehicles have been announced for 2025 (Norway), for 2030 (Ireland, the Netherlands, Slovenia) and for 2040 (France, the United Kingdom). Cities have also announced access restrictions for diesel cars by 2024 (Paris, Rome), 2025 (Athens, Madrid), 2030 (Milan) (CCC, 2018).

political obstacles because benefits are diffuse, are hard to measure, and lie in the future, while their costs are concentrated and immediate (Hughes and Urpelainen, 2015). They are often regressive in nature, imposing a disproportionate cost on poor people because they spend a greater proportion of their income on necessities such as food, energy and mobility. In addition, powerful industries (e.g. oil, coal, cars, utilities and retail) tend to resist their introduction, which often leads to defeat or watering down, as happened with the EU emissions-trading scheme (Jenkins, 2014; Tvinnereim and Mehling, 2018). It is notable, for example, that, despite years of advocacy for a shift towards increasing taxation of environmental harms, environmental tax revenues in the EU decreased from 2.54 % of gross domestic product (GDP) to 2.40 % between 2002 and 2017 (Eurostat, 2019b).

To address this second problem, some researchers recommend a policy-sequencing strategy (Meckling et al., 2017; Geels et al., 2017) that would first use technology-specific and green industrial policies, which build new social and business coalitions, and only later move towards general pricing instruments. These new coalitions would then provide support for the general instruments in struggles against incumbent industries.

4.2.3 Co-evolution of user practices and new technologies

Diffusion into markets and user environments implies not only that consumers buy things but also that they integrate them into daily life practices and routines. This domestication process involves sense-making and interpretation, development of new skills and competencies (learning by using), and adjustments in everyday routines and practical contexts (Lie and Sørensen, 1996). This means that user preferences and routines are not static (as economists often assume) but can co-evolve with new technologies. For example:

- Battery electric vehicles (BEVs) have a limited range — it is sometimes claimed that consumers have 'range anxiety' — fear of being stranded with empty batteries. However, research in Norway (Ryghaug and Toftaker, 2014) suggests that real-world driving experience with BEVs leads consumers to develop new skills to deal with this (e.g. better journey planning), as well as greater appreciation of environmental issues. There is also anecdotal evidence that learning by using changes the meaning of EVs: while some people initially plan to use one as a second car in the household (for short trips), once they start using an EV they like it so much that it becomes the main car (Axsen et al., 2015).

- The introduction of smart meters in households may give rise to domestic conflicts, when household members disagree about what constitutes appropriate energy use. This often pits husbands against wives and (teenage) children against each other (Hargreaves et al., 2013), especially when adults use smart meters to suggest that the children turn off particular appliances (television, computer, music system). Smart meters may also give rise to stress and anxiety (particularly in lower-income families), when people become aware of the costs of certain activities, for example provoking feelings of guilt about using the kettle or watching television. Visible reminders of how much energy these activities use may cause negative attitudes towards smart meters (nuisance, nag, intruders in private life).

- More positively, innovations such as smart meters or rooftop solar-PV may also have knock-on effects, in the sense of enhancing energy awareness, which then leads to subsequent innovations (e.g. insulation, energy-efficient appliances).

4.3 Promoting uptake in business

Diffusion of new technologies also requires organisational changes and company investments in employees, production facilities, infrastructures, and the creation of supply and distribution chains. Embedding new technologies in the business environment often entails interactions between new entrants and incumbents, which may give rise to struggles and patterns of change:

- When radical innovations are developed by new entrants, wide diffusion may lead to the **downfall of existing firms** (Christensen, 1997). The diffusion of renewable electricity, for instance, created substantial financial problems for German utilities and disrupted their traditional business models (Kungl and Geels, 2018).

- Incumbent firms may also **defend themselves** by improving their own technology, or through institutional strategies that aim to water down or overthrow existing policies (Smink et al., 2015). In the United Kingdom, for example, existing construction companies successfully lobbied for the removal (in 2015) of the challenging 2006 zero-carbon homes policy, which was meant to become effective in 2016 (Kivimaa and Martiskainen, 2018a).

- Incumbent firms can also **diversify and reorient themselves** towards green niche innovations. This is not easy, because it often disrupts existing competencies and business models, but it can be done. Electric utilities in Spain and the United Kingdom, for instance, are partially reorienting towards renewables (Box 4.6). Global car manufacturers are also diversifying towards BEVs and PHEVs, as indicated by their commitment to ambitious targets (Table 4.1).

Table 4.1 Examples of manufacturer commitments on electrification

Manufacturer	Timing	Commitment
Nissan	2025	BEVs 50 % of sales in Japan and Europe
Mercedes	2025	BEVs 15-25 % of sales
Volkswagen	2025	EVs 25 % of sales
Porsche	2030	EVs 100 % of sales
Toyota	2030	EVs and conventional hybrids 50 % of sales
Volvo	2030	EVs and conventional hybrids 50 % of sales
Honda	2030	BEVs, PHEVs and hydrogen vehicles 15 % of sales

Source: CCC, 2018.

4.3.1 Mainstreaming of grassroots innovations

The diffusion of grassroots innovations into the business environment may involve mainstreaming, which can create tensions with the moral values that guide initial activists (Smith, 2012). Such tensions between commercial success and original values occurred with car sharing (Truffer, 2003), community energy and organic food (Box 4.5).

4.3.2 Policies to stimulate business uptake of innovations

Governments can stimulate the uptake of innovations by businesses using a variety of policy tools. These include funding instruments, such as interest-free loans, capital grants, investment subsidies, loan guarantees and feed-in tariffs; regulations such as renewable energy obligations for utilities, or EV sales targets for car makers; and direct infrastructure investment.

As discussed in Box 4.1, Austria stimulated the construction of BMDH systems with subsidies and capital grants that in early phases could amount to 60 % of investment costs (Geels and Johnson, 2018). This reduced the commercial risks for new entrants (sawmill owners, carpenters, farmers) in the 1980s and 1990s. In 2002, the Green Electricity Act introduced a feed-in tariff for the sustainable generation of CHP, which created an attractive market for CHP-BMDH systems. This incentivised incumbent actors (such as Austrian energy utilities) to build these much larger systems, which required greater financial resources and technical and operational capabilities.

Governments also use various funding instruments to stimulate the diffusion of renewable electricity technologies (RETs). The choice of particular instruments can influence which actors (incumbent firms or new entrants) invest and what kinds of RETs are chosen, as Box 4.6 shows for Germany, Spain, and the United Kingdom. In all three countries, large public subsidies (in the order of tens of billions of euros) have received mounting criticism in recent years, leading to downwards adjustments and slower diffusion. In Spain the 2008 financial crisis led policymakers to scrap most RET subsidies, which almost entirely halted wind and solar-PV diffusion (Alonso et al., 2016). In Germany, concerns about rising subsidies and economic problems for incumbent utilities led to downwards adjustments in feed-in tariffs (since 2014) to constrain RET expansion and costs. In the United Kingdom, increasing cost concerns led to the 2015 'energy reset', which slashed support policies for onshore wind, solar-PV, carbon capture and storage (CCS) and biomass, subsequently leading to a 60 % decrease in private investment. These examples show that the strengthening and weakening of public policies can substantially influence business deployment of green innovations.

Box 4.5 Tensions and compromises in mainstreaming organic food

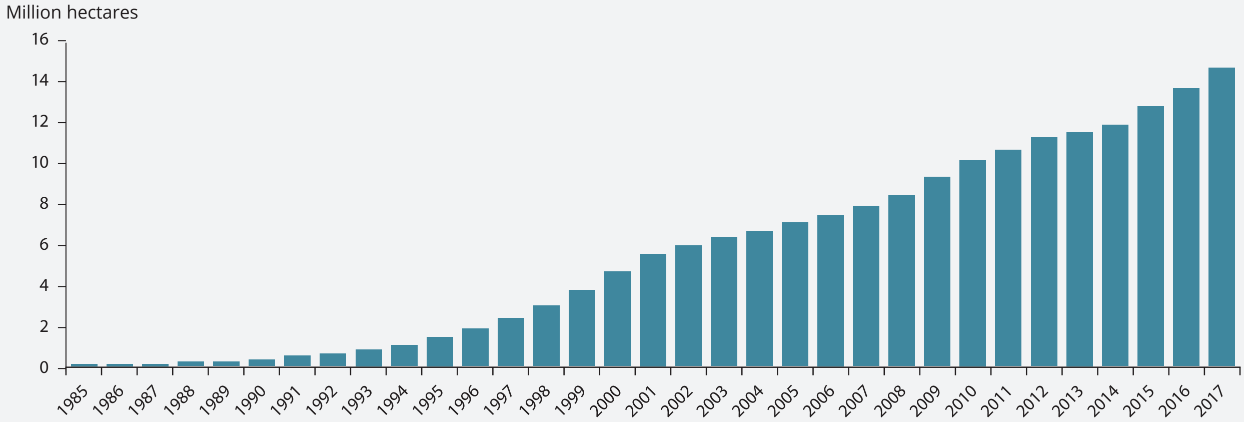
Before the Second World War, organic food was pioneered by activists (landowners, farmers, scientists), who advocated new farming practices based on the recycling of nutrients and organic matter to improve human and animal health. Between 1970 and 1990, a more organised organic food movement emerged, pushed by farming, health and environmental activists. They positioned organic food as a radical alternative to conventional food production and consumption, by using production processes that respected environmental carrying capacities (e.g. crop rotation, local nutrient recycling, soil management, seasonal harvesting and biological pest control) (Smith, 2006). The nascent movement also developed radical visions for food consumption and small-scale production based on localist values.

The network of actors broadened beyond initial activists to include some farmers. Dedicated associations were created that developed new farming techniques and organic standards to build consumer trust, and engaged in political advocacy to gain policy support (Smith, 2006; von Oelreich and Milestad, 2017). The niche became more professionalised, visible and credible, but still remained small (confined to farmers' markets, specialised outlets and cooperatives).

In the 1990s and early 2000s, market demand for organic food grew, partly in response to food safety scandals. Supermarkets became interested in this growth market, and policymakers introduced organic farming policies that supported organic conversion, research, and technical training. Market growth also expanded farmer interest in organics.

Supermarkets became the largest outlets and big farming businesses entered the market. Greater pressure on standardisation and predictable production drove small farmers out of business. The organic farming niche mainstreamed but diverged from some of the initial grassroots values such as local production and broader sustainability values (Smith, 2006).

Figure 4.5 Organic agricultural land coverage in Europe, 1985-2015



Sources: FiBL and IFOAM, 2016; FiBL, 2019.

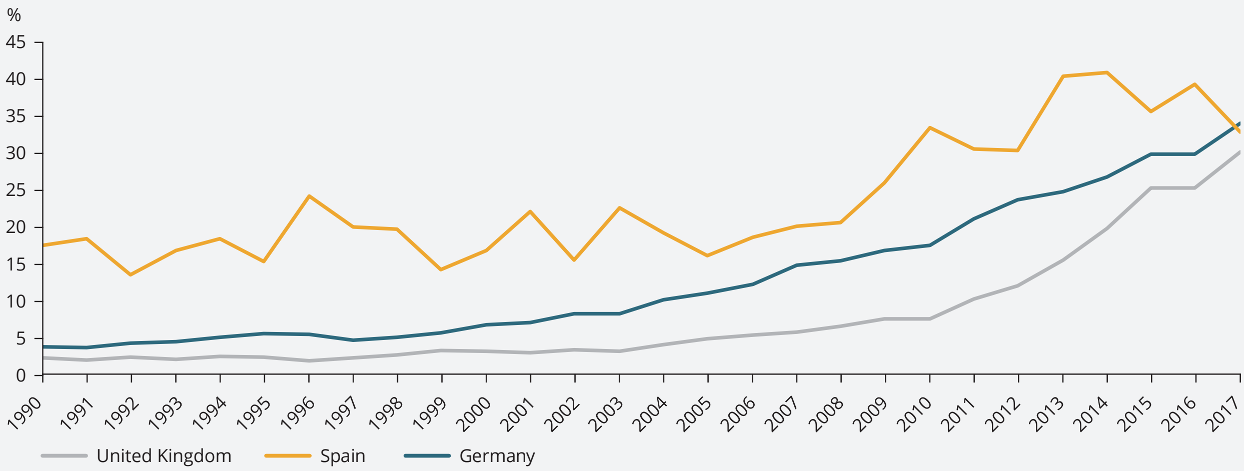
In response to the mainstreaming of organic food, new and more radical branches have emerged in the last 10 years. These have recommitted to initial organic principles and aimed to move the mainstream organic niche towards 'a new level of sustainability, complementing previous approaches with a stronger focus on systemic impact in terms of health, ecology, fairness and care' (von Oelreich and Milestad, 2017).

The organic food example shows that grassroots innovations can diffuse and upscale, but that this may take several decades and often requires dedicated efforts, in terms of community building, political lobbying, professionalisation and engagement with incumbent actors. This mainstreaming may also involve a degree of co-opting, for example through the involvement of supermarkets and large farming businesses, and divergence from initial grassroots visions and values (Berkhout, 2006; von Oelreich and Milestad, 2017). Although organic food has become a profitable and fast-growing market, it remains more expensive than mainstream food, which means that wider diffusion beyond affluent or willing-to-pay consumers may require continued policy support (Aschemann-Witzel and Zielke, 2017).

Box 4.6 Renewable electricity diffusion in the United Kingdom, Germany and Spain

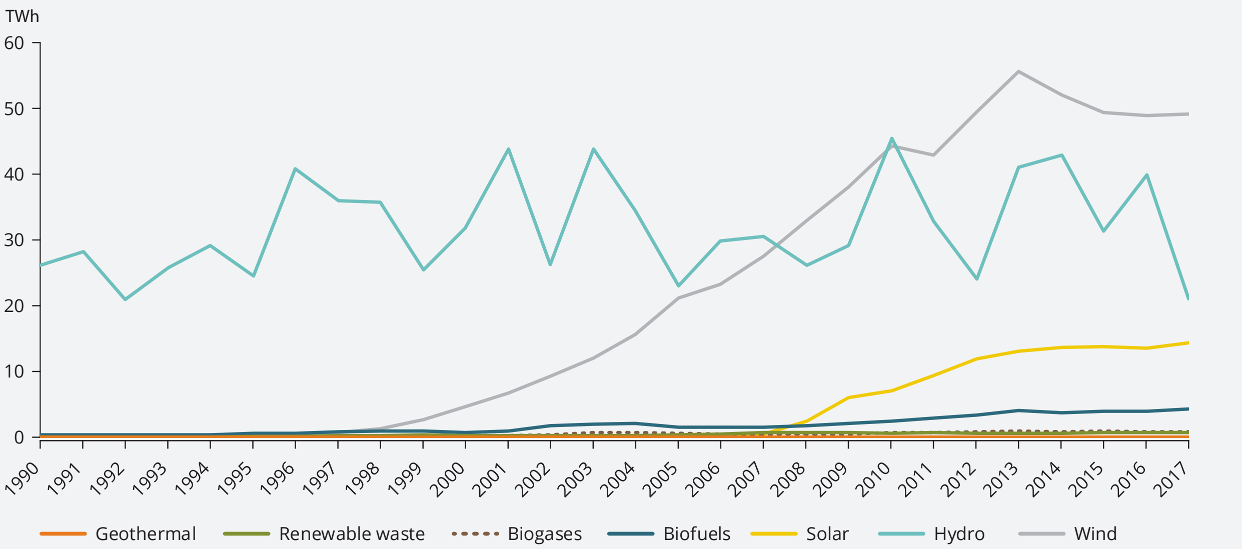
Renewable electricity has diffused substantially in many countries, including Germany, Spain and the United Kingdom, where it produced respectively 34 %, 33 % and 30 % of electricity in 2017 (Figure 4.6). Renewable electricity in Spain started from a relatively high level, based on substantial amounts of hydropower, which varies in output from year to year. Since the late 1990s, however, wind energy has diffused rapidly in Spain, and solar-PV started diffusing in the mid-2000s (Figure 4.7). Renewable electricity in Germany was mainly driven by small-scale options such as onshore wind (in relatively small wind park configurations), biogas and solar-PV (Figure 4.8). After encountering various stop-start dynamics, renewable electricity in the United Kingdom (Figure 4.9) was mainly driven by large-scale options such as onshore and offshore wind (both as large wind parks) and biomass combustion (mainly in converted coal-fired power plants). The rapid diffusion of solar-PV after the introduction of the 2010 feed-in tariff was a surprise to policymakers (Geels et al., 2016).

Figure 4.6 Percentage of gross electricity production from renewable energy, 1990-2017



Source: Eurostat, 2019a.

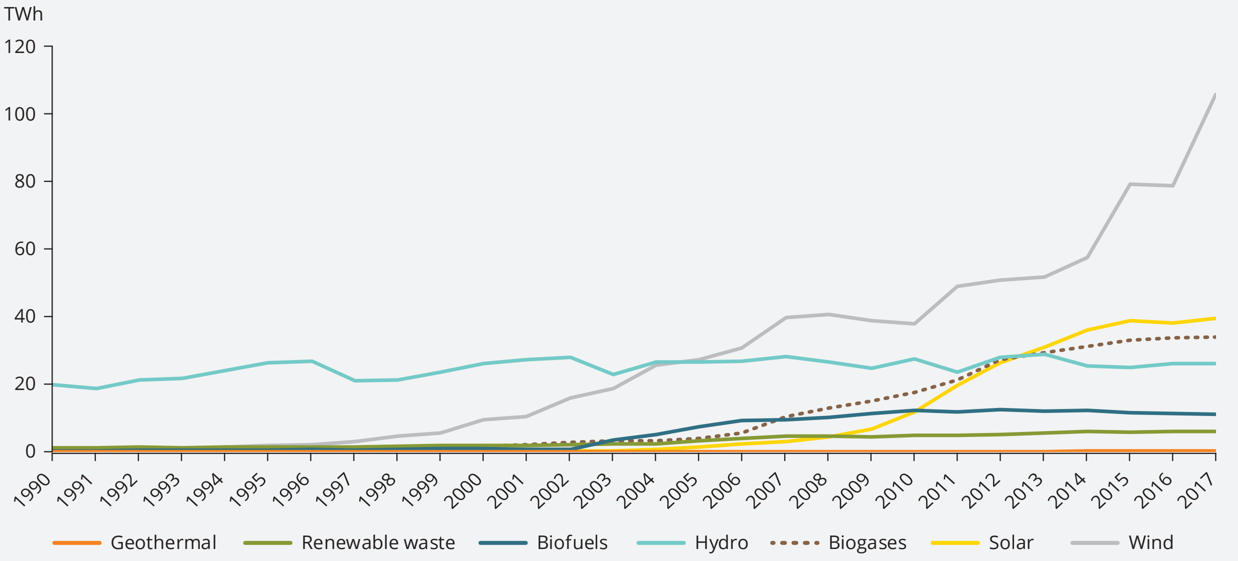
Figure 4.7 Gross electricity production from different renewable energy sources, Spain, 1990-2017



Source: Eurostat, 2019a.

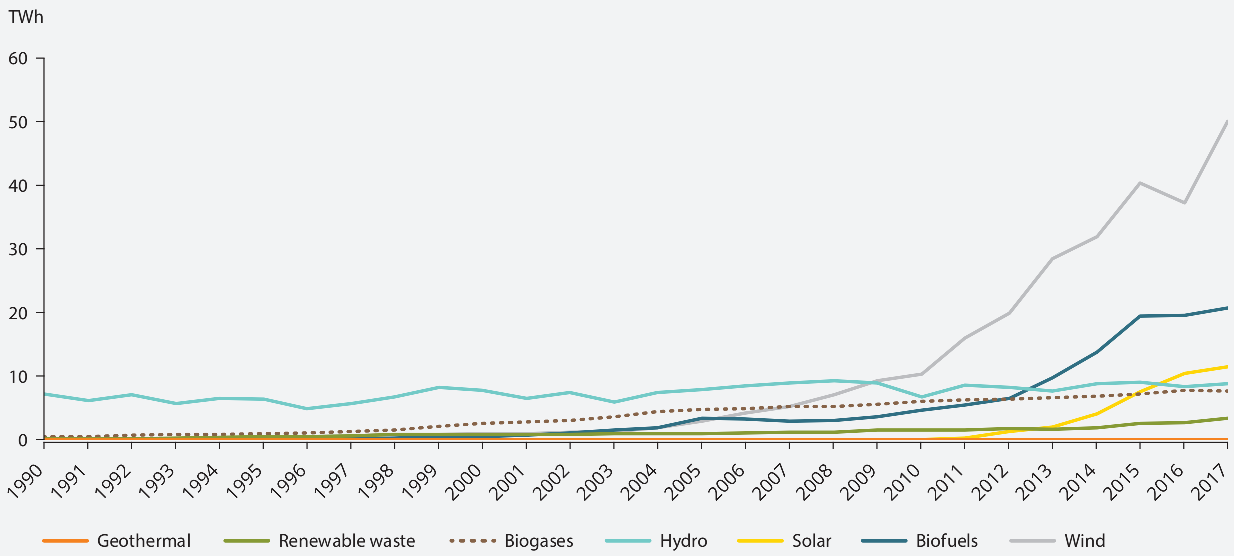
Box 4.6 Renewable electricity diffusion in the United Kingdom, Germany and Spain (cont.)

Figure 4.8 Gross electricity production from different renewable energy sources, Germany, 1990-2017



Source: Eurostat, 2019a.

Figure 4.9 Gross electricity production from different renewable energy sources, United Kingdom, 1990-2017



Source: Eurostat, 2019a.

RET diffusion in all three countries was shaped by a mix of energy policies (targets, plans, financial incentives), innovation policies (research and development, experiments) and industrial policies (Stenzel and Frenzel, 2008; Geels et al., 2016; Matti et al., 2017). The choice of particular funding instruments strongly influenced actor strategies and RET choice. Spain provided generous feed-in tariffs that especially stimulated incumbent utilities, which built and operated most RETs (Matti et al., 2017). In Germany, the 2000 Renewable Energy Sources Act (EEG) also provided stable and generous feed-in tariffs, but these were designed to unleash new entrants such as households, farmers, local utilities and communities (Geels et al., 2016). The United Kingdom policy mix has been very unstable, changing every couple of years. Early policies (non-fossil fuel obligations, renewable obligations) took the shape of auction and trading schemes, which created financial uncertainties that hindered new entrants. Later instruments (adjusted renewables obligations, contracts for difference) provided more stable and targeted support, but also favoured incumbents, who mostly chose large-scale RETs (Geels et al., 2016).

4.4 Enabling wider societal adoption and social acceptance

The diffusion of innovations is also shaped by public debates, cultural discourses and values. Positive discourses and narratives can enhance the cultural legitimacy and social acceptance of innovations (Geels and Verhees, 2011) and underpin stronger policies. 'Whatever can be done through the state will depend upon generating widespread political support from citizens within the context of democratic rights and freedoms' (Giddens, 2009). Negative discourses, on the other hand, may erode social acceptance, weaken political support and hamper diffusion.

RET diffusion in Germany, for example, was initially underpinned by positive stories about renewable energy, green growth and jobs related to German manufacturers of wind turbines and solar panels. It was also supported by a green advocacy coalition, which included not just environmental groups and solar-PV and wind associations, but also metal and machine workers, farmer groups and church groups (Geels et al., 2016). This narrative weakened in the 2010s. This was partly because imports of cheaper Chinese RETs bankrupted many German firms, which eroded the green growth discourse. Partly, it was because renewables deployment was financed by surcharges on consumers, which increased sharply from EUR 0.013/kWh in 2009 to EUR 0.062/kWh in 2014, making German retail electricity prices among the highest in Europe. The rising surcharges also encouraged political opposition from utilities and the Economics Ministry, which translated into a negative discourse.

Social and grassroots innovations sometimes face the challenge that their radical underlying values do not resonate with the wider population. 'Meat free Monday' initiatives (Table 3.5), for instance, have spread in the United Kingdom through some replication, but they did 'not succeed in translating the idea of eating less meat in any significant way into the mainstream, principally because their demands are too radical' (Morris et al., 2014). In this sense, the ideological commitment of grassroots activists may be a weakness for wider societal adoption (Steward, 2018). This problem may be exacerbated by limited diversity in the membership of social and community initiatives. Participants of transition towns, for instance, are overwhelmingly white, middle-class, highly educated and not representative of the demographics of their geographic community (Smith, 2012). This mismatch may create problems with scaling (Moore et al., 2015) and societal adoption.

Social acceptance of innovations is not only about discourses and narratives, but also about listening to stakeholders and addressing their potential concerns. Downplaying such concerns as NIMBY ('not in my backyard') risks creating controversies and stalemates, as happened with onshore wind in the United Kingdom. Planning procedures for project developers initially paid little attention to concerns of local residents about noise, visual burdens, shadow flicker and landscape impacts of wind turbines. This neglect turned many stakeholders into opponents (Ellis et al., 2009). Combined with rising concerns about subsidies and the perceived invasion of the countryside by corporate interests, this gave rise to an increasingly negative discourse and local opposition. As a result, approval rates in planning procedures declined from 73 % in 2007 to 50 % in 2012 (CCC, 2013). Increasing opposition also prompted 100 Conservative members of parliament to write an open letter to the prime minister arguing against wind subsidies (5 February 2012). It was in this context of social acceptance problems that the newly elected Conservative government decided in 2015 to end post-2020 subsidies for onshore wind, even though it is the cheapest RET.

Box 4.7 provides more examples of innovations that experienced social acceptance problems because of resistance against top-down decisions by public authorities and technical specialists, poor consultation procedures, limited trust in government experts or disagreement about what constitutes sustainable innovation.

Box 4.7 Examples of social acceptance problems with sustainability innovations

- Although burning biomass in converted coal-fired power plants can, in principle, reduce carbon emissions, environmental NGOs have criticised this option because of sustainability problems. For example, burning imported pellets from pristine forests in Canada and the United States actually increases emissions when indirect effects are included. In addition, the use of biomass for energy may compete with food production.
- The construction of new overhead transmission lines, which are needed to transport electricity from remote wind farms (e.g. in Scotland or northern Germany) to populations and economic centres (e.g. in England or southern Germany), often encounters local protests because citizens dislike the visual impacts, do not trust experts and feel insufficiently consulted (Cotton and Devine-Wright, 2013).
- Fracking for shale gas production has encountered substantial protests in various European countries (e.g. the United Kingdom, Germany) because of concerns about water pollution and because gas is a fossil fuel.
- In 2009, the Dutch government (and Shell) wanted to experiment with CO_2 storage in an empty gas field under the city of Barendrecht. Their highly technical way of handling citizen concerns exacerbated suspicions, and critical public debate blocked the project (Hajer, 2011). CCS projects in Germany have also been halted by social acceptance problems.

4.4.1 Political strategies to influence societal adoption

Addressing this challenge is less about particular policy instruments and more about wider political strategy: public authorities should not only approach sustainability transitions as techno-economic management challenges, but also engage with stakeholders and articulate appealing visions that inspire people. To prevent or alleviate social acceptance problems, governments could involve citizens, communities and stakeholders more in visioning future transition pathways, selecting preferred innovations, and concrete implementation in specific localities.
A wide range of public participation and co-creation methods have gained prominence in the last two decades, including referendums, public hearings, participatory foresight exercises, scenario workshops, consensus conferences, citizens' panels and public advisory committees (Street, 1997; Van de Kerkhof and Wieczorek, 2005). The European Commission's 'Lamy Group' for instance, 'calls on the European Commission to launch a wide stakeholder debate among citizens, scientists and innovators on potential future [research and innovation] R&I missions for Europe' (EC, 2017e).

Although methods vary in their suitability for different topics and decisions, public participation is generally claimed to offer the following advantages (Fiorino, 1990; Sclove, 1995; Hamlett, 2003):

- **Increasing the democratic legitimacy of decisions:** Involving citizens and stakeholders can help bridge the gap with policymakers, prevent the impression that important decisions are taken behind closed doors and increase trust in democratic processes.
- **Improving the sense that citizens can contribute to creating collective futures:** Involving citizens in decision-making is empowering and may help alleviate feelings of alienation and helplessness (that citizens have no influence).
- **Increased public support and acceptance:** When citizens and stakeholders are involved in decision-making, they are more likely to acknowledge complexities and accept difficult decisions or trade-offs.

- **Increased innovativeness:** Citizens and stakeholders may have specific (local) knowledge and perceptions, so their involvement may help identify problems early and enrich the search for innovative solutions.

- **Preventing delays:** When stakeholders and citizens can express their concerns in early phases of decision-making, they are less likely to protest later on (if they feel their concerns have been sufficiently addressed).

The European Commission recognises the importance of public involvement with regard to transitions, suggesting that 'What is needed is no less than a new pact between science, society and policy. ... R&I activities need to open up to new stakeholders, and citizens in particular' (EC, 2018l). It is important, however, that stakeholder involvement procedures are not just 'tick the box' exercises, that stakeholder involvement is not just passive (informing, consulting) but also active (advising, co-deciding), and that stakeholder concerns and preferences are addressed. Stakeholder engagement should aim to mobilise the 'energetic society' (Hajer, 2011) rather than focusing on technocratic procedures.

4.5 Adjustments in wider policy areas and institutions

The diffusion of green innovations may involve wider adjustments in sectoral policies (e.g. transport, energy, food) and cross-cutting policies (e.g. fiscal, education, industrial). The Commission's BOHEMIA foresight report acknowledges the importance of policy coordination: 'Conditions for uptake of new solutions ... are often defined by sectoral policies (e.g. regulation, standards, procurement), and it is through alignment between sectoral and R&I policies that change can be accelerated' (EC, 2018l).

Diffusion of innovations may also require **institutional and political adjustments.** Established policies and institutional contexts can obstruct the diffusion of radical innovations, especially when these contexts are well aligned with existing socio-technical regimes. In the United Kingdom, for instance, 'community renewables remain weakly developed' (Strachan et al., 2015), partly because of limited organisational capacities and partly because of 'the persistence of key features of socio-technical regime for electricity provision, which continues to favour large corporations and major facilities.' Policymakers may lack the incentives or skills to engage with innovations that are more difficult to assess, quantify and manage, such as social and grassroots innovations. In addition, the diffusion of innovations may be hindered by stop-start dynamics in policies and funding rules (as noted in Section 4.3).

Institutional changes that can support diffusion include establishing agencies (such as energy agencies in Austria or the Committee on Climate Change in the United Kingdom), articulating political goals or programmes, and creating constituencies or advocacy coalitions that support these programmes over time.

BMDH diffusion in Austria, for example (Box 4.1), benefitted from continuous policy support, but the advocacy coalitions and political goals changed over time (Geels and Johnson, 2018). Agricultural policymakers stimulated BMDH from the mid-1980s to address rural problems such as unemployment, a declining industrial base and depopulation.

From the mid-1990s, environmental policymakers in Austria also started supporting BMDH because of climate change concerns, although narratives about 'energy regions' combined economic goals and environmental benefits (Späth and Rohracher, 2010). BMDH was financially supported through the Environmental Promotion Fund (1995), the Green Electricity Act (2002), the CHP Law (2009), and the Law for the Expansion of District Heating and Cooling Networks (2009). From the mid-2000s, BMDH became part of wider biomass strategies (such as the 2006 Biomass Action Plan and the 2010 Austrian Energy Strategy 2020), which emphasised energy self-sufficiency, sustainability, green growth and export opportunities for Austria's world-leading biomass energy systems.

Austrian BMDH diffusion is thus a good example of an issue-linking strategy, in which policymakers framed innovations in relation to multiple policy goals (agricultural, environmental and socio-economic). This created legitimacy and built wider support coalitions that could provide long-term stability for policy support.

The challenges and policy recommendations for embedding radical niche innovations in wider policy environments are further discussed in Chapter 9 on horizontal policy coordination.

> 'The realisation of key transitions requires more than just evolutionary adjustments to current institutions. Significant organisational and institutional changes are necessary to stimulate and manage such transitions, both in the EU and globally.' (EC, 2018l)

5 Disruption and system reconfiguration

Message 3: Support the reconfiguration of whole systems, phase out existing technologies and alleviate negative consequences

- Reconfiguring entire systems should go beyond individual innovations or technological 'silver bullets' and promote synergies between multiple innovations.
- Sustainability transitions can be accelerated by deliberately phasing out unsustainable technologies and systems, for example using bans or targeted financial disincentives, or by removing implicit subsidies.
- Ensuring a just transition requires measures to alleviate negative consequences and help firms, employees and regions to reorient (e.g. compensation, retraining and regional adjustment).

5.1 Reconfiguring entire systems

The diffusion of innovations may require adjustments in wider electricity, transport or food systems (Geels, 2018b; Markard, 2018). But policy efforts often tend to focus on single technological solutions, such as promoting renewable electricity or EVs, potentially neglecting necessary complementary innovations and other changes such as relevant infrastructure development (Markard and Hoffmann, 2016). Such neglect may lead to problems, such as wind parks in Germany and China not being connected to the power grid (Reichardt et al., 2017).

For example, in the electricity system, where sustainability transitions have progressed furthest, the diffusion of RETs increasingly requires reconfigurations in other parts of the electricity system:

- electricity infrastructures need to be expanded (to increase capacity, connect remote renewables and link to systems in neighbouring countries), and upgraded into smart grids to enhance flexibility and grid management;
- energy storage (e.g. batteries, flywheels, compressed air, pumped hydro) is required to address the intermittency of wind and solar energy;
- demand responses (e.g. new tariffs, smart meters and intelligent loads) are needed to improve flexibility;
- new business models and market arrangements (such as capacity markets) are required to improve system security;
- social acceptance and political feasibility is becoming an issue both with regard to electricity costs and levels of public subsidies, and with regard to specific innovations (e.g. smart meters, new overhead power lines, onshore wind turbine siting, nuclear power).

Another example is the mobility transition, where discussions tend to centre on technical innovations such as EVs. The EV30@30 campaign (Box 4.4), for instance, set the collective aspirational goal for all members of the Electric Vehicle Initiative of a 30 % market share for EVs by 2030. Although a shift to EVs would require some degree of system reconfiguration (e.g. battery charging facilities), they would not alter the architecture of the wider mobility system in which the automobility regime dominates railway, bus, cycling and walking regimes in all European countries. Since low-emission vehicles would not address other sustainability problems (e.g. parking, congestion, accidents and urban quality-of-life problems), research suggests that wider reconfigurations of the mobility system are required that go beyond vehicle improvements (Banister, 2008; Creutzig et al., 2018). Such measures would include the following:

- Reducing car use through a **modal shift** from cars to railways, bus or cycling regimes. The integration of bus, subway and railway regimes into an **intermodal transport** system could also make such a modal shift more attractive, as happened in London, where car use declined by 25-35 % between 1995 and 2015 (Geels, 2018b). London's modal shift was enabled by the Oyster card (a smart card, which aligned payment methods and facilitated intermodal travel), investments in public transport and the London congestion charge, introduced in 2003.

- Reducing trip lengths by changing **spatial planning** regimes, e.g. compact cities or transit-oriented development, which aims to mix residential, business and leisure space within walking distance of public transport. These changes in urban space often require very large investments, which is why they are not yet widely spread. Less expensively, some cities have started to close city centres to cars, making them into pedestrian areas with the aim of improving quality of life, shopping and relaxation. In many French cities, this urban reconfiguration was associated with the diffusion of electric trams, which were deployed in the context of more stringent planning rules, raised urban environmental requirements and local infrastructure investment incentives. Trams were introduced in the 1980s to reduce urban car transport, but by the 1990s cities started using them as transformative infrastructure to revitalise city centres and address environmental issues (Turnheim and Geels, 2019).

- Reducing **mobility demand** by teleworking, teleconferencing or internet shopping. The diffusion of computers, laptops and rapid internet is enabling changes in mobility demand, although the system effects are often more complicated than simple substitution. Teleworking may reduce (or postpone) the commute into work, but generate travel for visiting friends to compensate for a lack of social exchange (Cohen-Blankshtain and Rotem-Mindali, 2016). Internet shopping reduces shopping trips for certain goods (e.g. books, groceries, small electrical items), but also increases light van travel to deliver goods at home. There are also speculations that information and communications technology (ICT) devices contribute to young people's lifestyle changes, including reduced desires to own cars or acquire driving licences (McDonald, 2015). Others, however, suggest that these trends may be more related to the economic crisis, youth unemployment, higher fuel costs and a tendency for millennials to delay having children and buying a house (Garikapati et al., 2016).

These examples illustrate that transitions policy should focus on whole systems rather than on single innovations. Not addressing complementarities between innovations may hamper transitions or lead to narrow technology-push approaches. Changing one part of complex systems may also generate unexpected changes in other parts, or feedbacks that undermine sustainability improvements. The potential for such surprises points to the need for adaptive policy approaches (discussed in Chapter 11).

Connections between systems should also receive more attention, as deep changes in one system may require changes in other systems. For example, transitions in mobility patterns may require changes in land use and spatial planning. District heating systems can be coupled with electricity and gas grids, leading to integrated systems in which thermal energy fulfils storage and back-up functions for intermittent electricity (Lund et al., 2014). Combatting climate change requires that shifts to EVs be complemented with transitions towards renewable electricity. Otherwise, EVs in Europe may not generate much less CO_2 than conventional diesel cars (Figure 5.1). Again, these interdependencies reinforce the wider point that transition policies should address entire systems and avoid the displacement of sustainability issues.

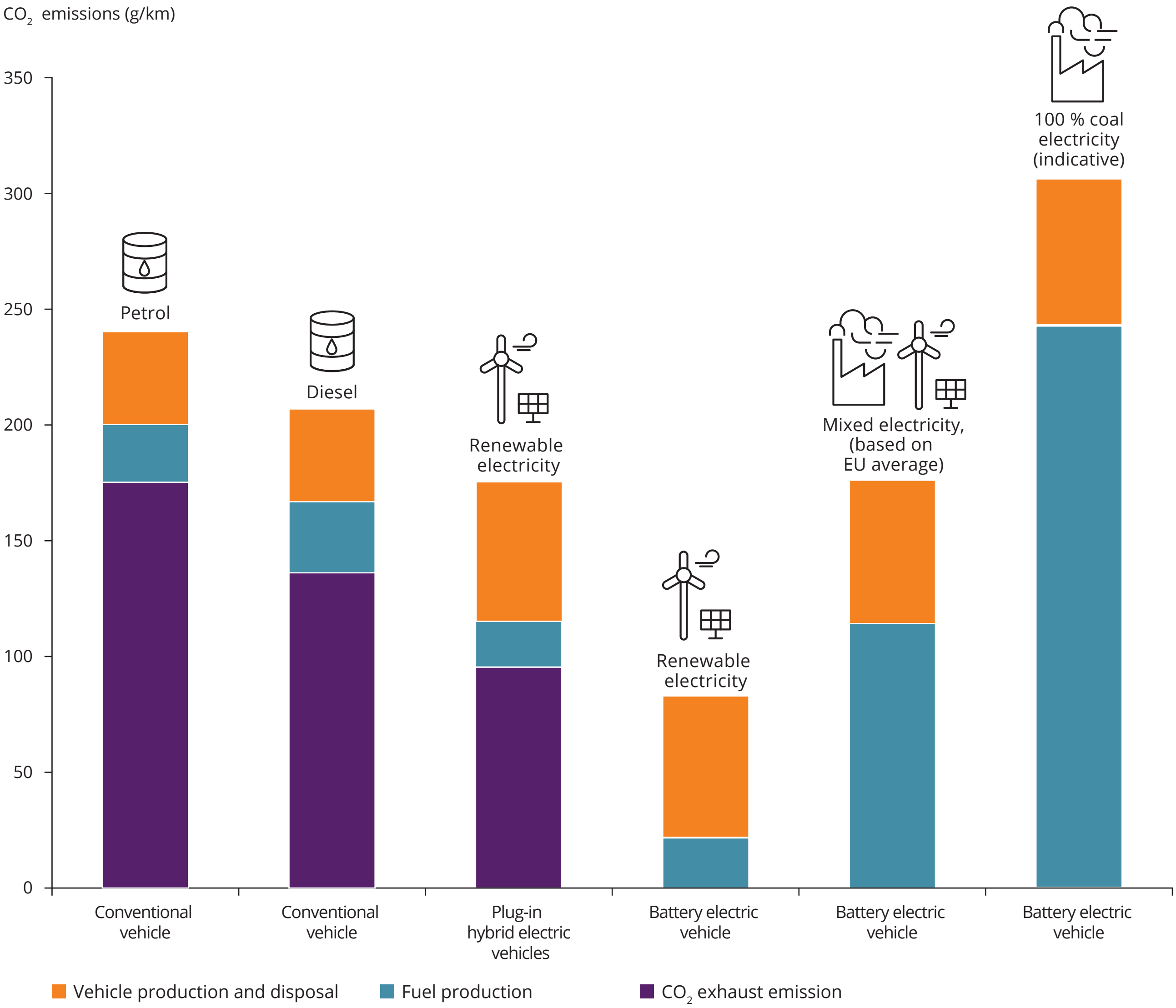
5.2 Deliberate phase-out

Urgent environmental problems such as climate change require an acceleration of sustainability transitions. This implies not only faster diffusion of radical innovations (Chapter 4) but also the deliberate phase-out and decline of existing technologies and practices.

Civil society organisations, activists and social movements can play an important role in destabilising existing regimes (McAdam et al., 1996; Giugni, 1998; Turnheim and Geels, 2012; David, 2018). For example:

- Media campaigns, public debates, (scientific) publications and reports can advance particular frames, discourses and metaphors that erode the

Figure 5.1 **Life-cycle CO_2 emissions for different vehicle and fuel types**



Source: EEA, 2016a.

cultural legitimacy of technologies or practices (Benford and Snow, 2000) and indirectly create pressure on policymakers. Although these cultural changes in meanings and perceptions are often slow, they may profoundly shape views of normality, such as may be currently happening in relation to single-use plastics.

- Public demonstrations, rallies, marches, direct actions, boycotts, petitions and legal actions can draw attention to particular problems and push them onto political agendas.

- Protests and boycotts may exert direct pressure on firms to change particular products or firm practices (Den Hond and De Bakker, 2007).

Table 5.1 provides examples of protest activities aimed at regime destabilisation in various domains.

Public authorities can also be instrumental in the decline of existing technologies and practices (Kivimaa and Kern, 2016; David, 2018). Although explicit phase-out policies are still quite rare, they are gaining political salience and have already been used in some instances.

- **Incandescent light bulbs:** The European Commission's 2009 phase-out decision accelerated the transition towards compact fluorescent lights (CFLs) and LEDs.

- **Nuclear power:** The 2011 German nuclear phase-out decision accelerated the transition to renewables, although it also (temporarily) increased the use of brown coal to fill the production gap. Governments in Belgium, South Korea, Switzerland and Taiwan have also decided to phase out nuclear power.

- **Unabated coal-fired power stations:** In 2015, governments in Finland, the Netherlands, Quebec and the United Kingdom decided to phase out coal. In November 2017, 19 countries created the 'Powering Past Coal Alliance', which pledged to phase out coal use.

Table 5.1 Protest activities aimed at regime destabilisation in various domains

Domain	Examples
Coal	In 2007 and 2008, when the United Kingdom government was considering future coal-fired power plants, environmental activists occupied a chimney at Drax power station and blocked the coal supply to Kingsnorth power stations. These protests and the subsequent trials attracted substantial media attention, which informed public debate, and contributed to the government's decision to phase out unabated coal.
Oil	In 2018, Friends of the Earth Netherlands threatened Dutch Shell with legal action unless it stepped up efforts to comply with the Paris Agreement on climate change. In 2018, New York City, Oakland and San Francisco sued five oil companies for climate change damages. They alleged that the oil companies had known about the detrimental effects of burning fossil fuels for decades but had delayed and actively frustrated actions.
Air pollution and diesel cars	The activist organisation ClientEarth successfully launched three successive air pollution court cases against the United Kingdom government. In 2018, the courts criticised the government for the third time for failing to produce an adequate plan to tackle air pollution (especially from diesel cars). The high court ruled that the government's policy on air pollution was unlawful and ordered changes.
Dairy milk	NGO media campaigns have criticised dairy milk farming on environmental, animal welfare and health grounds. The 2010 campaign 'healthy planet eating' by Friends of the Earth linked dairy production and consumption to climate change, water pollution and health problems (such as strokes, cancer and obesity). The 2014 'white lies' campaign of the animal welfare group Viva! attacked the dairy industry's claims that milk is healthy and nutritious. Drawing on peer-reviewed academic studies, they suggested that dairy milk is implicated in many diseases (including allergies, arthritis, some cancers, and coronary heart disease). PETA's (People for the Ethical Treatment of Animals) 2014 'ditch dairy' campaign also attacked milk's health claims, linking dairy consumption and autism. It also portrayed dairy milk consumption as unnatural, since only humans consume milk across species. These campaigns have started to erode the positive meanings that were long associated with milk, changing consumer preferences in some population segments (Mylan et al., 2018).
Fossil fuels	In 2017 and 2018, the divestment movement organised student protests on many campuses, demanding that universities divest from fossil fuels. Although the direct financial effects have remained small, the divestment movement has succeeded in shaping wider public discourses (Bergman, 2018).

- **Petrol and diesel cars:** Sales bans for internal combustion engine vehicles have been announced for 2025 (by Norway), for 2030 (by Austria, China, India, Ireland, Israel, the Netherlands and Slovenia), and for 2040 (by France, Sri Lanka, Taiwan and the United Kingdom) (CCC, 2018).

5.2.1 Contrasting phase-out patterns

Phase-out policies are challenging, especially when they threaten large and powerful industries, which are likely to resist to protect their vested interests (Geels, 2014). Phase-out policies can take many forms (Kivimaa and Kern, 2016), including bans or regulations; removal of implicit or explicit subsidies; and targeted financial incentives, which make a technology more or less attractive. Box 5.1 shows that combinations of these policy instruments can lead to particular phase-out patterns. To reduce the likelihood of resistance against phase-out policies, policymakers should consider transitional strategies such as phased tightening of regulations, financial compensation, retraining of personnel and redevelopment programmes for disadvantaged regions (Section 5.3).

Box 5.1 Different phase-out patterns in lightbulbs, nuclear energy and coal

Technological phase-out can follow different patterns, as illustrated in the following three examples.

1. Gradual regulatory tightening, culminating in a deliberate phase-out decision

The European 2009 decision to phase out incandescent light bulbs (ILBs) followed this pattern. In the early 1990s, governments tried to stimulate the shift towards more energy-efficient lighting, such as CFLs, by providing information to consumers. The 1992 Energy Labelling Directive (EU, 1992), for instance, required manufacturers to indicate light bulb efficiency on packaging. When this proved to have limited effects, governments in the late 1990s urged electric utilities to promote energy-efficient lighting, initially through voluntary measures, later through mandates (Visser, 2012; Howarth and Rosenow, 2014).

Even though utilities subsidised the sale of CFLs at the point of retail, consumer uptake remained low. These repeated failures helped to create the grounds for the 2009 EU phase-out decision. However, this European decision also resulted from pressure from various Member States, such as Germany and the United Kingdom, which had already in 2007 decided to phase out ILBs. Major light bulb manufacturers, such as Philips, Osram-Sylvania and General Electric, also lobbied for the ban because they were losing the commercial struggle with Chinese manufacturers of ILBs. For them, the ban shifted the battleground to CFLs and LEDs, where they had a (temporary) advantage (Visser, 2012). Thus, the ILB ban could be introduced because it was the result of gradual regulatory tightening over time, and because it combined environmental, energy-efficiency, industrial and trade policy goals. It therefore also highlights the role of issue linkage and horizontal policy coordination (see Chapter 9).

2. An external (landscape) shock destabilises a regime and leads to a rapid phase-out decision

The 2011 German nuclear phase-out decision was introduced after the Fukushima accident, although prior developments had already eroded the German nuclear power regime. In the early 1980s, the German anti-nuclear movement developed a discourse that framed nuclear power as an existential threat. The 1986 Chernobyl accident reinforced this framing, leading to negative public views and discourse (Hermwille, 2016). Successive right- and left-wing governments protected and propped up the nuclear power regime. However, the formation of a coalition government between the Social Democrats and the Green Party in 1998 led to a nuclear phase-out decision in 2002, with a gradual implementation path that would start in 2020. Utilities fought this decision between 2002 and 2009. In 2009, the new coalition government between the Christian Democrats and the Free Democratic Party overturned the earlier phase-out decision, which led to public protests.

The 2011 Fukushima accident then created public outrage, which led Chancellor Merkel to perform another political U-turn and decide on a nuclear phase-out. This decision was also shaped by contextual contingencies, namely two state-level elections that Merkel thought she might lose (Rogge and Johnstone, 2017). This example demonstrates the importance of longitudinal event chains (without the 2009 U-turn, the public outrage in 2011 might have been less pronounced).

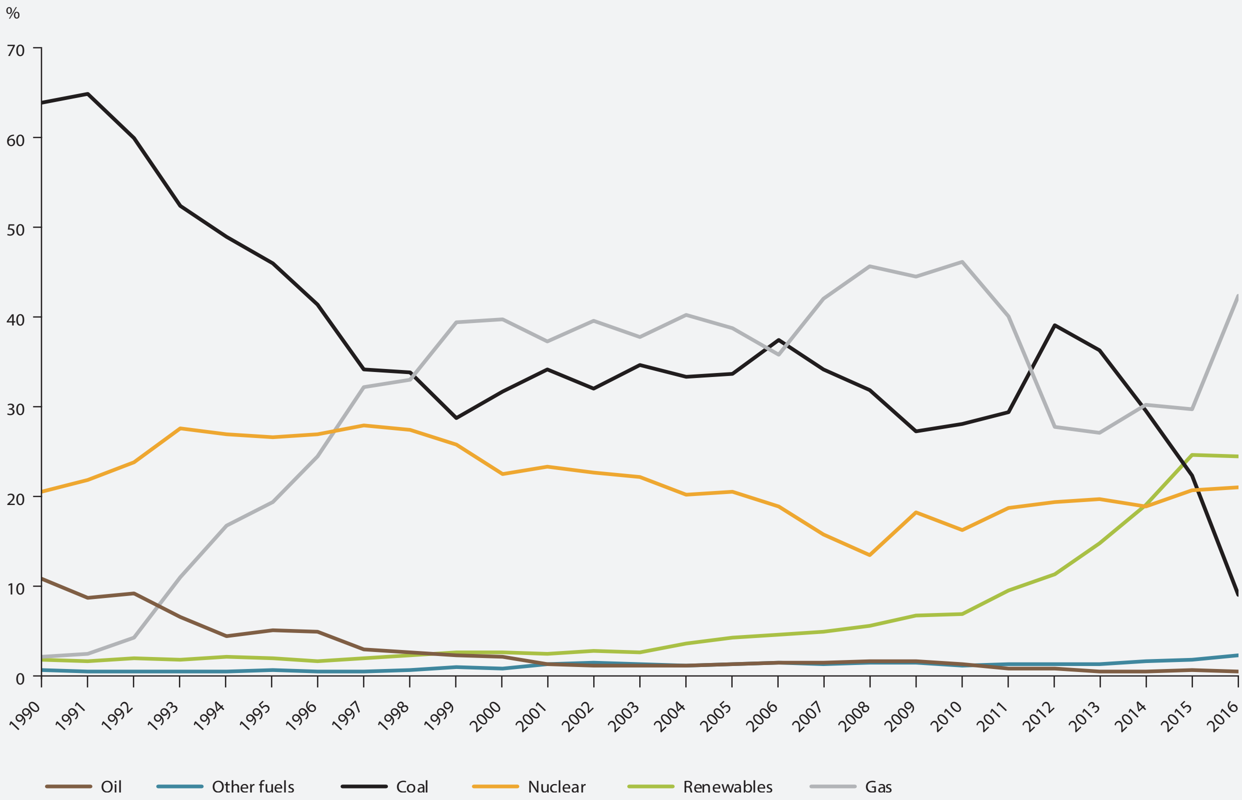
It also shows that shocks and crises create opportunities for drastic policy change, including phase-outs. Strategically, this implies that policymakers could prepare particular solutions, which they can then push through when shocks open particular windows of opportunity (Kingdon and Thurber, 1984; Klein, 2007).

Box 5.1 Different phase-out patterns in lightbulbs, nuclear energy and coal (cont.)

3. Market-driven phase-out modulated by strengthening policies

In 2015, the United Kingdom government announced its intention to phase out coal-fired power generation by 2025. A decline of coal-fired power generation was already under way and accelerated further in 2015 and 2016 (Figure 5.2). This was partly the result of market forces: for example gas prices fell by 19 % between 2015 and 2016, while coal prices increased by 16 %. Partly it was the result of climate policies that made coal use more expensive. The United Kingdom Carbon Floor Price policy added a tax on CO_2 emissions from power generation on top of the carbon price from the European Emissions Trading Scheme. Coal has therefore been largely driven from the United Kingdom electricity system by market forces, amplified by public policies.

Figure 5.2 United Kingdom electricity generation by fuel type, 1990-2017



Source: Eurostat, 2019a.

5.3 Alleviating negative consequences and helping firms, workers and regions to reorient

Besides positive impacts, the diffusion of sustainability innovations can also have negative consequences in particular regions or locations or for particular social groups.

- Sustainability innovations may have **negative effects for local residents and communities.** As noted in Chapter 4, local communities may be negatively affected by renewable energy infrastructure, such as overhead power lines or wind turbines because of visual effects or noise (Cotton and Devine-Wright, 2013).

- The diffusion of sustainability innovations may have **distributional effects.** For example, middle-class households tend to be early adopters of subsidised solar panels or electric cars. But this, in effect, implies a regressive distribution of taxes, with poorer households benefiting less from the transition (Jenkins et al., 2018). Similarly, essentials such as energy and food normally account for a comparatively high percentage of the consumption expenditure of poorer households, so tax measures that increase energy and food prices will affect those households disproportionately (EEA, 2011).

- Some social groups may experience **vulnerabilities with regard to particular innovations.** The roll-out of smart meters, for example, may not benefit certain social groups, such as people with limited computer skills (e.g. the elderly or those with poor education) or people living in high-rise social housing complexes or in rural areas, where smart meters do not function properly (Sovacool et al., 2017b).

- Sustainability innovations may disrupt established systems and lead to the **economic decline of existing industries**, often located in specific regions. Renewable energies, for example, are threatening coal-fired power plants and coal-mining regions in Germany (Vögele et al., 2018), while shale gas is having similar effects in the United States (Mayer, 2018). This is leading to acute threats of political opposition in communities and regions where high-carbon industries are major employers and sources of local tax revenue.

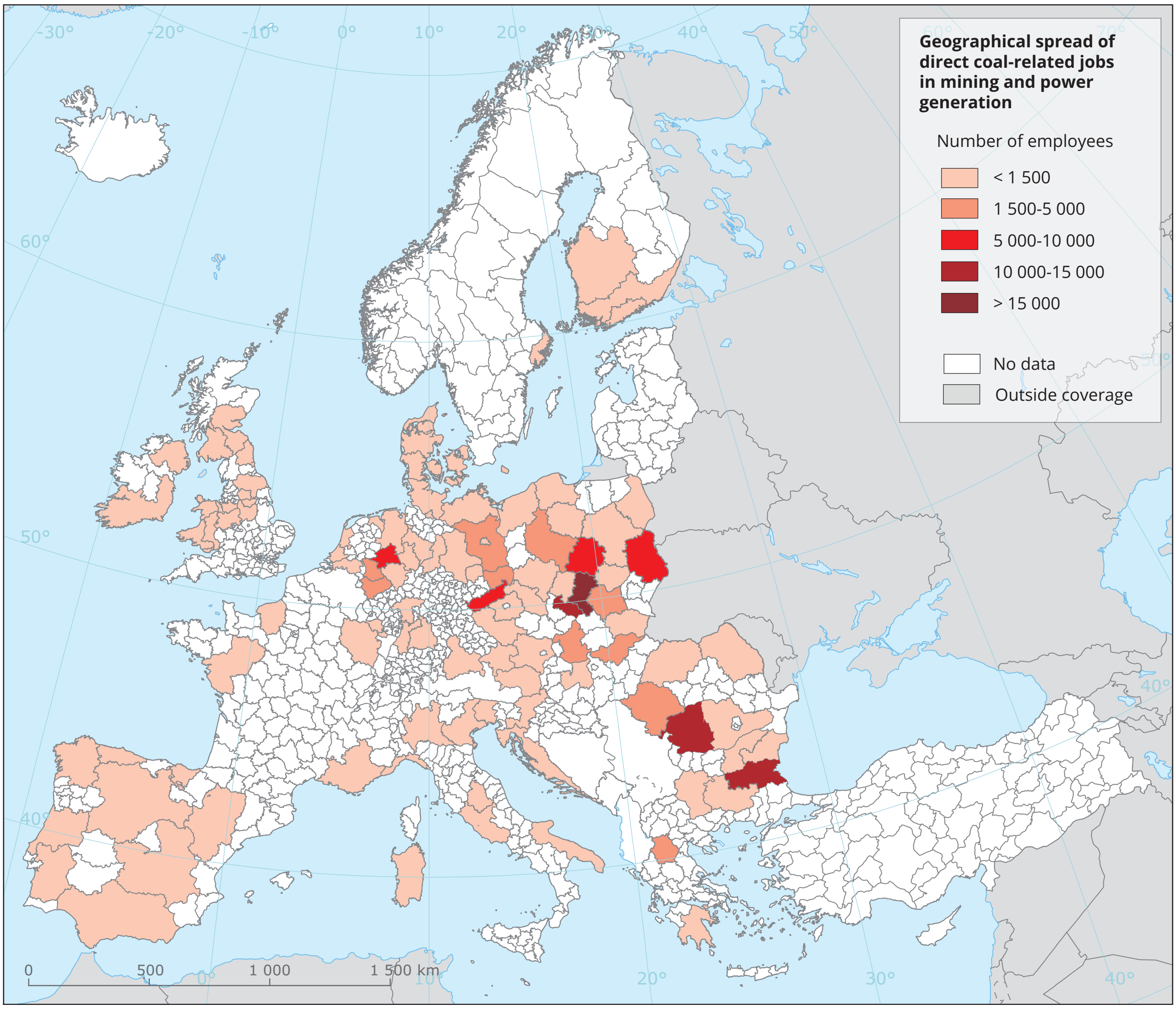
Real or expected negative consequences may lead particular communities, social groups, firms or regions to resist sustainability transitions through public protests, media campaigns or political lobbying strategies (Geels, 2014). To mitigate social protests and make transitions more fair and inclusive, the literature on just transitions (Swiling and Annecke, 2012; Jenkins et al., 2018) argues that public authorities should try to alleviate negative consequences. The International Labour Organization has elaborated *Guidelines for a just transitions towards environmentally sustainable economies and societies for all*, which acknowledge that transitions create both employment opportunities and challenges (ILO, 2015). Calls for a just transition have also become increasingly salient in policy contexts. For example, the Paris Agreement on climate change includes a commitment to take into account 'the imperatives of a just transition of the workforce and the creation of decent work and quality jobs' (UNFCCC, 2015).

The first three negative effects listed above can be alleviated by listening to stakeholder concerns, consulting them in early policy design processes (which may lead to design alterations to mitigate concerns), offering (financial) compensation if no solutions can be found, and providing assistance or training to vulnerable groups.

Addressing the fourth effect (economic decline of existing industries) is more difficult. The decline of certain technologies (such as the extraction and use of coal) is the direct and often intended effect of sustainability transitions. However, this decline is likely to have negative socio-economic consequences for incumbent firms, employees and regions. For instance, the past decline of old industrial regions dependent on coal, steel or bulk chemicals (e.g. Lorraine in France, Limburg in Belgium and the Midlands in the United Kingdom) disrupted entire communities, creating long-lasting unemployment and other social problems (Baeten et al., 1999; Campbell and Coenen, 2017). As an important example, the transition to a climate-neutral Europe is likely to have disruptive socio-economic consequences for the coal sector, which in Europe provides about 60 000 jobs in coal-fired power plants and about 180 000 jobs in coal mining. These are mostly concentrated in eastern Europe (Map 5.1).

Historically, governments have not always sufficiently intervened in the decline of old industrial regions. To alleviate negative socio-economic consequences of sustainability transitions, policy should therefore assist reorientations more actively than in the past. Kohler (2014) argues that a just transition requires three elements: sustainable industrial policy, robust social protection or safety nets, and wide-reaching and creative labour adjustment programmes. Of these, 'a robust social safety net is an absolute prerequisite to a just transition' (Kohler, 2014). Table 5.2 distinguishes several potential policy options with regard to workers, regions and companies, divided

Map 5.1 Geographical spread of directly coal-related jobs in mining and power generation



Source: Alves Dias et al., 2018.

Table 5.2 Different kinds of policies to address negative socio-economic consequences of transitions for workers, regions and firms

	Compensation (defensive, reactive)	Structural reorientation (active)
Workers	Compensation for losses, e.g. redundancy payments, early retirement benefits	Skill-upgrading and retraining programmes, financial assistance to relocate, wage subsidies, assistance in finding new jobs
Regions, communities	Compensation for losses (e.g. increased resource transfers to local policymakers or regions), relocating public agencies to particular regions	Regional assistance for economic diversification, e.g. direct investments in public goods (e.g. infrastructure), regional innovation policy, subsidies or tax incentives to new businesses in growth sectors, technical assistance
Firms	Compensation for lost asset value or continuation of existing privileges; state subsidies of company liabilities (e.g. pension or site remediation liabilities)	Grants or in-kind assistance to (i) upgrade existing technologies or practices, (ii) stimulate reorientation towards new technologies and markets

Source: Adapted from Spencer et al., 2018.

into defensive ones (focused on compensation or the continuation of sector-specific employee privileges, e.g. the use of company cars) and more active ones (aimed at reorientation, innovation and skills). The relatively successful reorientation of the German Ruhr region in the 1980s and 1990s involved both kinds of policies (Box 5.2).

The European Commission has recently created the multi-stakeholder Platform on Coal and Carbon-Intensive Regions (EC, 2017f). Its aim is:

> to assist Member States and regions in their efforts to modernise their economies and prepare them to deal with the structural and technological transition in coal regions. It brings together regions, national authorities, societal and business stakeholders, innovation and financing experts in order to identify the best ways to seize the opportunities of the transition. EU Cohesion Policy contributes to the initiative by providing a structural and long-term response to industrial transition and restructuring of European regions. (EC, 2018b)

The platform will help develop structural reorientation policies to support regional transitions from coal towards other sectors, such as electric mobility, digitalisation and data centres, local energy communities, tourism and agricultural activities. Pilot projects have started in Silesia (Poland), West Macedonia (Greece) and Trencin (Slovakia).

More generally, the European Commission has several broad policy areas that could be further mobilised to mitigate potential negative consequences of sustainability transitions:

- **Cohesion policy**, which in general has started to move from a reactive social welfare orientation (transferring funds to less developed regions) to more active reorientation approaches, could assist regional reorientation towards sustainability transitions. Smart Specialisation Strategies, in particular, which steer cohesion policy funding for innovation and deployment, are well suited for this. Their focus on innovation, public-private

Box 5.2 Restructuring Germany's Ruhr coal region

In the 1970s and 1980s, the Ruhr region's coal, steel and related industries, which employed more than half a million people, faced economic decline because of cheaper imports. Initial efforts aimed to improve competitiveness by means of subsidies and mergers. When this proved insufficient, controlled mine and plant closures provided compensation payments, early retirement packages and wage subsidies.

By the mid-1980s, the state of North Rhine-Westphalia also engaged in proactive industrial policy, aimed at stimulating 'sunrise technologies' such as environmental technologies (e.g. energy efficiency, renewable energy, recycling and waste combustion), which could build on existing engineering capabilities. This regional diversification strategy succeeded in making the Ruhr area one of the key centres for environmental industry, technology and research in Germany. The diversification strategy also focused on 'industrial culture', using former mines and steel factories for tourist purposes: the Zollverein industrial coal complex, for instance, became a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site and regional museum.

The reorientation strategy deviated from traditional top-down industrial policy and was enacted in partnership with municipalities, universities and private actors. 'The late 1980s and 1990s witnessed the beginning of new bottom-up development approaches, guided by regional planning and key State (Land) institutions, but designed and implemented by local groups. The 'renewal from within approach' was organised in close dialogue with and met with approval in the local community' (Campbell and Coenen, 2017).

The reorientation initiative of the Emscher sub-region, for instance, which lasted from 1989 to 1999, was based on proposals from municipalities, companies, NGOs and individuals to address five strategic themes: renovation of the Emscher landscape into parkland, ecological regeneration of the Emscher River system, development of new work locations in derelict industrial sites, development of new housing forms and urban districts, and new uses for industrial buildings and industrial monuments. In a 10-year period, 123 cooperative projects were implemented, varying from setting up technology centres to innovative and green renovation of apartments and the restoration of industrial monuments for touristic purposes.

Although policymakers were important for providing strategic direction, quality control and funding, their crucial role was also to facilitate 'dialogue and collaboration between stakeholders that led to the inception of 'regional development coalitions', i.e. bottom-up, horizontally based co-operation between different actors in a local or regional setting based on a socially broad mobilisation and participation' (Campbell and Coenen, 2017).

Source: Drawing on Campbell and Coenen, 2017.

partnerships, entrepreneurial discovery and bottom-up learning (Capello and Kroll, 2016) resonates closely with the policy messages on promoting transformative innovation and experimentation (see Chapter 3). Current Smart Specialisation Strategies primarily focus on economic growth, but they could be reoriented more towards sustainability transitions. Since innovation capacities, administrative skills and political institutions vary across European regions, Smart Specialisation Strategies are developed through bottom-up processes involving local and regional actors and do not follow a 'one-size-fits-all' model.

- **Industrial strategy** can also be mobilised to facilitate structural reorientation, as the German Ruhr example (Box 5.2) illustrates. Although the EU's Renewed Industrial Strategy (EC, 2017c) is driven by concerns that Europe is lagging behind in new industries (robotics, artificial intelligence, Internet of things), it also puts strong emphasis on transitioning to a circular and low-carbon economy. An effective European industrial strategy will require vertical coordination and multilevel governance (see Chapter 10), since 'most tools to stimulate and support industrial competitiveness are available on the national and regional level' (EC, 2017c).

- **The EU Skills Agenda** also offers potential for alleviating negative consequences, noting that 'the transition to a low-carbon and circular economy means creating and adapting to business models and job profiles' (EC, 2016e). Again, the fact that responsibilities for teaching, education and training mainly lie with Member States implies that a European skills strategy for sustainability transitions will require vertical coordination (discussed in Chapter 10).

> 'The benefits of industrial transformation need to be widely spread and those who lose out must be able to find opportunities and support to adapt. Lifelong learning, equal opportunities and fair access to education, training and technological skills are at the heart of building such resilience.' (EC, 2017c)

6 Strengthening the role for cities and urban action

Message 4: Leverage and strengthen the role of cities in sustainability transitions

- Cities are key hubs of innovation and experimentation. Governments can support this transformative potential with more resources and local responsibilities, and with clearer criteria for urban sustainability.
- Diffusion of urban sustainability innovations can be further supported by attending to learning, networking and replication of best practices. City networks may act as crucial vehicles for diffusion.
- Urban transitions are also about whole system reconfiguration at city levels. Governments can support system change by providing financial, technical and administrative support and capacity-building.
- Monitoring and evaluation of local sustainability actions are often weak, undermining opportunities for learning. EU and national actors can help develop robust metrics and evaluation procedures.

International policy frameworks increasingly recognise the relevance of cities for transitions. The Paris Agreement on Climate Change created a new space for local and non-state action. SDG 11 aims to 'make cities inclusive, safe, resilient and sustainable' and the United Nations has adopted a 'New Urban Agenda' (UN, 2017).

In Europe, the 2016 Pact of Amsterdam (EU, 2016b) established the 'Urban Agenda for the EU', providing a new working method to improve cooperation between urban areas and European bodies, to address societal challenges. The Pact of Amsterdam recognises an important role for cities and 'strives to involve urban authorities in achieving better regulation, better funding and better knowledge' (EU, 2016b). In effect, it has afforded cities a 'seat at the table' of EU governance (Potjer and Hajer, 2017).

Cities have a particularly important role in sustainability transitions because they are a locus for innovation, they provide great opportunities for learning and networks, and they offer the possibility of achieving

Table 6.1 Core governance principles of the Urban Agenda for the EU

Principles	Recognition within the EU Urban Agenda	Relevant transition processes and mechanisms
Local	'Urban areas play a key role in pursuing the EU 2020 objectives and in solving many of its most pressing challenges ... Urban authorities are often the level of government closest to the citizens'	**Experimentation** • Local initiatives • Trial and error, learning by doing
Horizontal	'Knowledge on how urban areas evolve is fragmented and successful experience can be better valorised, diffused and exploited. The Urban Agenda for the EU therefore intends to enhance a better urban policy knowledge base and the exchange of good practice'	**Diffusion** • Shared learning • Circulation of knowledge • Replication of practices • Generic lessons
Vertical	There is a need 'to establish a more effective integrated and coordinated approach to EU policies and legislation with a potential impact on urban areas ... to involve urban authorities in the design of policies, to mobilise urban authorities for the implementation of EU policies, and to strengthen the urban dimension in these policies to work in a more systematic and coherent way towards achieving overarching goals'	**System reconfiguration** • Institutional innovation • Vertical coordination

whole system change at local scales. The potential for cities to contribute to key transition processes — experimentation, diffusion and wider system reconfiguration — is emphasised in the EU's Urban Agenda (UN, 2017; Table 6.1).

6.1 Cities as sites for innovation and experimentation

Urban experimentation has become a new means of governance of sustainability challenges (Broto and Bulkeley, 2013), particularly with regard to long-term systemic issues. Cities present specific kinds of socio-technical settings characterised by densely networked infrastructures and services. Cities and regions have strategic agency, dedicated budgets and responsibilities for providing local services such as fresh water and sanitation, mobility, energy and waste disposal, particularly in countries with political decentralisation (such as Sweden) or federalism with strong municipal autonomy (such as Germany) (Ehnert et al., 2018). For local systems, cities may thus be in a position to support key transition processes, in close interaction with citizens and other actors.

> 'Cities are the hubs where the different ingredients of innovation come together to unleash social and economic dynamics. They are also important laboratories to harness the forces of change and to learn how to establish new collective learning mechanisms in face of fast and disruptive change.' (EC, 2018l)

Cities such as Birmingham, Castellon, Frankfurt, Valencia and Wroclaw, have begun to implement comprehensive urban transition programmes that promote 'stakeholder partnerships to maximise the learning and economies of scale that arise from a focused, concentrated approach' (CKIC, 2015). Other cities are actively engaging with more sustainable heating technologies and local transport systems (Table 6.2) or developing experimental neighbourhoods and urban living labs, which are 'sites devised to design, test and learn from social and technical innovation in real time' (Marvin et al., 2018). Many cities are engaging actively in transforming urban food systems and sharing successful practices, for example as signatories of the Milan Urban Food Policy Pact (MUFPP, 2019). A number of pioneering cities are also setting ambitious local targets, sometime exceeding national pledges, in an effort to lead by example and demonstrate that transitions are possible (Table 6.3).

The groundswell of urban sustainability experimentation is apparent in a variety of domains. For example:

- **mobility:** bike sharing, modern tram and bus systems, innovative public transport links, multimodal mobility and integrated ticketing;
- **energy provision and distribution:** generation of CHP, district heating, urban community energy;
- **food:** AFNs, urban farming and gardening.

Table 6.2 Examples of city engagement with sustainable heating and transport programmes

Domain	City	Action
Heating	Rotterdam (NL)	Promotion of residual heat use in district heating
	Vienna (AT)	Promotion of district heating and waste incineration
	Stockholm (SE)	Large proportion of renewable energy in district heating
	Munich (DE)	Geothermal energy deployment and 100 % renewables target
	Barcelona (ES)	Ordinance supporting large proportion of solar thermal water heating (60 % target)
Transport	Oslo (NO)	Highest density of EVs in the world
	Amsterdam (NL)	Highest density of private EV-charging points
	Barcelona (ES)	Experimentation with wind-powered EV-charging station
	Linköping (SE), Stockholm (SE)	Large-scale roll-out of biogas and biomethane bus fleets
	Aargau (CH), Bolzano (IT), Milan (IT), London (UK), Oslo (NO)	Experimentation with fuel cell hydrogen bus fleets

Note: EV, electric vehicle.

Source: Based on IRENA, 2016.

6.1.1 *Strengths of cities in developing sustainability solutions*

Cities present several advantages for developing sustainability solutions in terms of governance, stakeholder relationships, infrastructure and institutional support mechanisms.

First, local authorities can trial solutions on a relatively small scale before rolling them out more widely. For example, some pioneering bike-sharing schemes started with fewer than 100 bikes. The Vélib' scheme in Paris started with 7 000 bikes in 2007 and gradually expanded to over 20 000 (DeMaio, 2009). Cities can also use portfolio approaches and experiment with different options in various districts (Heiskanen and Matchoss, 2018), or urban authorities can enable commercial innovation trials by generating special conditions (testbeds), for example autonomous public transport or EVs.

Second, the city scale provides opportunities for engagement with users, citizens and other relevant actors that can support concrete implementation, feedback, learning and adjustments to innovation efforts. For instance, the deployment of modern tramways in French cities involved stakeholder consultations in on-going learning processes, leading to ways of handling grievances about disruptions during construction (e.g. through compensations, dialogue, rerouting) (Turnheim and Geels, 2019).

Third, urban sustainability experiments can use infrastructural opportunities. For example, urban gardening schemes can re-appropriate under-used infrastructure (parking lots, rooftops, pavements) for environmental and social purposes. Cities such as Frankfurt have mobilised public buildings to support an ambitious energy retrofit programme, demonstrating technical feasibility and generating local capabilities and partnerships (CKIC, 2015).

Fourth, local authorities can support social innovation and grassroots initiatives in urban sustainability experiments by providing institutional support, such as facilitation, reducing risks, political commitment and access to unused urban space. London, for example, supported experimentation with urban farming and gardening in the context of its 2012 Olympics investment and marketing campaign, notably providing support and encouraging local initiatives through the Capital Growth programme. This social initiative received direct support from the Mayor of London, the Greater London Authority, and the Big Lottery Fund's Local Food Programme.

6.1.2 *External support for urban experiments*

While local actors are important for driving urban experiments, they often depend on some form of external support and nurturing, such as from the EU, public utilities or central government schemes (Rydin et al., 2013). They may also depend significantly on the wider regional areas that form the urban hinterland (particularly concerning mobility and food systems). This means that cities are not autonomous in designing and implementing sustainability innovations and that multilevel governance and new forms of administrative cooperation are important (further discussed in Chapter 10).

At the European level, a number of funding mechanisms exist to support the development of innovative urban sustainability solutions. The Urban Innovative Actions initiative provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges, with a total budget of EUR 371 million for the period 2015-2020. URBACT is a European exchange and learning programme that promotes sustainable urban development and helps cities work together to develop pragmatic solutions to urban challenges. It is co-financed by the European Regional Development Fund, EU Member States, Norway and Switzerland. URBACT III has a budget of EUR 96.3 million for the period 2014-2020.

The European Investment Bank and European Investment Fund provide further financing and funding streams that can be mobilised by local authorities to support large urban and regional projects, such as local urban transport, water management and renewable energy projects involving local authorities.

6.1.3 *Challenges for urban experimentation*

While urban experimentation holds numerous opportunities for sustainability transitions, it also faces challenges. For example, experimentation is risky and inevitably involves a degree of failure, which may create accountability challenges (about appropriate spending of public money). This means that governance by experiment may require new ways of funding, managing, evaluating and learning: portfolio approaches are crucial to maximise the chances of identifying workable solutions. However, there is also a need to combine them with adaptive forms of governance (further discussed in Chapter 11) that are flexible enough to increase funding for projects that are delivering promising results, and to decrease commitments to less successful ones.

Experimentation involves learning by doing, but the lessons from individual initiatives are often partial and frequently remain with local participants if dedicated learning and sharing are not stimulated. To prevent reinventing the wheel and to stimulate more systematic learning, more should be done to compare experiences in different cities and circulate and aggregate best practices. 'Across Europe there are hundreds of imaginative and innovative low-carbon projects under way. A key policy task is to set out a methodology that will help cities and regions to maximise the potential of these projects and chart a path for successful low carbon transition' (CKIC, 2015). Such learning should lead to the development of portfolios of best practices that take account of structural, cultural and geographical differences across European cities.

Urban experimentation is not a panacea or a substitute for planning. Because they are often project-based, urban sustainability initiatives tend to be short term and may be terminated after a few years (Ehnert et al., 2018). Political actors may prefer highly visible flagship initiatives rather than long-term and scalable or replicable solutions. Therefore, there is a risk that policymakers use low-cost urban experiments to create the impression of policy action, instead of more programmatic policy (Eadson, 2016). This contributes to the fragmented nature of local initiatives (Turnheim et al., 2018b) and underlines the need to move beyond individual projects and initiatives towards more comprehensive programmes for urban transitions (CKIC, 2015).

Citizen and stakeholder engagement does not mean that urban initiatives are consensual and conflict-free. Investigation of two local projects in Copenhagen, Madsen and Hansen (2019) revealed that 'contestation and conflicting interests are prominent features in both experiments', which can lead to failure and abandonment. The identification and handling of conflicts should therefore be an important dimension of urban sustainability projects.

Experimentation efforts and capacities are unevenly distributed geographically, which relates to differential resources, skills or political commitments. The European Commission's 'smart specialisation' strategies, for instance, require various ingredients to be successful, including a political inclination to foster bottom-up participatory processes, an ability to design and implement strategic regional innovation policies, and an ability to engage with processes of discovery and experimentation (Capello and Kroll, 2016). These ingredients have been particularly absent in eastern and southern Europe. This points to the need for tailored approaches to supporting deployment and diffusion of experimental urban governance.

6.2 Diffusion of urban sustainability innovations

To prevent isolation and fragmentation of individual initiatives, it is important that sequences of urban projects build on each other, as discussed in Chapter 4. The replication, transfer, scaling up and mainstreaming of successful experiments can be supported with more systematic cooperation between initiatives and the cities that support them.

Ehnert et al. (2018) identify a variety of ways in which urban transitions initiatives extend their impact. The growth of members, supporters or users of a single transition initiative can spread new ways of thinking, organising, and practising. The new ways of doing, thinking and organising that are piloted in one transition initiative may be taken up by another initiative. Pooling and/or complementing of resources, competences and capacities between different initiatives can create synergies. The practices or results developed in local initiatives can also be integrated into city-regional governance patterns.

Learning is a central mechanism in supporting the diffusion of urban sustainability initiatives and their outcomes. There are two main ways to support more structured learning in and between cities:

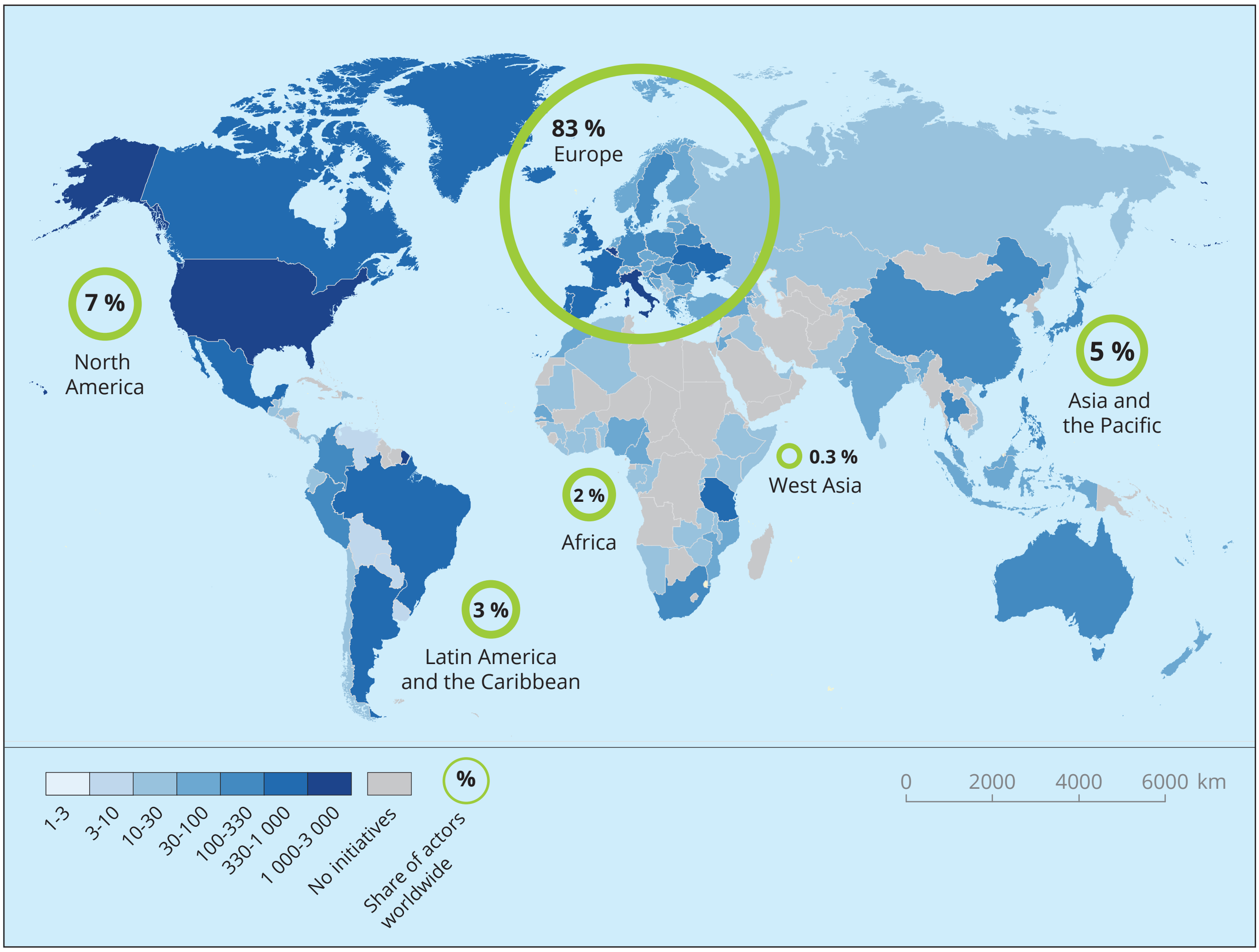
- **Intracity learning** focuses on knowledge flows between multiple experimental transitions initiatives within a given city or region. This can be facilitated by bringing together participants from multiple urban living labs or experimental neighbourhoods to enable exchange of experiences (e.g. through ad hoc workshops or more systematic working groups). Alternatively, experts can visit different projects, compare experiences and abstract more generic lessons, which can be shared more widely.

- **Intercity learning** focuses on knowledge flows between cities through networks, aimed at sharing practices, experiences and evidence across multiple localities. The European Commission recognises the importance of this mechanism, committing in its Third Report on the State of the Energy Union to 'work with pioneering cities and regions to support cross-sectoral, innovative projects that can serve as testbeds for new business models and applied technologies. Such innovative projects should be replicated across Europe and globally' (EC, 2017b).

City networks can help diffuse urban innovations by transferring lessons across localities (Evans et al., 2016). As illustrated in Map 6.1, participation in climate-oriented city networks is particularly concentrated in Europe. For example:

- In 2014, mayors of 17 international cities (e.g. Copenhagen, Portland, Stockholm) stated intentions to become carbon-neutral. In 2016, the Global Covenant of Mayors for Energy and Climate Change was created 'to assist cities and local governments in their transition to a low-carbon economy', involving more than 7 000 cities worldwide (GCOM, 2018). While their main activity relates to local low-carbon targets and the monitoring of progress, they also actively seek to share best practices to fulfil such goals, for example via online repositories or urban action.
- In 2016, the Alliance for Urban Sustainability network was created, bringing together five French and five Swedish cities seeking to develop knowledge about successful and unsuccessful sustainability solutions. Its specific aims are to provide support in establishing international contacts with like-minded cities; to provide opportunities to learn and develop through international collaboration; and, in the longer term, to provide opportunities to develop joint proposals for the financing of projects from the European Union.

Map 6.1 Regional distribution of city participants in various networks supporting non-state climate action



Note: The networks included in this map are carbonn, C40 Cities, CDP Cities, thee Global Covenant of Mayors for Climate and Energy, and Climate Mayors.

Source: Hsu et al., 2018.

- The International Council for Local Environmental Initiatives (ICLEI), founded in 1990, is increasingly engaging with systemic local sustainability transformations (ICLEI, 2015). Activities include training, study visits, practitioner workshops, reports and handbooks on local solutions, and wider information-sharing activities. They are also involved in political advocacy action to influence and shape the debate on urban sustainability policies, legislation and funding.

- EIT Climate-KIC has promoted community engagement with urban sustainability challenges by introducing the Climathon, a hackathon format on climate change that takes place simultaneously in major cities around the world. Starting with 19 cities in 2015, the format has grown to 59 cities in 2016 and 107 in 2017, operating across six continents. Participants includes businesses, academics and entrepreneurs, who identify priority areas of action and co-create solutions based on an open innovation environment. Cities participating in this activity are able not only to engage with a variety of stakeholders, but also to explore collaborations with new global partners through an international network.

The emergence of city networks certainly supports learning and diffusion but the process is complicated. Replicating successful initiatives across local settings requires careful consideration of contextual factors and may depend on the translation of elements that are not readily transferable (Hildén et al., 2017).

Partly for this reason, national city networks have an important role in supporting the diffusion of urban sustainability innovations, since the initiatives operate in the same legal environment and share both geographic proximity and cultural relatedness (although they may also compete with each other for public funding) (Lee and Jung, 2018). In the context of climate action, national city and municipality networks, such as the Dutch Klimaatverbond, Sweden's Klimatkommunerna and Finland's KINKU network, may be particularly well positioned to support the diffusion of innovations (Fenton and Gustafsson, 2017; Kern, 2019; Box 6.1).

Intercity learning processes can be supported by making more resources available for the aggregation and circulation of knowledge (e.g. repositories of cases, knowledgeable experts and practitioners, successful implementation guides/guidebooks) and evaluation efforts; enabling the circulation of knowledgeable experts and practitioners across sites; further supporting the pairing, pooling, collaboration and partnering of city administrations that have contextual similarities and are best positioned to support each other; and developing shared tools and practices to support implementation, monitoring, evaluation and exchange between municipalities.

The Urban Agenda for the EU goes in the right direction. However, it will be important that it focuses on a broad array of projects, not just the most visible flagship ones, and that implementation support is sustained over time.

Box 6.1 HINKU: towards carbon-neutral municipalities in Finland

In Finland, municipalities are collaborating to curb their GHG emissions beyond the requirements of EU targets and schedules. The project, 'HINKU: towards carbon-neutral municipalities', brings together local authorities, businesses, experts and citizens to find cost-effective ways to reduce emissions, especially in the transport, housing and food sectors. By 2030, they hope to reduce emissions by 80 % from 2007 levels.

HINKU started in 2008 as a network of five small municipalities with 36 000 inhabitants. By 2018, it had expanded to 42 municipalities totalling more than 750 000 inhabitants. The results have been positive. HINKU municipalities have already reduced GHG emissions by 30 %, while creating jobs and improving energy self-sufficiency. Finland's climate and energy legislation, based on international and EU laws, was a key driver behind the HINKU process. The programme also enjoys support from across the political spectrum and at different levels of government. At the national level, the Finnish Environment Institute (SYKE) coordinates and facilitates the HINKU process, for example by calculating annual GHG emission inventories for each HINKU municipality, supporting public relations and helping to access external research funding.

Communication and sharing information and ideas through a common platform are central to the HINKU process. A network for forerunners — the HINKU forum — helps to create innovative solutions and to distribute data, experiences and good practices to other localities and stakeholders. Experimentation in municipalities is helping to identify ways to engage residents and overcome barriers to the uptake of new technologies. For example, joint procurement of solar panels enables municipalities and households to combine their purchasing power and secure lower costs. First carried out in 2014, this practice is now expanding in Finland.

Sources: EEA and Eionet, 2016, and updated information on HINKU at: http://www.hinku-foorumi.fi/en-US

6.3 Reconfiguration of urban systems — progress and disparities

Urban networks and infrastructure (built environment, transport, energy, sanitation) are deeply entrenched in the spatial fabric of a city. Urban transitions are therefore likely to involve multiple innovations and the reconfiguration of existing infrastructures and systems, such as large-scale retrofits and repurposing of existing building stock; gradual shifts towards larger proportions of renewables in urban energy production and distribution; or shifts towards multimodal transport, potentially involving public transport and cycling infrastructure, pedestrianisation and major built environment projects, vehicle restrictions and ICT-enabled mobility services.

Major urban infrastructure projects in local transport, buildings and energy systems can also fundamentally reshape cities (Bulkeley et al., 2014; Frantzeskaki et al., 2018) by transforming systems at the city scale. Box 6.2 describes Sweden's transitions in district heating, in which pioneering municipalities played a critical role.

Infrastructure projects can also have important spillover effects and co-benefits for urban populations. Major urban transit projects, such as tramways, can also fundamentally alter the urban fabric (new neighbourhoods, tourism, mobility and commuting patterns, and appropriation of urban landscape and built environment), and have significant knock-on effects on wider urban systems. The development of Strasbourg's modern trams, for instance, has been used to fundamentally reshape the urban fabric, as it was combined with multiple interventions (e.g. pedestrianisation, automobility restrictions, parking measures and new urban developments) in a strategic approach that became a blueprint for further similar schemes (Turnheim and Geels, 2019).

6.3.1 Disparities between urban areas

While some cities and towns are leading urban sustainability reconfigurations and receive much attention, other cities, towns and regions are trailing behind. It is important to acknowledge and understand the significant disparities in progress with urban sustainability transitions and the underlying actions of local authorities (Fenton and Gustafsson, 2017). Various factors can help explain disparities, for example:

- **Larger cities tend to attract more visibility and investment.** They often also benefit from special institutional and regulatory conditions, which facilitate innovation and deployment.
- Urban authorities may have **different attitudes and be willing to engage with sustainability transitions.** Some cities may also resist change because of the importance of local (polluting) industries and the fear of the economic and social consequences of destabilisation.
- There can be significant **disparities in terms of the skills and competences** of urban authorities to lead transition efforts and to develop appropriate strategies to orchestrate innovative activities.
- Urban authorities may face **different barriers to entering city networks** and benefit from the knowledge sharing that they offer. These barriers can include limited capacity, language barriers and local institutional rules.
- In some instances, **national and European governance levels may prevent local authorities from pursuing more experimental approaches,** particularly for key infrastructures (Monstadt, 2009; Ehnert et al., 2018; Madsen and Hansen, 2019), because of a lack of devolved resources or responsibilities, or conflicting goals. The EU's Urban Agenda acknowledges the need to tackle this issue: 'By identifying and striving to overcome unnecessary obstacles in EU policy, the Urban Agenda for the EU aims to enable urban authorities to work in a more systematic and coherent way towards achieving overarching goals' (EU, 2016b).

6.4 Monitoring and evaluating urban sustainability action and pledges

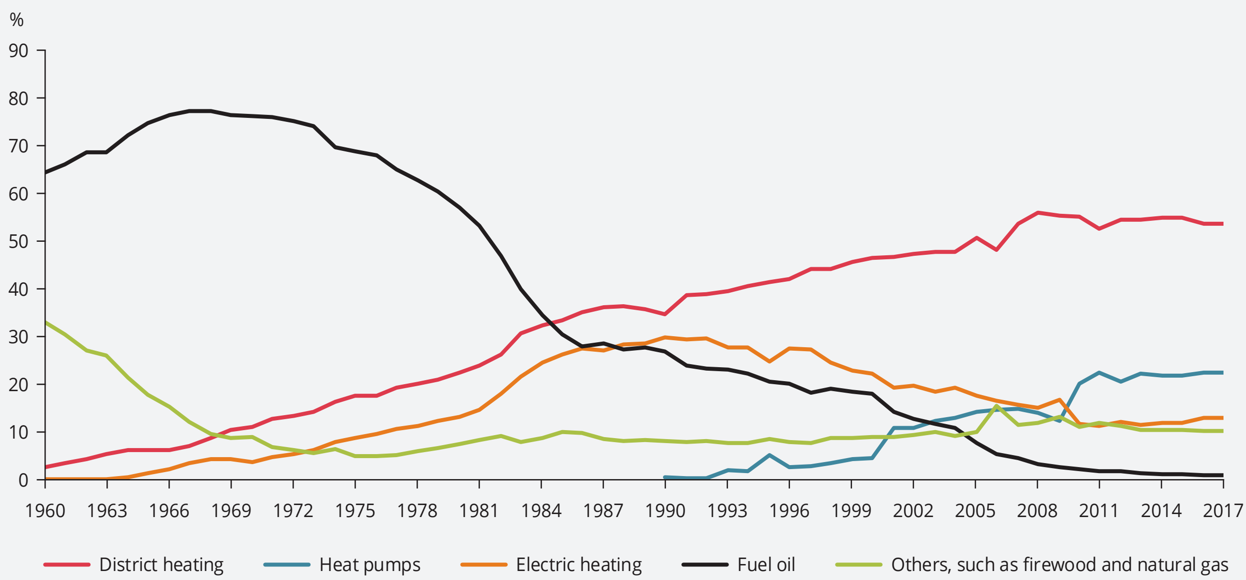
Currently, local implementation of sustainability action largely results from voluntary action based on locally set targets. This bottom-up, open-ended logic is useful for experimentation but creates difficulties for harnessing the wider potential of city-level contributions to global sustainability challenges.

Some cities are positioning themselves as frontrunners of sustainability transitions, pursuing local targets and policies that are more ambitious than European or national pledges. Since the Paris Agreement was adopted in December 2015, a growing number of cities have committed to achieving 100 % renewable energy by 2050 (in total energy use, the electricity sector or public sector operations) (REN21, 2017).

Box 6.2 Swedish district heating transitions

The development of district heating in Sweden illustrates how system reconfigurations at the city scale can contribute to broader transitions. From pioneering experiments in Karlstad in 1948, followed by nine other municipalities in the 1950s, district heating has developed into the main urban form of heat production and distribution. More than 500 registered systems are now spread across all major Swedish cities and towns, as well as some villages (Werner, 2017). Collectively these supply more than 50 % of all residential and service sector heat (Figure 6.1), a proportion that far exceeds European averages.

Figure 6.1 Market shares for heat supply to residential and service sector buildings in Sweden



Source: Werner, 2017.

The success of Swedish district heating was made possible by the conjunction of favourable conditions and opportunities. In the early phase, pioneering municipalities became interested in CHP as an efficient option for their own supply of energy, enabling greater independence and cheap heating supplies. Municipal commitment was crucial, as well as the organisation of municipal energy utilities into a heat utilities association, which acted as a district heating promotion body (Di Lucia and Ericsson, 2014). The million homes programme (a significant planned increase of the residential building stock, which ran from 1965 to 1974) made it possible to link new homes to district heating networks and develop long-term demand for heat as a basis for further expanding networks. The oil crises led to a programme for replacing oil-fired boilers and further expansion of district heating, which also saw a shift of fuel sources towards gas, waste and biomass. Climate policies implemented since the 1990s, such as emissions reduction targets and carbon taxes, supported the further diffusion of district heating.

Local transitions to district heating represent significant transformations of energy supply, from on-site heat conversion in fossil-fuelled boilers to more collective forms of supply and distribution (including communal ownership). They deliver significant efficiency improvements and broader options for fuel input. Crucially, however, district heating requires the development of significant infrastructure, for which public funding commitments and long-term contracts are crucial. In the Swedish success story, public actors (municipalities, local energy utilities) and regulating authorities (energy agency and housing board) were crucial for the early stages, whereas larger energy utilities became more involved in buying up district heating networks after deregulation in the 1990s (Dzebo and Nykvist, 2017).

Table 6.3 A selection of European city-wide energy targets

Target	Year	City (country)
100 % renewables in total energy mix	2029	Sønderborg (DK)
100 % renewables in total energy mix	2030	Fredrikshavn (DK), Malmö (SE), Växjö (SE)
100 % renewables in total energy mix	2040	The Hague (NL)
100 % renewables in total energy mix	2050	Copenhagen (DK), Frankfurt (DE), Hamburg (DE)
100 % renewables in electricity mix	2020	Skellefteå (SE)
100 % renewables in electricity mix	2025	Munich (DE)
100 % renewables in electricity mix	2030	Osnabrück (DE)
100 % renewables in electricity mix	2035	Groningen (NL)
50 % renewables in energy consumption	2040	Amsterdam (NL)
29 % renewables in energy consumption	2020	Balmaseda (ES)
25 % renewables in energy consumption	2025	Amsterdam (NL), Paris (FR)
20 % renewables in energy consumption	2020	A Coruña (ES), Amurrio (ES), Ancona (IT), Areatza (ES)
17.8 % renewables in energy consumption	2020	Berlin (DE)
13 % renewables in energy consumption	2020	Antwerp (BE)
10 % renewables in energy consumption	2024	Barcelona (ES)

Source: REN21, 2018.

Table 6.3 presents a selection of city-wide energy targets with different time horizons. Similar urban targets have been set for heat supply (e.g. renewable heat, district heating or solar thermal) and transport (e.g. bans on petrol and diesel cars in Athens, Madrid and Paris) (REN21, 2018).

There are therefore high expectations regarding the potential for urban action to complement existing national and international action. This has become particularly prominent in climate debates, notably since the Paris Agreement and with the increasing focus on the role of non-state and local action. Hsu et al. (2018), for instance, report mitigation pledges from more than 7 000 cities in 133 countries, and suggest that the associated mitigation potential of individual commitments and single initiatives may be large.

It should not be assumed, however, that these ambitions will automatically produce the required results. It has been noted, for example, that the targets set are often not explicit, goals are unclear and actions are not concrete enough (Graichen et al., 2017; Hsu et al., 2018). Analysing 400 city-level sustainability initiatives, Broto et al. (2018) find a lack of evidence of transformative capacity, particularly concerning energy and transport initiatives. Moreover, large proportions of voluntary pledges that were announced at the 2002 World Sustainable Development Summit failed to materialise (Pattberg, 2012).

Measuring, monitoring and evaluating the sustainability impacts of urban action, as well as their outcomes on transitions, are essential — both as a means to learn from the successes and failures of different approaches, and to build trust in increasingly polycentric systems of governance (Jordan et al., 2018b). At present, however, the required mechanisms are often inadequate. Jordan et al. (2018b) note, for example, that 'across the emerging landscape of climate governance, very few of the new forms of governing appear to be that well monitored. For example, the majority of transnational city networks have few or no monitoring provisions ..., potentially rendering them mere talking shops.'

EU and national policymakers can support the development of robust metrics and evaluation procedures. A number of challenges and potential solutions stand out:

- **Evaluating sustainability potentials and impacts:** It is not yet clear how much urban sustainability initiatives have contributed or could contribute to addressing environmental problems. From an evaluation perspective, the lack of harmonised data and reporting criteria creates a risk of overestimating the contribution of urban action to sustainability objectives, including double-counting (Roelfsema et al., 2018). In addition to better monitoring of individual urban projects, there is also a need to more actively engage with the evaluation of wider expected impacts from experiments, including sustainability impacts, collective learning outcomes, network and coalition formation, and the mainstreaming of viable solutions applicable to multiple sites (Turnheim et al., 2018c).

- **Greater clarity of goals:** Urban sustainability commitments are often vague (Vojnovic, 2014), unclear (Graichen et al., 2017) or poorly formulated. This can be an obstacle to concrete implementation or even result in a misleading lack of transparency. Properly formulated goals and targets can improve the commitment and trust of participants. From an evaluation perspective, the lack of clear goals hampers the comparability of local action across contexts.

- **Greater consistency over time:** For targets to support effective and substantial interventions, it is crucial that they lead to actions or milestones that can be regularly evaluated. The evaluation of goals in light of experience is an important source of learning (Van Asselt et al., 2018). Progress reporting can also improve the credibility of local action and hence positively influence its momentum. In the climate context, recent studies find a low level of progress tracking and follow-up on stated targets (Graichen et al., 2017; Hsu et al., 2018).

- **Capturing multiple unquantifiable aspects:** Evaluating progress with urban sustainability action remains challenging. While some interventions lend themselves to measurement and targets (e.g. CO_2 reductions for climate mitigation), others may be inherently more difficult to measure. A target-based approach is unlikely to be suited to evaluating some of the crucial mechanisms that support the development and diffusion of urban sustainability action (e.g. learning, partnerships, resource commitments and transformative capacity).

7 Financing innovation and system change

Message 5: Reorient financial flows towards sustainable and transformative innovations

- There is a need for much greater investment in sustainability-oriented research and experimentation. Ambitious goals for public investments in climate solutions could be extended to other areas.
- Policy support is key to help innovations bridge the 'valley of death' between research funding and commercialisation, e.g. through co-funding, loan guarantees and market creation (e.g. feed-in tariffs, loans).
- Meeting the investment needs will depend on policies that correct market incentives, reduce risk and uncertainties, and incentivise private investment, as well as more fundamental financial reforms.

Finance is essential for the emergence and diffusion of new technologies and practices, driving long-term economic growth and enabling the transformation of production-consumption systems. Yet ensuring that society's investments promote sustainability goals is a major challenge, because of barriers and market failures that extend from invention through to diffusion (Box 7.1). Fundamentally, investment incentives are heavily distorted by market prices, which often fail to reflect the social and environmental costs of goods and services. Although governments have policy tools available to create a level playing field for eco-innovations, they face significant constraints in adjusting prices to levels that will guarantee the necessary shift in investments (Section 2.2). Indeed, in some instances policy failures create additional obstacles to sustainable investment, for example in the form of erratic shifts in incentive structures.

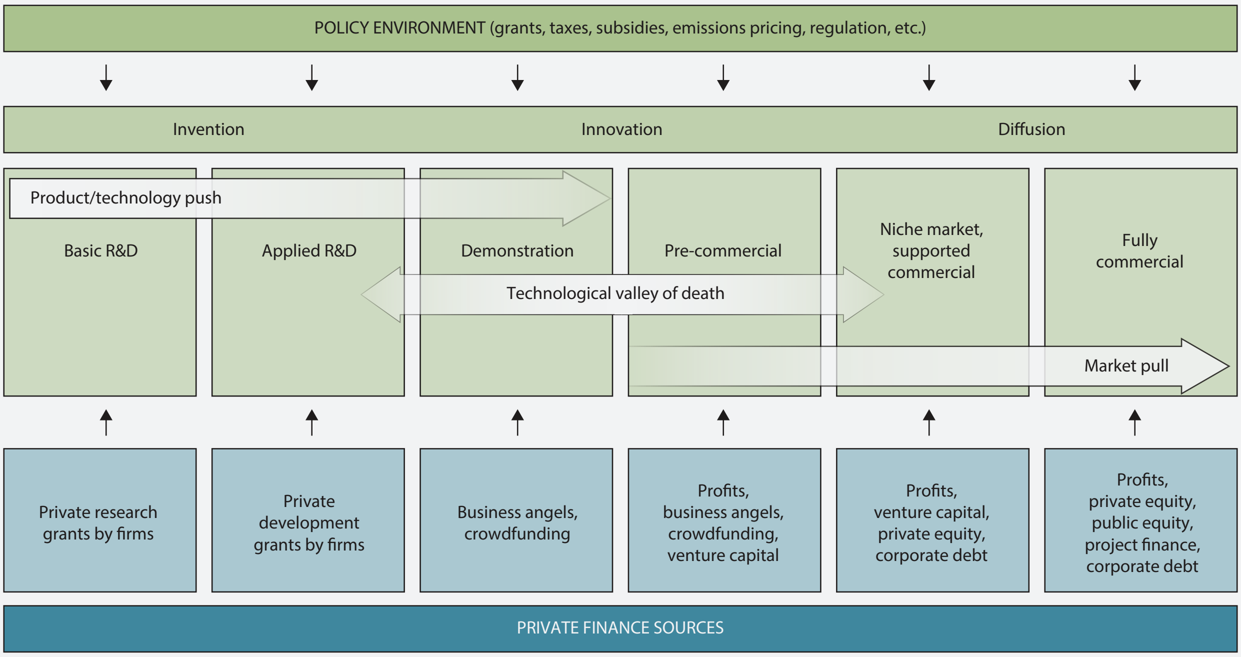
These market failures and other barriers to private investment imply that financing sustainability transitions and a 'green technological revolution' will depend critically on public policy and interventions across the entire innovation chain (Mazzucato and Perez, 2015).

> 'Finance is a keystone in the transition to sustainable development. As such, it can catalyse or impede much-needed change. Today, it is both. Clearly, some capital is flowing to the new economy that we need. But far more is continuing to support the old economy, through an inability or unwillingness on the part of owners and intermediaries to redeploy it.' (UNEP, 2018)

Box 7.1 Evolving barriers, financial needs and funding sources across the innovation chain

The linear model of innovation (see Box 3.1), comprising invention, innovation and diffusion, provides a useful framework for understanding the different financial needs and opportunities as innovations emerge and spread (Figure 7.1).

Figure 7.1 Public and private sources of finance across the innovation chain



Sources: Based on Polzin, 2017; Würstenhagen and Menichetti, 2012.

At the earliest phase of innovation, a variety of factors are likely to deter private actors from investing in new ideas. These include fundamental uncertainties about returns on investments and the potential time horizon, the public good characteristics of R&D (meaning that it is hard for inventors to capture the returns on their investments), and the fear that radical innovations may undermine existing investments in established technologies and production methods (Christensen, 1997). These market failures have long been recognised as necessitating state investments in research to ensure socially desirable levels of innovation (e.g. Arrow, 1959; Nelson, 1959).

As inventions and new approaches move from the research phase to demonstration and commercialisation, public funding often declines and new sources of private finance become increasingly important, including business angels (wealthy individuals who invest in start-ups), crowdfunding and venture capital. The fragmentation of these funding sources and investor uncertainties about the viability and desirability of innovations mean that entrepreneurs often face declining or uncertain funding at the same time as their financial needs to develop production capacity and human resources are growing fast (In et al., 2017). This particularly vulnerable phase, before economies of scale and learning enable reliable revenue flows, is termed the valley of death. The funding gap can be particularly severe for domains (such as energy) with low R&D intensity, large and long-term investment needs, and limited direct connection to consumers (Grubb et al., 2014). Lack of funding is also an important barrier to the diffusion of social and grassroots innovations (Hossain, 2018; see Section 4.1).

For many innovations, the transition to wider diffusion enables the venture to start making profits and secure access to a substantially broader and deeper set of financial support, including financial institutions, corporate debt, private equity and project finance. Yet the barriers remain considerable. The viability of a new technology (and its sustainability impacts) may depend on costly and long-term investments in related infrastructure or changes in other systems (see Section 5.1). Indeed, the sheer scale of investment needed to achieve transitions to sustainability represents a huge challenge. Achieving the SDGs has been estimated to require global investments of USD 5-7 trillion annually, with climate/energy, transport and food requiring the greatest spending (UNCTAD, 2014).

7.1 Mobilising finance for invention and experimentation

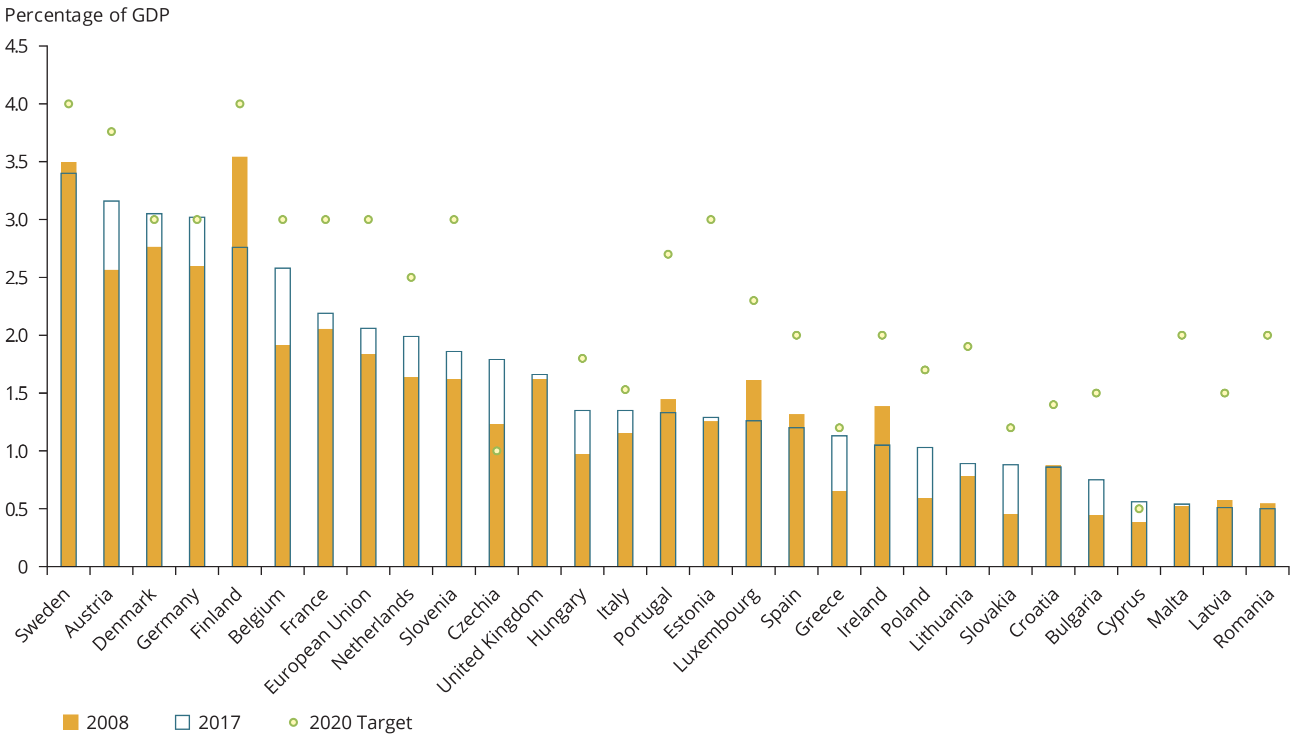
Analysing financial flows to sustainability-oriented invention and experimentation is difficult. Disentangling investments that contribute to sustainability transitions is very hard and there is also inadequate information regarding non-technological innovations, including local initiatives and social innovation. As a result, analysis tends to focus on the level of R&D spending. Although this has limitations (Arundel and Kemp, 2009), it does provide a sense of the proportion of resources devoted to innovation.

In general terms, research spending is an acknowledged weakness for the EU. Although EU R&D spending has improved over the last two decades, reaching 2.06 % of GDP in 2017, it remains far short of the 3 % target stipulated in the Europe 2020 strategy (EC, 2010), and is well below the level in Japan (3.2 %) and the United States (2.79 %) in 2017. China's R&D expenditure has increased rapidly, from less than 1 % of GDP in 2000 to surpass the EU by 2015. In 2017, it stood at 2.13 % of GDP.

While there is substantial variation in R&D spending across Europe, from more than 3 % of GDP to less than 0.5 %, few countries are on target to achieve national targets for R&D spending (Figure 7.2).

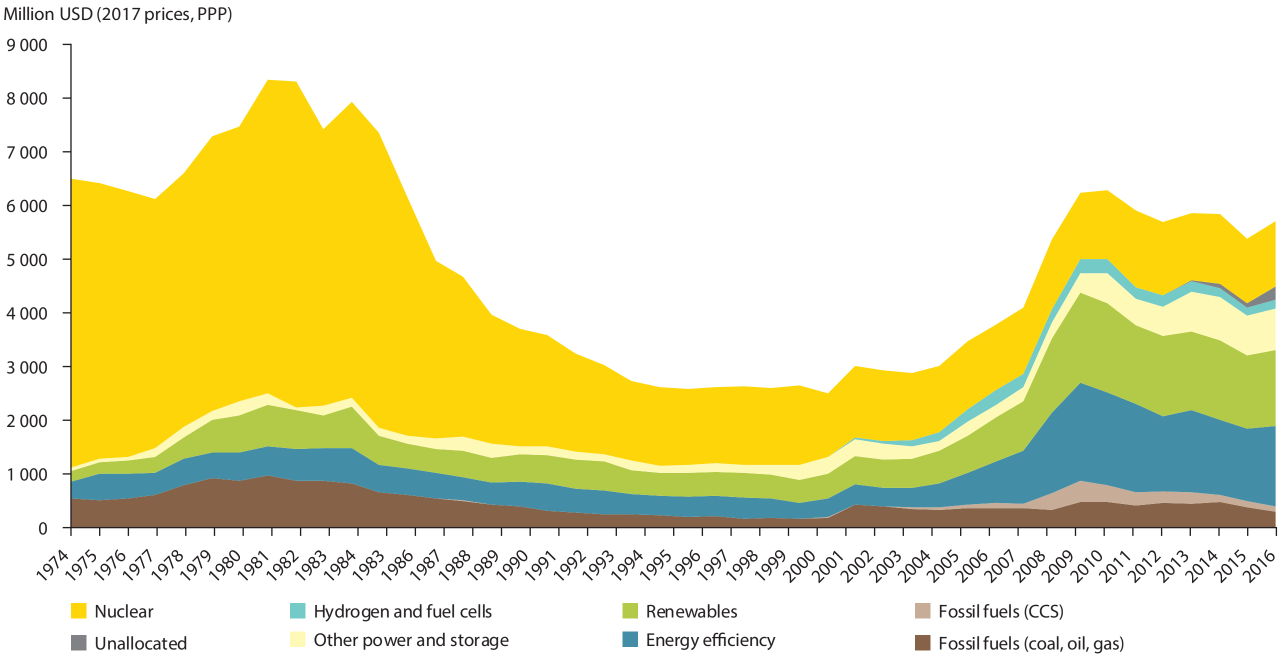
This overall performance is a concern because of 'the essential role that R&D investments play in triggering smart and sustainable growth and in addressing societal challenges' (EC, 2016f). Investments in sustainability-related domains have seen stronger growth, however, notably in the area of energy R&D (90-95 % of which goes to low-carbon technologies). Although RD&D spending on energy has not recovered to its peak of the 1980s, it more than doubled between 2001 and 2010 (Figure 7.3), benefiting significantly from the 'stimulus package' expenditures in 2009 that aimed to prevent economic collapse after the financial crisis. By international standards, Europe is today a significant investor in energy RD&D, with Horizon 2020 making the European Commission a major contributor (Figure 7.4). Spending has also diversified significantly, shifting from a heavy (and arguably wasteful) focus on nuclear energy towards a much broader portfolio of low-carbon technologies. Since 2010, however, spending has declined.

Figure 7.2 **Gross domestic expenditure on R&D (% of GDP) — progress towards national and EU targets for 2020**



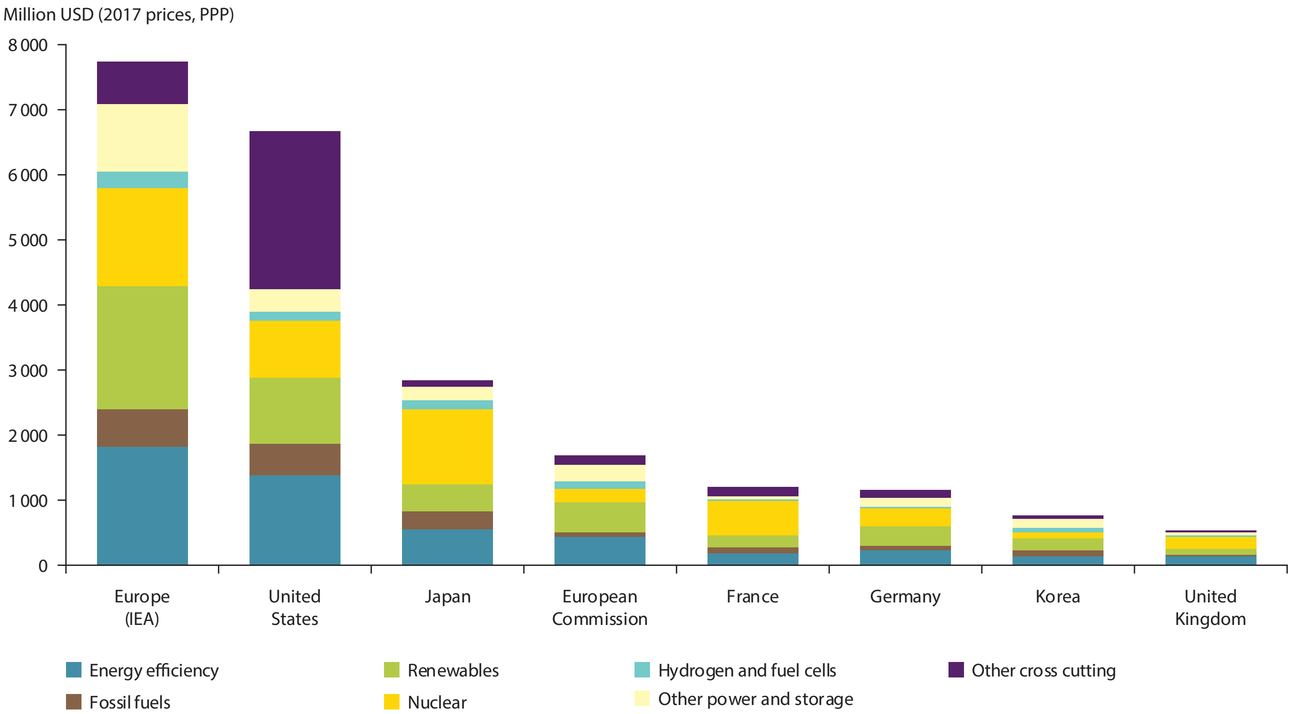
Source: Eurostat, 2019d.

Figure 7.3 **Evolution of total European energy RD&D spending by technology (USD million, 2017 prices) (based on International Energy Agency estimates)**



Source: IEA, 2018c.

Figure 7.4 **Total energy RD&D spending by technology in selected regions and countries, 2016 (USD million, 2017 prices)**



Note: The 'Europe' total represents the 23 European countries that were International Energy Agency (IEA) members in 2018, plus the European Commission. It therefore includes the totals for France, Germany, the United Kingdom and the European Commission, which are also shown separately in the figure.

Source: IEA, 2018c.

Similar trends are apparent in other sustainability-related sectors, although in these areas robust time-series data are available for only public R&D spending. As in the energy area, Europe's state-funded R&D in the transport, environment and agricultural domains has increased significantly since 2002, with transport in particular receiving a boost after the financial crisis (Figure 7.5). However, investment has subsequently declined in all three areas. R&D spending on environment and agriculture by the governments of the 28 EU Member States (EU-28) was lower in 2016 than in 2005. These trends potentially weaken European competitiveness and opportunities for a green transition.

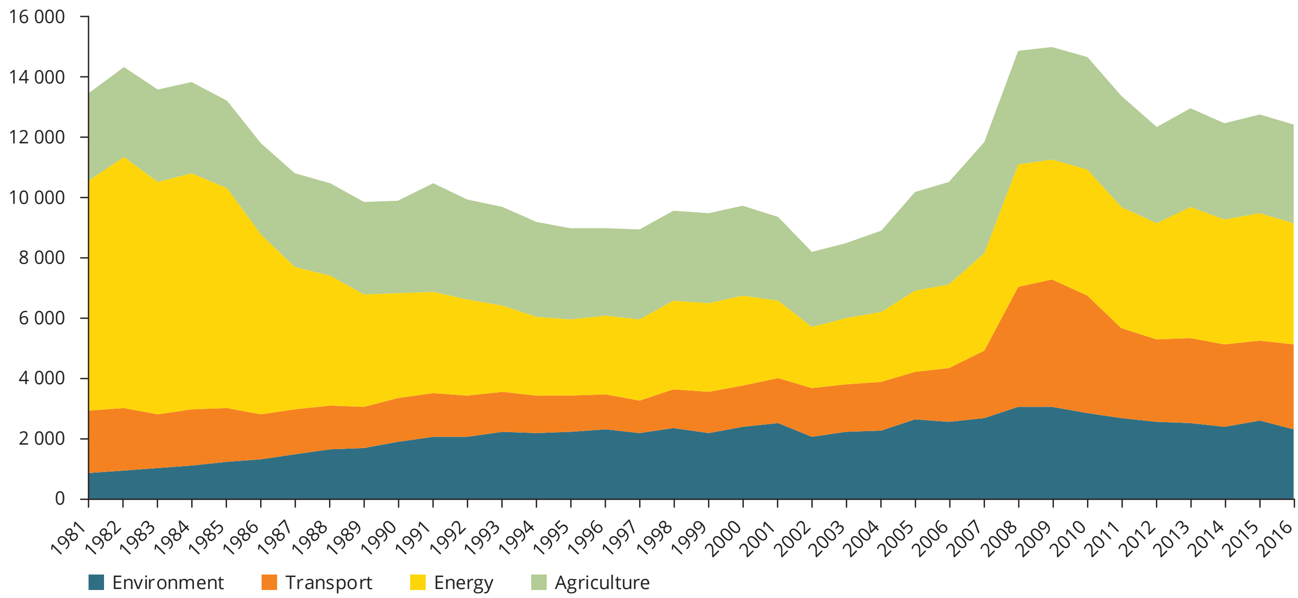
The urgency of global sustainability challenges has sparked growing recognition of the need for much greater public investment in sustainability-oriented R&D. For example, the EU and 23 countries outside the EU, which together account for 80 % of global investment in clean energy R&D, have pledged to double that spending to approximately USD 30 billion annually by 2021 as part of the 'Mission Innovation' initiative. This increase is intended to accelerate significantly the availability of affordable clean energy (Mission Innovation, 2018).

There is a strong case for extending this level of ambition beyond a narrow focus on clean energy technologies towards supporting diverse forms of innovation in other systemic domains. Public investments in R&D have a particularly important role in supporting activities, such as fundamental research, where the returns on spending are highly uncertain. Indeed, their value may be growing amid concerns that short-termism in corporate governance is weakening private investment in basic scientific research (Mazzucato, 2015). Perhaps most fundamentally, public spending on R&D creates the seeds for transitions and economic development.

7.2 Supporting innovation and bridging the 'valley of death'

Moving beyond the invention stage, there are further questions about the availability of finance in Europe to support progress towards commercialisation and successfully bridge the 'valley of death'. During this phase, private actors become more prominent sources of finance but have important limitations. The state therefore has an important role in incentivising and

Figure 7.5 **Government R&D in energy, transport, environment and agriculture domains (14 EU Member States), 1981-2016 (USD million, 2010 prices)**



Note: This figure presents data for current EU Member States for which Organisation for Economic Co-operation and Development (OECD) data are available over the period 1981-2016. The countries included are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. Together, these countries accounted for 92 % of EU-28 public R&D in energy, transport, environment and agriculture in 2016.

Source: OECD, 2019a.

> 'Europe is a world leader in science. We are home to some of the most creative and entrepreneurial minds and some of most innovative ideas anywhere in the world. This takes a long way but we still struggle to bring that innovation to the market.' (EC, 2018f)

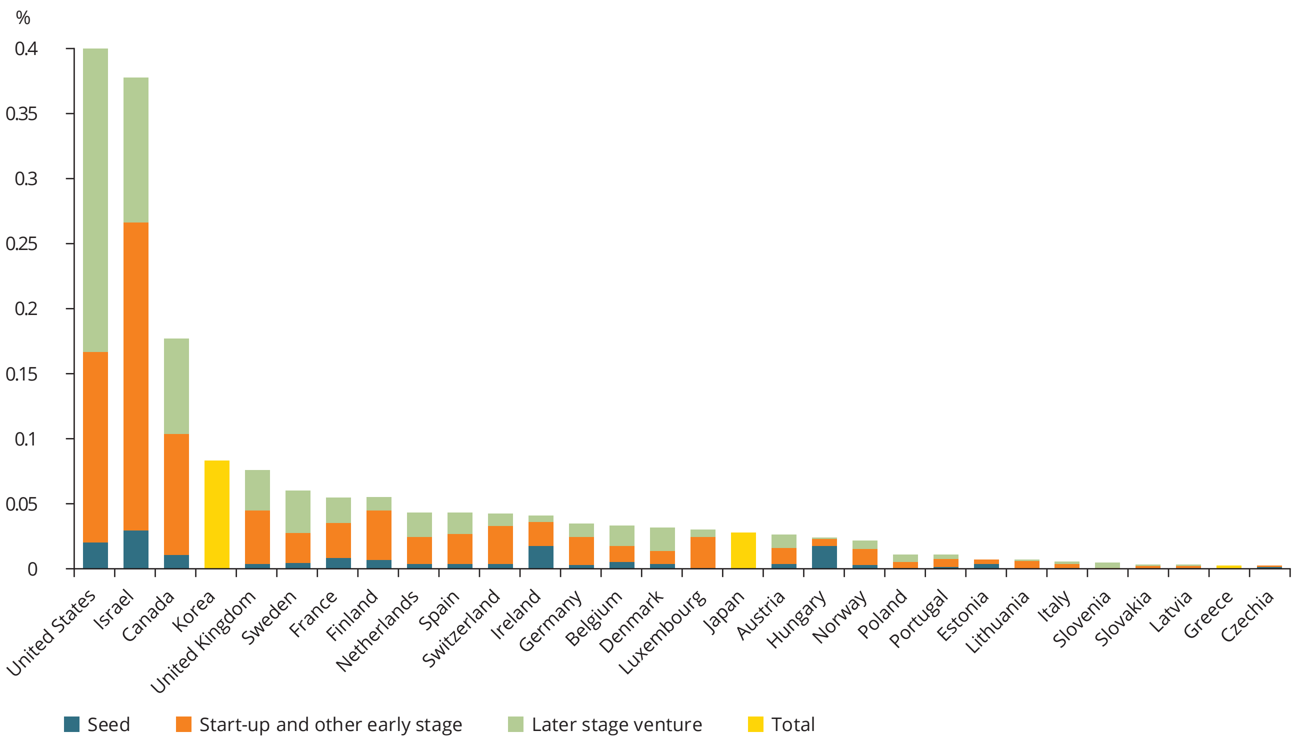
steering the direction of private investment, and provide a source of financial resources in its own right.

Venture capital is a widely recognised source of funding for start-up firms with unproven technologies or business models. It is also an acknowledged area of weakness in the European financial architecture (EC, 2018j). The EU venture capital market is considerably smaller than that in the United States, although there are strong differences between Member States (Figure 7.6). It has declined in size since the financial crisis, contrary to EU policy ambitions. And there is also evidence that venture capital is much easier to access in the United States than in Europe (Whittle et al., 2016).

While Europe can certainly benefit from a stronger venture capital market, its relevance to sustainability-oriented innovations is limited in some respects. The venture capital business model is grounded on broad portfolios of short-term, high-risk investments that produce many weak performers and occasional outstanding successes. This means that it is seldom suitable for providing the large, long-term investments of 'patient capital' often needed to commercialise innovative scientific or engineering ideas (Gaddy et al., 2016).

Venture capital investment trends illustrate these limitations. Although venture capital contributed to the emergence of RETs, energy efficiency and EV start-up companies, its focus has shifted more recently towards smaller investments in more mature (late stage) and software-focused companies. While this reduces uncertainty and risk for the investors, it potentially undermines support for more radical and novel innovations (Saha and Muro, 2017; Sopher, 2017). Similarly, food sector venture capital investments have surged since 2013, partly driven by subsidiaries of large food corporations, but again much of this spending has focused on software (AgFunder, 2017; CBInsights, 2018). While innovations in information technology can contribute to sustainability transitions, for example by enabling new business models and the sharing economy, they offer only one part of the solution.

Figure 7.6 Venture capital as % of GDP in OECD countries, 2017 or latest available year



Source: OECD, 2019b.

The selective character of venture capital investment and its focus on late-stage companies implies an important role for other private actors (OECD, 2011a). Business angels (wealthy individuals that invest in start-ups), for example, are a much more important source of seed and early-stage finance for start-ups than venture capital; they also report having a long-term investment horizon, normally 5-10 years or longer (EBAN, 2018). Like venture capitalists, however, business angels direct much of their investment to ICT and financial services, which together accounted for almost half of business angel investments in 2017. Total European business angel investment is estimated at EUR 7.3 billion in 2017, accounting for 55 % of the early-stage investment market. Crowdfunding and blockchain funding are also emerging as increasingly important sources of finance for start-ups, respectively accounting for 5 % and 13 % of early stage investments in 2017 (EBAN, 2018).

These private investment sources can all support the emergence of radical, disruptive innovations. Yet the urgency of today's sustainability challenges and the need to direct innovation processes towards particular long-term societal goals imply a key role for governments in stimulating, orienting and complementing private investments (Saha and Muro, 2017; Sopher, 2017). This active role for the state arguably runs counter to mainstream economic reasoning, which perceives markets as the primary engine of innovation and therefore recommends that states focus primarily on correcting market failures. There is growing recognition of the foundational role that public investments across the innovation chain played in many of the most transformative innovations during the 20th century (Auerswald and Branscomb, 2003; Mazzucato, 2015; Söderholm and Wihlborg, 2015). Achieving a green transformation may well require even greater levels of ambition, engagement and risk taking from the state, accompanied by a willingness to accept failures alongside successes (Mazzucato and Perez, 2015).

Governments have a broad range of financial tools at their disposal. These include grants (e.g. those awarded based on competitions), funding or co-funding by public investment banks or agencies, loans or loan guarantees, and tax incentives or measures to remove regulatory barriers to investing. The proliferating initiatives under the EU's Capital Markets Union illustrate this diversity, for example:

- the European Fund for Strategic Investments (EFSI), which co-funds projects in strategic sectors;
- EU Finance for Innovators (InnovFin), which supports demonstration projects in renewable energy;
- the European Energy Efficiency Fund, which invests in energy and transport projects at regional and local scales;
- the VentureEU initiative, which establishes a 'fund of funds' with EU financial input to leverage private venture capital investment;
- the European Innovation Council (EIC), which combines funding, advice and networking opportunities.

These initiatives are complemented by additional measures to stimulate investments by business angels and to alleviate barriers to crowdfunding initiatives (EC, 2018d; EIF, 2018). Translating sustainability challenges and broad visions into more concrete missions as envisaged under Horizon Europe (discussed in Chapter 8) provides a means to mobilise and coordinate public and private investments, engaging coalitions of financial actors in ways that can support sustainability transitions (RISE, 2018). Programmes for renewable energy in Germany, EVs in Norway and the circular economy in Belgium exemplify this approach (OECD, 2018).

7.3 Financing diffusion and fixed capital formation

Moving beyond the invention and innovation phases, it is evident that the diffusion of clean technologies and the transformation of whole production-consumption systems will require huge investments. Estimating future investment needs for sustainability transitions is complicated and highly dependent on assumptions about issues such as the sustainability problem being addressed, geographical focus, transition paths, future costs of technologies, future lifestyles and demand patterns. The estimates presented in Table 7.1 therefore vary significantly, but they do provide an impression of the magnitude of additional investments required to meet various sustainability goals.

Although the sums are very large in absolute terms, they appear more manageable when compared with global and European economic output (respectively USD 75.4 trillion and EUR 14.8 trillion in 2016). Total investment (gross capital formation) accounted for about a quarter of global economic output during the last three decades. By comparison, the estimated annual investment required to meet the SDGs indicated in Table 7.1 equates to approximately 4-10 % of global economic output.

Table 7.1 Estimates of additional future investments to reach particular sustainability goals

	Additional annual investments	Reference
SDGs (global)	USD 5-7 trillion	UNCTAD, 2014
Green economy (global)	USD 1-2.6 trillion (over 2010-2050)	UNEP, 2011b
Climate mitigation (global)	USD 550-860 billion	UNDP, 2018a
	USD 800 billion (over 2010-2050)	McCollum et al., 2013
	USD 650-900 billion	Campiglio, 2016
	USD 1.7 trillion	IEA and IRENA, 2017
	USD 1.38-3.25 trillion (over 2016-2035 to accelerate transitions and limit climate change to 1.5 °C)	IPCC, 2018
Climate mitigation (Europe)	EUR 180 billion (to reach 2030 climate targets)	EC, 2018h
	EUR 130 billion in 2011-2030 and EUR 30 billion in 2030-2050 (to reduce greenhouse gas emissions 80 % by 2050)	De Bruyn et al., 2016
	EUR 179 billion to reach 2030 climate change targets (in addition to planned investments in the EU Reference Scenario 2016)	Trinomics, 2017

Note: These investments are additional to business-as-usual investments for upgrading ageing infrastructures, modernising cities, etc.

Figure 7.7 Disaggregated estimates of additional annual global investment needed in low-carbon sectors

Source: Campiglio, 2016.

'Some take-off has happened in areas such as such as investment in renewable energy, green bonds as well as fiduciary duty and risk-based disclosure. But substantial lags remain in large parts of the system, for example, in housing finance, often the largest asset class in banking portfolios; and of course more broadly infrastructure investments. In short, flows of capital across the sustainable development agenda are increasing but remain insufficient.' (UNEP, 2018)

Disaggregation of the data provides interesting insights. As illustrated in Figure 7.7, achieving climate targets will particularly require additional investments in demand-side sectors, notably buildings and transport. In a European Commission study, Rademaekers et al. (2017) estimate that achieving the EU's 2030 climate and energy targets will require more than EUR 1 trillion of investments in transport and buildings in the period 2021-2030, compared with less than EUR 80 billion for power generation and the electricity grid. These numbers highlight the importance of spending decisions by households and users (e.g. vehicle owners) in financing transitions — and the need for policies to incentivise and enable sustainable investments.

7.3.1 Diverse, interacting sources of finance

Financing socio-technical transitions will necessarily draw on a diverse array of interacting funding sources and mechanisms. These sources differ significantly in terms of the scale of resources at their disposal and the ways in which market and policy incentives guide their decision-making.

European Union: The EU budget, which Member States have capped at around 1 % of EU GDP, is an important source of public investment expenditure. This is particularly true for the 13 Member States that joined in 2004 or thereafter, where EU cohesion funds accounted for 45 % of total public investment in 2017. As already noted, the EU provides funding via various means, including spending programmes, grants and subsidies, often with the aim of leveraging private investment. In 2011, the EU agreed that at least 20 % of its budget for the period 2014-2020 should be spent on climate-related action.

Public administrations: National, regional and local governments and public agencies have a particularly important role in financing public infrastructure and other projects through direct investments or public-private partnerships. Policy tools, such as grants, fiscal incentives and cheap loans, aim to encourage private sector spending on projects or innovations by reducing risks or addressing barriers such as upfront capital costs. In addition, public procurement of goods and services amounts to 19 % of GDP in the EU, implying that it can provide a major stimulus for innovation and diffusion, as highlighted in the EU's Innovation Union initiative and the related Procurement of Innovation Platform.

Institutional investors: Pension funds and insurance companies, for example, manage large amounts of capital for beneficiaries (individuals, organisations), providing funding by purchasing bonds or equity. Compared with commercial banks, their investments are longer term and more risk averse. Some institutional investors invest in green activities for ethical reasons (Campiglio, 2016), focusing on mature technologies such as wind, solar and energy efficiency innovations. Institutional investors prefer large investment volumes (e.g. at least EUR 100 million), making smaller projects uninteresting. Institutional investments in European renewable energy projects have increased but still account for only about 1-2 % of total assets, compared with 5-10 % for 'brown' sectors and 20-25 % for high-carbon sectors such as oil, gas, utilities, chemicals and automobiles (Rademaekers et al., 2017). 'Greening' of institutional investments has a long way to go but there is substantial potential.

Development banks are publicly owned or underwritten, and include national promotional banks (e.g. Germany's Kreditanstalt für Wiederaufbau or Poland's Bank Gospodarstwa Krajowego) and multilateral public financial institutions (e.g. the European Investment Bank, the International Bank for Reconstruction and Development). They provide concessional loans to companies on more favourable terms than the market, targeting projects or sectors that commercial banks are reluctant to finance. They can engage in risk sharing (e.g. providing guarantees or participating in public-private partnerships) as a means to leverage private funding. They may also aid project development by providing technical assistance or capacity-building.

'Banks, insurance companies and pension funds are the main source of external finance for the European economy and ... could provide the critical mass of investments needed to close the gap for the transition to a more sustainable economy.' (EC, 2018h)

'Investors were particularly vocal in their collective contribution to the Paris climate negotiations, with 400 signatories with USD 24 trillion of assets under management, signing the Global Investor Statement on Climate Change, which called for a robust climate agreement and clear market signals on climate policy.' (UNEP, 2016)

Collectively these actors have the resources to finance sustainability transitions. Acknowledging that the required investments exceed public funding abilities, the European Commission's Action Plan on Sustainable Finance (EC, 2018h) emphasises the importance of leveraging private investments: 'Banks, insurance companies and pension funds are the main source of external finance for the European economy and … could provide the critical mass of investments needed to close the gap for the transition to a more sustainable economy'. At present, however, private funders are deterred from investing in sustainability transitions by a variety of barriers and misincentives linked to market prices, risks and uncertainties, information flows, capacities and knowledge. Tackling these is a critical policy priority.

Commercial banks provide an important source of lending. About half of global asset finance for renewable energy comes from non-recourse project finance, mostly in the form of bank loans or equity. Banks are willing to fund mature, large-scale technologies because they offer good returns and have relatively low technical and commercial risk. Banks are often much less interested in lending to small investors (small and medium-sized enterprises, households, communities), as they lack the expertise and time to assess their project proposals (Jacobsson and Jacobsson, 2012). Because the viability of many wind and solar projects depends on policy support, banks are also sensitive to policy risks. Moreover, a focus on deleveraging and strengthening balance sheets following the financial crisis has constrained bank lending to the productive economy (Campiglio, 2016).

Private companies are a key funding source through balance-sheet finance, e.g. recycling profits, investing savings, taking on debt and issuing green bonds. In 2017, utilities and energy companies invested USD 121 billion of balance sheet finance in global renewable energy. Private company investment is shaped by the health of their balance sheet, borrowing costs and perceptions of project viability, which often depend in part on public policies (e.g. grants, long-term subsidies, minimum guaranteed income). European utilities are currently constrained in their ability to make balance-sheet-financed investments in renewables because of the need to reduce debt following the financial crisis and mergers and acquisition activities after market liberalisation (Hall et al., 2017).

Small end-users: As noted already, households, farmers and small cooperatives are important sources of finance for energy efficiency improvements in buildings (e.g. double glazing, insulation, retrofit) and in transport (e.g. hybrid or EVs) and for well established RETs (e.g. rooftop photovoltaics or community energy initiatives operating a few wind turbines). Small end-users mostly self-fund their investments from savings, often supported by public grants, subsidies or feed-in tariffs. Expansion of these investments is constrained by high upfront capital costs, split incentives (e.g. landlords bear the costs of energy efficiency investments but tenants secure the benefits), and a lack of appeal or funding ability beyond middle-class households with green orientations.

7.3.2 Creating clear signals for investments

The policy reforms needed to reorient capital flows vary in their depth and ambition. Investments in sustainability innovations and related infrastructures can be stimulated using well-known policy tools such as financial incentives, regulations and standards to correct market incentives and reduce risk and uncertainty. Many sustainability innovations have unattractive risk-return profiles in terms of technological risks (especially for less mature innovations), commercial risks (especially if sustainability innovations are more costly or have uncertain business models) and long payback times.

Policymakers have a mixture of tools at their disposal that can help create markets for sustainability innovations and provide a clear signal of intended development pathways, thereby reducing risks and stimulating investment (Table 7.2 presents selected tools in relation to energy investment). To be effective, however, it is essential that policy signals are robust and stable. Sudden shifts in policy represent an important source of risk that can significantly undermine investor confidence.

Combining investment sources through 'blended finance' mechanisms can also increase financial flows. For example, increased investments by development banks or government agencies that cover the high-risk elements of investments could leverage and stimulate private investment. Indeed, this is the logic behind the EU's European Fund for Strategic Investments, which aims to catalyse investments of at least EUR 500 billion,

Table 7.2 Selected policy tools for reorientation of energy investment

Type of project	Typical policy tools that facilitate investment	Other measures that can affect future investment decisions
Utility-scale renewables	Auctions for long-term power purchase agreements; portfolio standards; tradable certificates	Carbon pricing; long-term arrangements with modulated market premiums
Distributed generation (e.g. rooftop photovoltaics)	Feed-in tariffs and net metering	Carbon pricing; retail electricity tariff design; minimum building performance standards
Coal-to-gas switch and biomass power	Carbon pricing; minimum performance standards	Rules for export credits and multilateral financing; financial disclosure rules
CCS in industry and power	Grants to cover additional costs of CCS; CO_2 storage tax credits	Carbon pricing; CO_2 infrastructure deployment; minimum performance standards
Industrial energy efficiency	Utility obligations; energy efficiency auctions; mandatory efficiency opportunity audits	Carbon pricing; minimum performance standards; elimination of energy subsidies
Buildings and appliances efficiency	Minimum performance standards; utility obligations; property tax repayment schemes; public procurement; tradable certificates; revolving funds	Energy performance certificates; performance data transparency; energy services companies
Vehicle efficiency and EVs	Fuel economy standards; fuel and vehicle taxation	Differential road pricing and congestion policies; elimination of consumer fuel subsidies
Electricity storage	Purchase subsidies; charging infrastructure deployment; tradable credits; fleet average fuel economy standards; exemptions from traffic fees	Differential road pricing; parking restrictions; minimum performance standards

Source: IEA and IRENA, 2017.

with 40 % targeting innovation and infrastructure projects that contribute to climate action.

7.3.3 Facilitating investments by financial institutions

A second layer of policy interventions could address barriers that hinder investments by large financial institutions. One key issue for banks and institutional investors is a reported shortage of high-quality and sizable projects that offer stable investment returns (Rademaekers et al., 2017). Energy efficiency investments, for example, are potentially plentiful in number but are often small and distributed across numerous households and businesses, implying high transaction costs. Responding to this challenge is likely to involve developing technical and knowledge capacity — for example at city level — to help ensure a steady pipeline of good-quality projects (OECD, 2018).

Another useful approach involves 'securitisation', i.e. bundling together small projects or assets (such as green mortgages) into a larger pool so that they can be traded in financial markets. This refinancing enables the original lender to extend more loans to customers. In creating a new green asset, it also responds to the growing demand for securities with environmental and sustainability benefits.

Since households will need to provide a substantial proportion of the investments to achieve Europe's climate targets (Figure 7.7), it will be particularly important to find ways to help them meet these costs. Elaboration of government guidelines on green securitisation could support the development of this market (Aldersgate Group, 2018). As outlined in Box 7.2, mobilising banks to finance small-scale projects is possible but may require some active efforts to coordinate different actors (in this case

Box 7.2 Energiesprong in the Netherlands

Shifting to energy-efficient buildings is a huge challenge. The EU requires that all new houses be 'zero energy' by 2021, meaning that they produce as much energy as they use for heating, cooling and lighting. The revised Energy Performance of Building Directive (2018) also highlights the need to improve the existing housing stock towards zero energy. New houses represent only a tiny proportion of the continent's total housing stock. As about 40 % of Europe's CO_2 emissions come from heating, lighting and cooling in buildings, retrofitting existing buildings is crucial for climate change mitigation. Typically, retrofitting requires a substantial investment from home owners, while the benefits are spread over many years.

Launched in 2010, the Dutch initiative Energiesprong — later expanded to France, Germany, North America and the United Kingdom — tackles this financial obstacle with a clever shift in perspective. Dutch households spend about EUR 13 billion on energy each year. If they were to use the same money to repay a long-term loan or the provision of improved energy services, it would effectively free up about EUR 225 million today to invest in the housing stock, which is equivalent to between EUR 30 000 and EUR 40 000 per house.

Energiesprong received a EUR 50 million grant from the Dutch government to facilitate the creation of a self-sustaining market for net-zero-energy homes. Crucially, this included establishing a market development team to generate a shared vision, skillset and knowledge base, and to undertake extensive legal and policy work (Brown et al., 2018). The highly innovative business model created by the market development team includes a net-zero-energy performance contract (with 30-year energy performance guarantee, 21 °C indoor temperature and a set allowance for hot water and electricity), a single customer interface and coordinated governance through market development teams, and an integrated and industrialised supply chain (with off-site manufacturing of insulated wall facades).

Energiesprong takes a system innovation approach, which succeeds by coordinating relevant sectors and identifying win-win situations. By securing the 30-year energy performance guarantee on refurbished homes and brokering a deal to refurbish 111 000 housing association properties in the Netherlands, Energiesprong was able to persuade banks to finance energy refurbishments. The developments in the United Kingdom (10 delivered retrofits) and France (24 delivered retrofits) are in an earlier phase, and are supported with a mix of funding from national and EU innovation funds, local authorities and industry partners (Brown et al., 2018). The building sector and the economy as a whole also stand to gain from these big investments, while households benefit from better insulated homes, higher property values and more spending power once loans are repaid. Energiesprong is focused on delivering retrofit by coupling it with health and comfort benefits for the households (Brown et al., 2018).

Experimentation and learning have played an important role in upscaling the programme. A focus on cost reductions in the initial phase resulted in a 30 % improvement in the price/performance ratio, greatly improving the initiative's financial viability. Reducing the renovation time to one week per dwelling likewise made the process more appealing to homeowners. As the programme extends into France and the United Kingdom, economies of scale and continued innovation should drive further improvements in performance.

securing a long-term performance guarantee on refurbished homes and a deal to refurbish more than 100 000 housing association properties).

Green bonds provide another mechanism for increasing large-scale institutional investments, in part because of the availability of secondary markets for investments. The green bond market has expanded very rapidly, rising from global issuance of USD 3.4 billion in 2012 to USD 161 billion in 2017. However, optimism about the rapid growth of green bonds needs to be tempered. First, increased transparency is needed to ensure that they are not used for 'greenwashing' (Aldersgate Group, 2018). Second, despite the rapid growth, green bonds account for less than 1 % of the global bond market. The flow of investments into fossil fuel exploitation continues to dwarf global investments in renewables (OECD, 2018).

Additional measures could seek to reformulate institutional rules and formal expectations of financial actors. For instance, pursuant to its 2018 Action Plan on Financing Sustainable Growth, the European Commission plans to:

- develop a unified classification system (to better define what counts as sustainable finance);
- develop standards and labels for sustainable financial products (including green bonds);
- better integrate sustainability into ratings and research by credit-rating agencies;
- change the fiduciary duties of institutional investors and asset managers (so that they more

systematically consider sustainability factors and risks in investment processes);

- strengthen disclosure responsibilities and accounting rules (so that companies are required to inform investors about sustainability performance and risks);
- pay particular attention to the possible negative impact of the Basel III regulatory framework on European bank lending, investment and other activities, which are critical for sustainable finance.

7.3.4 Deeper financial system reforms

A third and deeper layer of policy reform could address structural problems such as short-termism in the financial sector or incentives that encourage speculative investments over long-term investment in the real economy, including in sustainability transitions (Mazzucato, 2015; Haldane, 2016). Radical structural reforms could, for instance, aim to reduce the profitability of short-term, speculative investments through a financial transactions (Tobin) tax or even ban certain forms of non-transparent financial products, such as credit default swaps or collateralised debt obligations (Røpke, 2016).

Other structural reforms could reintroduce divisions between ordinary banking and investment banking, to make less money available for speculation. More radically, some researchers have suggested changing the mandate of central banks, from the narrow focus on price stability and (more recently) financial stability and regulation that predominates in western countries (Campiglio et al., 2018). In many emerging economies (Brazil, China), central bank mandates are broader (e.g. focused on economic development or support for strategic sectors). The activism and innovation of central banks after the financial crisis, when interventions such as quantitative easing helped curtail risks of a global depression (El-Erian, 2012), arguably point to their potential role in supporting sustainability transitions. Changes in central bank mandates could, for example, enable green quantitative easing (Campiglio et al., 2018), involving purchases of green bonds, investments in low-carbon financial assets or providing additional liquidity to companies interested in shifting to clean forms of production.

While these structural reforms would help reorient financial flows and accelerate sustainability transitions, they are difficult to introduce because of opposition from very powerful vested interests (Røpke, 2016; Campiglio et al., 2018).

Part 3 Managing complexities in transition processes

Sustainability transitions are societal processes of change that combine government actions across multiple policy areas and levels with bottom-up innovation and experimentation by a variety of actors. Such processes present three related sets of governance complexities:

- How can such complex, dispersed and emergent processes be steered towards multiple, long-term sustainability goals?
- How can societies achieve coherence across policy areas and scales of governance to support transitions?
- How can the inevitable risks and trade-offs associated with systemic change be managed?

Part 3 addresses these questions and explores how governments and other actors can promote directionality and coordination, and anticipate and adapt to unintended consequences of transitions.

The challenges and related policy recommendations addressed in Chapters 8-12 differ in some important respects from those in Part 2 (Chapters 3-7). First, although transitions research and other relevant literature have touched upon or started to investigate the issues discussed in Chapters 8-12, many topics require more data, analysis and knowledge. Since there is no settled position in the emerging academic literature on many issues, the messages and recommendations are preliminary.

Second, and more importantly, many of the policy and governance challenges referred to are not instrumental questions for which analysis can derive recommendations about optimal policy. They are political challenges, which require political solutions. Therefore, some of the recommendations focus more on processes and procedures than on policy design.

8 Visions, missions and targets to provide long-term directionality

Message 6: Promote a clear direction for change through ambitious visions, targets and missions

- Developing ambitious long-term visions, targets and missions using collaborative and forward-looking approaches such as foresight is essential to guide transitions. Such instruments help in developing shared narratives and values, as well as conveying urgency and commitment.
- To make long-term visions concrete and to incentivise supporting actions, it is important to translate these visions and missions into sectoral and cross-sectoral policy strategies, programmes and instruments.
- Ambitious and consistent short-, medium- and long-term sectoral and cross-sectoral targets are needed to make the vision and related policy strategies credible and to measure progress.
- Progress towards visions and missions must be reviewed periodically to enable policy learning, and to improve and adapt actions to help achieve the overall vision.

8.1 The role and value of long-term visions, missions and targets

Sustainability transitions differ from past examples of change in societal systems in that they are purposeful and directional, aiming to address environmental and societal problems (Kemp and Rotmans, 2004; Schot and Steinmueller, 2018). The complexity and uncertainty of societal change means that the future of society cannot simply be planned. Yet the desired outcomes are already reasonably clearly defined — most prominently in the UN SDGs but also in the growing body of long-term visions and targets in instruments such as the Paris Agreement and the EU's long-term framework policies addressing themes such as climate, energy, mobility and biodiversity (e.g. EC, 2011c, 2015b, 2017b, 2018e; UN, 2015b; UNFCCC, 2015).

Visions, missions and targets provide a means to create directionality in complex and uncertain transition processes (Box 8.1). Directionality means 'making social choices over alternative pathways of development', taking a question of direction as a starting point in policymaking and establishing a process of determining collective priorities (Schot and Steinmueller, 2018). It means addressing, as part of policy mixes or portfolios, the questions 'what future do we want?', 'what is the ultimate goal?', 'why do we want this future?' and 'why is this particular goal important?' (Schlaile et al., 2017). For example, societies may choose to fund innovation or industry from public subsidies on the basis of shared goals (such as environmental sustainability and social justice) instead of funding all innovation or companies equally or merely focusing on the speed of innovation.

Failure in directionality means a deficiency in directing 'innovation efforts and collective priorities in a certain direction to meet societal challenges' (Scordato et al., 2017).

Box 8.1 Visions, missions and targets

Visions articulate a desired end-state for a particular socio-technical regime (energy, mobility, food) supported by an actor network, to guide and motivate processes of technological, institutional and behavioural change (Berkhout, 2006). Visions are a means for introducing directionality into policymaking. An example is a vision of 'a resource-efficient and low-carbon energy system' or 'a sustainable and flexible mobility system'.

Missions identify an opportunity and provide a solution and approach to address societal challenges (Mazzucato, 2018). Often used in the innovation and defence policy areas, they create directionality and a focus for coordinating activities by different actors, sometimes across sectors. A mission is more specific than a vision, often expressing urgency and the need for immediate action. Examples of missions include having plastic-free oceans, or 100 carbon-free cities by 2030 (Mazzucato, 2018).

Targets make concrete a vision or a mission, often in quantifiable and measurable terms. In contrast, visions and missions can include non-quantifiable or only partially measurable elements and are often less concrete. Examples of targets are reduction of energy demand by industry by 50 % by 2030, replacing 30 % of combustion engine vehicles with EVs by 2025, or halting the use of non-recyclable single-use plastics by 2020.

8.1.1 Visions

Transitions research emphasises the need to develop ambitious, positive long-term visions as a means to direct transition processes in societally desirable directions. Such visions can contribute to societal developments by providing a shared storyline for actors (policymakers, businesses, civil society organisations, citizens) and by building acceptability for a direction of travel.

Visions can be used to specify a desired end-state for a particular socio-technical system (e.g. energy, mobility, food) (Berkhout, 2006) or across several systems. They can outline what technologies and resources will be used, what kind of services will be offered to people, what institutions and policies will be needed, and how people could live their day-to-day lives. Visions can therefore reduce some of the uncertainty related to the future state of the world.

In the context of sustainability transitions, visions can (Smith et al., 2005; Berkhout, 2006):

- provide direction for search and learning processes;
- identify credible and desirable alternatives to existing ways to meet social needs or redefine such needs;
- raise attention and acceptability to sustainable alternatives;
- provide a means to attract resources from actors and to guide investment;
- coordinate actors and create new actor networks, acting as a common reference point that brings actors together;
- create a frame for setting more specific missions and targets, and for monitoring progress.

'The purpose of this strategic vision is not to set targets, but to create a vision and sense of direction, plan for it, and inspire as well as enable stakeholders, researchers, entrepreneurs and citizens alike to develop new and innovative industries, businesses and associated jobs.' EU's long-term strategy for a climate neutral economy (EC, 2018g)

Sustainability transition scholars emphasise that visions regarding future socio-technical systems should be developed collaboratively (Kemp et al., 1998; Rotmans et al., 2001), to create a shared understanding of what the future should look like, the concrete goals and alternative pathways to realising the vision, and the trade-offs involved. Visions can only fulfil their collective functions if they are shared between many actors, including public and private sector actors and civil society organisations. It is important to include political backing or involve politically influential actors to enable concrete follow-up actions such as policy programmes and instruments.

In practice, developing a coherent vision for a sustainability transition is far from unproblematic. Visions of the future may be contested. Multiple, potentially competing visions are also likely to exist (Smith et al., 2005). Joint visioning exercises depend on successful arbitration to reconcile different expectations, often reflecting political choices. Differences between the expectations of different actors mean that consensual visions are unusual (Berkhout, 2006). Box 8.2 describes a process of vision formation in the Dutch transition programme and the challenges that it entailed.

Box 8.2 The Dutch energy transition programme — opportunities and challenges in collaborative vision formation

In 2001, the Dutch government set up a dedicated energy transition programme, led by the Ministry of Economic Affairs. The programme applied early insights of the transition management literature and was a dedicated attempt to influence the direction of change in the energy system towards sustainability. The process included producing a broad, long-term overall vision; bringing together stakeholders and policymakers in transition arenas to develop shared visions and expectations in specific fields (such as sustainable mobility or renewable electricity); using back-casting techniques to explore different transition pathways; providing dedicated funding for transition experiments to explore the pathways; and monitoring the unfolding developments.

The process began with the formulation of a vision of Dutch energy supply by a working group of civil servants from the Ministry of Economic Affairs. In 2001 they conducted a scenario project entitled *Long-term Vision of the Energy Supply*, which identified long-term trends and produced four possible future scenarios for energy supply for 2050. The overall vision was that the future Dutch energy system should be clean, affordable and reliable.

To further specify the vision and explore how to get there, the Dutch government selected seven areas that it considered 'robust elements' (in the sense that they would play an important role in any of the four scenarios) and in which the Netherlands could have a competitive advantage: biomass, new gas, energy efficiency in the built-up environment, sustainable electricity, sustainable mobility and the greenhouse as an energy source. They then established transition platforms in these areas, to which the government invited a range of selected actors, including firms, NGOs, policymakers, academics and intermediaries. Each platform developed a more specific strategic vision for its area for 2030 and explored various transition pathways using back-casting techniques. For example, the biomass platform formulated the ambition that 30 % of Dutch primary energy consumption and 40 % of sustainable electricity production should be based on biomass by 2030 and specified three transition pathways along which that ambition could be achieved.

Laurens-Jan Brinkhorst, Dutch Minister of Economic Affairs, remarked that 'Energy transition brings us into contact with ambitious people, people with a daring vision of innovation and sustainability.' In practice, however, the composition of the platforms developing the strategic visions and pathways was dominated by big incumbent firms such as Shell, Gasunie, BP, Unilever and Essent, while civil society organisations were under-represented. This had three consequences:

- First, it undermined the legitimacy of the process, as it came to be seen as an elite-driven process of regime incumbents with vested interests, which was heavily criticised by environmental NGOs.
- Second, it led to the use of conventional selection criteria for the themes, pathways and experiments (such as market potential), which failed to open up sufficient space for a wide variety of different energy practices (such as low-carbon lifestyles). This made the optimisation of the existing socio-technical system more likely than structural change.
- Third, the reliance on regime incumbents made it politically difficult for the government to put pressure on these firms (e.g. through tougher carbon pricing) because this would undermine their commitment to the transition management process (Kern and Smith, 2008).

This experience shows that it is possible to develop broad sustainability goals and visions jointly with a range of public and private actors. However, there are important decisions about whom to involve in such processes, as it can undermine legitimacy and lead to a loss of momentum of the transition (Kern and Smith, 2008; Hendriks, 2009).

8.1.2 Missions

Missions have long been used as a mechanism to orient and coordinate innovation processes in relation to societal challenges and goals. Prominent examples include NASA's Apollo mission and Japan's energy efficiency push after the oil crisis of the mid-1970s, although earlier examples date back centuries. Recent years have seen a revival of interest in missions as a key component of industrial strategy. Within EU policy, missions have emerged with particular prominence in planning for post-2020 innovation policy (Horizon Europe). Table 8.1 summarises two ongoing missions in Germany and Norway, drawing on a set of national case studies of mission-oriented policies that has been compiled by the European Commission's Directorate-General for Research and Innovation (EC, 2018i).

Table 8.1 Examples of mission-oriented research and innovation policies: Energiewende and Norway's EV initiative

	German *Energiewende*	**Norwegian electric vehicle initiative**
Mission	The development of a low-carbon energy system based on renewable energy and energy efficiency.	The development of EVs as mainstream mobility option.
Targets and objectives	Phase out Germany's nuclear power plants by the end of 2022 (since the Fukushima disaster in 2011).	Carbon pricing; retail electricity tariff design; minimum building performance standards
Timeline	1990-present, with a long pre-history. The mission was largely formalised in 2010, around the *Energiekonzept*.	1990-present. The mission was formalised in steps, notably in 2009 with a plan of action for the electrification of road transport and periodically raised ambitions.
Governance bodies	Federal Ministry for Economic Affairs and Energy, with strong interactions with German regions (*Länder*) and other stakeholders.	Norwegian Parliament and the Norwegian Electric Vehicle Association
Implementation mechanism	National long-term strategy, including: • commitment to 21 % GHG reductions between 1990 and 2008; • *Energiekonzept* (2010) envisaging an economy based on renewables by 2050, including medium- and long-term targets. Accumulation of federal laws: • feed-in tariffs for renewable energy (1991); • the Renewable Energy Sources Act and its periodic revisions (2000, 2004, 2009, 2012, 2014, 2017); • specific tariffs for photovoltaics within the PV Interim Acts (2003, 2010, 2013); • law on nuclear phase-out by 2022 (2011).	Tax incentives: exemption from import tax (1990), 25 % VAT exemption (2001), low annual road tax (1996), 50 % reduced company car tax (2000), 25 % VAT exemption for leasing (2015). Investments: national investment in charging stations (2008). Behavioural nudging: exemption from toll road and ferry charges (1997, 2009), free municipal parking (1999), access to priority bus lanes (2005).
Overall result	Some significant progress: • 27 % RET in electricity generation; • progress with nuclear phase-out; • has stimulated significant private investments and generated R&D and industry capacity. But some challenges: • GHG target unlikely to be met (because of continued fossil fuel burning, especially coal); • moderate progress with energy efficiency.	In 2018, the market share of EVs reached 31 %, with the total number of EVs in Norway totalling almost 200 000. The market share of electric and hybrid EVs in 2018 was 49 % (Norsk elbilforening, 2019).

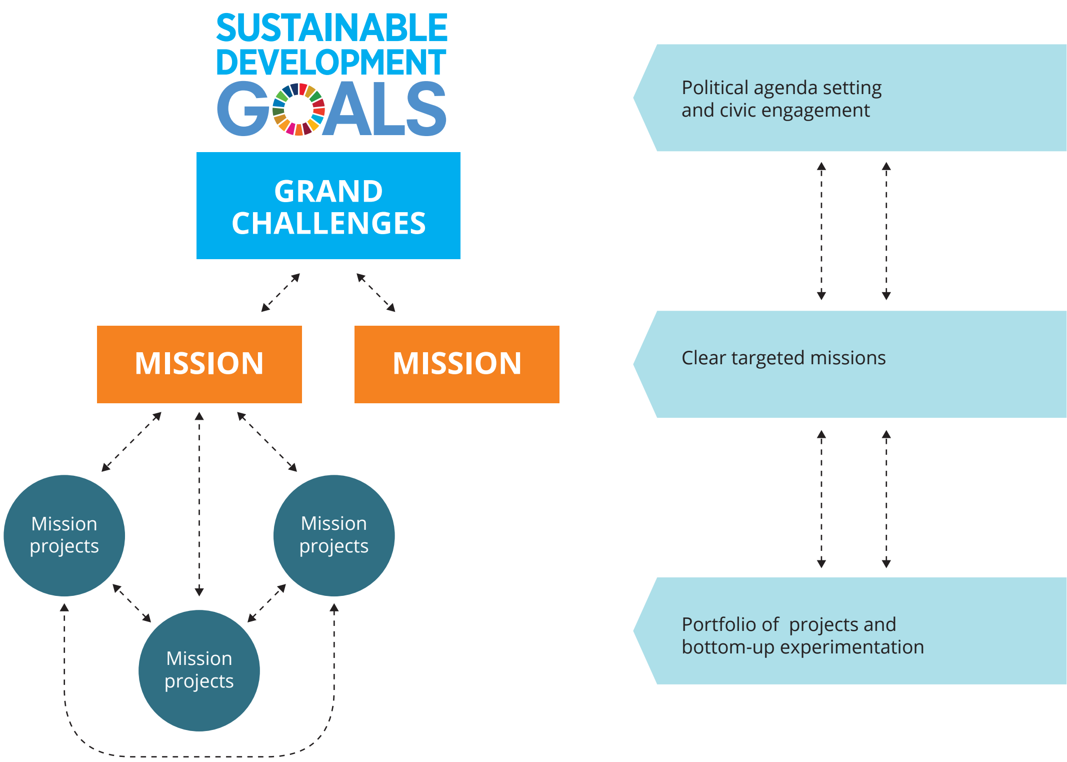
Missions offer 'a solution, an opportunity, and an approach to address the numerous challenges that people face in their daily lives', setting clear and ambitious cross-sectoral objectives and targets that are measurable and time-bound (Mazzucato, 2018). Missions 'should be broad enough to engage the public and attract cross-sectoral investment; and remain focussed enough and achieve measurable success' (Mazzucato, 2018). They generally function at a middle level, between broad societal goals and ground-level projects and experiments (Figure 8.1). They are thus more specific than visions and convey greater urgency, commitment and purpose.

Mission-oriented policies are defined as systemic public policies that draw on frontier knowledge to attain specific goals (Ergas, 1987). They have particularly been used in connection with R&I policy and defence policy. Ideally, the objectives set within missions are followed by mixes of cross-disciplinary R&I projects and are coupled with other policy instruments, new kinds of partnerships and the involvement of end users (Mazzucato, 2018). Together, these enable a range of different solutions to achieve the mission. Such solutions can result in novel cross-fertilisation of technologies (Cantner and Pyka, 2001) that help achieve the mission.

In practice, mission-oriented policies require highly skilled policymakers and stringent procedures to avoid traps linked to mission-oriented projects, such as ending the project too early, premature lock-in to a specific technological trajectory (before the advantages and disadvantages of alternatives have been explored) and capture by special interests (e.g. private companies) (Fagerberg, 2018). As already highlighted in relation to visions and pathways, a key risk is becoming locked in to a specific technological trajectory at an early stage, rather than exploring alternatives.

Achieving sustainability transitions will require a more open and inclusive approach to missions than in previous decades, when missions in R&I policy were largely oriented towards economic or defence goals. Historically, public agencies were both the final users and the sources of finance for mission-oriented projects, for example in the case of the Manhattan Project (atom bomb development) and the Apollo mission (Fagerberg, 2018). As discussed in Chapter 3, today's missions will need to tap into the ideas and

Figure 8.1 Missions: bridging between macro-level goals and micro-level projects



Source: Mazzucato, 2018.

energy of entrepreneurs, social innovators and the general public. There is scope for missions to advance sustainability, 'if the missions are formulated in an open-ended way that encourages experimentation and diversity' (Schot and Steinmueller, 2018a). More work is needed to deliberate how to solve potential trade-offs between economic growth and environmental sustainability through missions.

8.1.3 Pathways and targets

Combining visions, i.e. the end-state depiction of future socio-technical systems, with the exploration of more specific transition pathways is important. To accommodate uncertainties and varying expectations, analyses of pathways in connection to a vision should explore a variety of innovations and related pathways, which provide different ways of reaching the end-state. For example in Finland during 2017, the Smart Energy Transition Consortium organised an energy transition arena in collaboration with the Finnish Innovation Fund, Sitra, including a range of stakeholders from business, government and civil society. Those involved identified and elaborated 12 complementary transition pathways to transform the Finnish energy system, covering issues such as coal phase-out, demand response, building energy use, mobility and clean technology export (Hyysalo et al. 2017).

Multiple visioning, foresight and back-casting methods exist to explore possible futures. Their use is related to the skills and capabilities of actors in governing transitions (further discussed in Chapter 12). The development of visions and targets can occur at different governance levels and is often tied to specific socio-technical systems in countries, regions and cities (see Chapter 10). There are different ways to address these in European policymaking. Sometimes targets are left for Member States to determine, following joint vision setting and some specific requirements. In other cases, both the vision and targets have been set at the EU level.

The EU's Roadmap for a Resource-Efficient Europe, for example, envisages that:

> By 2050 the EU's economy has grown in a way that respects resource constraints and planetary boundaries, thus contributing to global economic transformation. Our economy is competitive, inclusive and provides a high standard of living with much lower environmental impacts. All resources are sustainably managed, from raw materials to energy, water, air, land and soil. Climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored. (EC, 2011d)

It outlines responsibilities for the Member States to set more specific targets to work towards this vision.

The EU's Energy Performance of Buildings Directive (EU, 2010) set a target for all new buildings to be nearly zero-energy by the end of 2020 and all new public buildings to be nearly zero-energy by 2018. The revised Energy Performance of Buildings Directive (EU, 2018a) extended the scope of the Directive, following a vision of 'a sustainable, competitive, secure and decarbonised energy system', to also cover transformation of existing buildings into nearly zero-energy buildings. Furthermore, the revised Directive includes new requirements regarding electromobility through conditions pertaining to charging points and the smart readiness of buildings. Nearly zero-energy buildings (NZEBs) have very high energy performance and meet most remaining energy needs through renewable energy sources and smart energy systems. The directives require EU Member States to develop national action plans for new buildings to be NZEBs and for long-term renovation strategies to support the renovation of the national stock of residential and non-residential buildings, producing a highly energy-efficient and decarbonised building stock by 2050 and translating the vision into concrete policy programmes.

> 'Foresight and other forward-looking tools complement quantitative modelling with a system thinking and long-term approach that is developed through qualitative and participatory methods involving all relevant stakeholders. They facilitate thinking out of the box. The objective is to engage with different possible futures (e.g. providing alternative futures) and challenge present assumptions thereby broadening the policy horizon … Such forward-looking processes will help identify targets and new ways for policy interventions in a more systemic manner.' EU Better Regulation Toolbox (EC, 2018a).

8.2 Translating visions into sectoral and cross-sectoral strategies and instruments

While the process of developing ambitious long-term visions, missions and targets sends important signals to society, these instruments also need to be translated into or backed up by sectoral and cross-sectoral policy strategies, programmes and instruments, to be credible and contribute to change in practice.

As a result of limited resources available and a lack of sufficient framework conditions supporting systemic change, translating visions and missions into innovation policy mixes often entails choices between technology preference and neutrality (Azar and Sandén, 2011). Visions are often broader and less technology specific, while mission-oriented policies may involve the selection of particular technological paths to be supported by public resources (Fagerberg, 2018) that depend on the specificity and urgency of the mission. Early mission-oriented policies especially tended to favour specific technological paths (Cantner and Pyka, 2001). While policymakers often argue that governments should stress competition among options, and technology neutrality rather than specific technology support, the Organisation for Economic Co-operation and Development (OECD) acknowledges that 'judicious use of more technology-specific measures may be required to overcome the barriers facing low-emission technologies and drive transformative rather than incremental innovation. Feed-in-tariffs (FITs), for example, were instrumental in bringing wind power in Denmark and Germany to full commercialisation at a time when the technology was not commercially competitive' (OECD, 2018).

The systemic perspective on innovation emphasises that no single policy instrument can act as a silver bullet to improve socio-technical systems towards sustainability transitions (Scordato et al., 2018). Hence, a policy mix approach is recommended for translating sustainability transition visions and missions into practice (Kivimaa and Kern, 2016; Rogge and Reichardt, 2016; Mazzucato, 2018).

8.2.1 *Promoting specific innovations and altering framework conditions*

To shape the direction of sustainability transitions towards a vision or mission, policymakers can simultaneously work on two fronts: innovation-specific policies and generic framework conditions.

First, policy strategies and instrument mixes can support the exploration of specific innovations and transition pathways. Visions, missions and targets create expectations among actors about the future system, showing signs of what kind of solutions may be needed and where new markets may lie. Such directional influence can be strengthened by supportive policy instruments targeting experimentation, innovation and new market creation, such as RD&D and deployment subsidies available for transition pathways involving, for example, solar energy, wind energy, zero-energy buildings, EVs and non-meat protein alternatives. These should take into account different development phases (invention and emergence, commercialisation and take-off, diffusion and mainstreaming). The precise instrument mix required to stimulate societal activity may vary over time. The sequencing and timing of public interventions are not easy decisions and depend on the rate of development of relevant technological and social innovations — for example, when to invest heavily in the charging infrastructure for battery EVs and industrial restructuring (Nilsson and Nykvist, 2016).

Second, policy mixes can shape and alter the general framework conditions for transitions, ideally in support of the vision or the mission adopted. Policymakers can influence decision-making with taxes or subsidies that provide price signals, punishing undesirable, and rewarding positive, behaviour and decisions (Aghion et al., 2016). Environmental regulations or performance standards can encourage, forbid or prescribe certain courses of action (Ashford et al., 1985). The EU emissions-trading scheme is an example of an instrument that aims to change the framework conditions of actors making decisions in covered sectors (such as electricity producers) by putting a price on carbon emissions. Regulations for the energy performance of buildings have been successful in achieving progress towards visions, particularly in countries where they have been implemented effectively, creating changed framework conditions for construction and renovation, and where they have been coupled with a mix of other policy instruments (subsidies, information, voluntary agreements) (D'Agostino et al., 2017; Kern et al., 2017).

8.2.2 *From policy programmes to broader institutional reforms*

In some cases, a vision may be implemented by launching a new policy programme, incorporating a well-designed instrument mix. For example, in the case of comprehensive energy renovations of existing buildings, such a mix could include a regulation setting the minimum energy performance for existing buildings, RD&D funding for the development of new business models, subsidies or low-interest loans for renovation projects, and the establishment of an advisory organisation. In other cases, a new mix of instruments is not enough, and the urgency of the challenge requires dismantling or significantly changing institutional structures, policy instruments and policy processes that act as barriers to innovation and system change (Kivimaa and Kern, 2016). For example, the significant uptake of renewable energy has necessitated significant changes in related systems that control the issuing of permits, taxation, and distribution and transmission network connections.

Generally, policy mixes are likely to be more effective, from a transitions perspective, when larger scale institutional and legislative reforms are carried out (Kivimaa and Kern, 2016) as part of broader political strategies or programmes addressing sustainability (e.g. to decarbonise electricity generation or mobility). For example, in an analysis of the decarbonisation of Germany's electricity sector, Rogge et al. (2018) find that changes in institutional and governance arrangements matter for the effectiveness of transformative policy mixes regardless of the transition pathway pursued. The United Kingdom's Climate Change Act, which created a binding framework across electoral cycles and a system of carbon budgets, is also an example of institutional reform and a visionary policy (Box 9.2).

An example at the European level is the Energy Union strategy for a secure, affordable and sustainable energy system, launched in 2015, which combines a wide range of interventions, including support for energy innovation and the funding of transboundary infrastructure. It is underpinned by a long-term vision for a clean energy transition ('a prosperous, modern, competitive and climate-neutral economy by 2050'), associated medium-term targets, and a Clean Energy Package comprising eight EU legal instruments. The Regulation on the Governance of the Energy Union and Climate Action (EU, 2018b) specifies the coordination mechanism between the EU and Member States, enabling the fulfilment of targets. This governance mechanism is based on 10-year plans (Integrated National Energy and Climate Plans), EU and national long-term strategies, reporting and monitoring rules, and public consultation.

8.2.3 Barriers to translating visions

Institutional reforms and holistic policy programmes may be better equipped than more incremental policy changes to identify and address barriers to new sustainable products or services, and to reduce inconsistencies or conflicts between policy goals, policy instruments and policy processes — across both policy areas and scales of governance.

One difficulty in the European context is that, while the EU has set ambitious visions for the future of Europe (e.g. the European strategy for low-emission mobility at the EU level, or the Smart Specialisation Strategies for regional innovation as part of EU Cohesion Policy), translating these visions into policy action often takes place through Member States. This means that translation will vary, sometimes significantly.

Returning to the example of the Energy Performance of Buildings Directives, which require all new buildings to be nearly zero-energy by the end of 2020 and existing buildings thereafter, the policy strategies and programmes to implement this target — and a broader vision of a zero-carbon buildings system — rely on Member States, which are required to draw up national plans to increase the number of nearly zero-energy buildings (NZEBs). However, the European Commission progress report from 2013 found that 'EU countries had to significantly step up their efforts to take advantage of the opportunities presented by NZEBs' (EC, 2013b). The United Kingdom, for example, dropped the target for zero-carbon homes altogether in 2015. Even before that decision, the construction industry's confidence in the government's seriousness around this agenda had been eroded by policy ambiguity and inaction, which led to little activity towards achieving the target (Edmondson et al., 2018; Payne and Barker, 2018). Such policy shifts represent a major barrier to effective governance. As Bontoux and Bengtsson (2015) note, 'Regulatory (un)certainty and the focus of policy initiatives can be game changers; clear and steady policy directions can play a very important role in managing change and steering the evolution of society and the economy.'

The ways in which transition pathways in different sectors are advanced in EU Member States depend on national priorities and other policy sectors. In translating visions and missions into concrete policies, one of the key issues is how to ensure the credibility of long-term aspirations in the context of short-term political cycles (e.g. Rogge and Dütschke, 2018). This highlights the importance of looking at policy mixes and their consistency in relation to different transition pathways (see Chapters 10 and 11) when translating visions into practice.

8.3 Target setting and periodic

review

Visions and missions — and the policies that translate them into practice — should be complemented with specific long-, medium- and short-term targets. Targets help to make vision and strategies credible and actionable, and allow policymakers to measure progress. For example, a mission for plastic-free oceans can be coupled with targets to reduce plastics entering the marine environment by 90 % and to collect more than half of the plastics present in our oceans, seas and coastal areas by 2025 (Mazzucato, 2018). In contrast, Sweden's National Food Strategy envisages that 'The Swedish food chain in 2030 is globally competitive, innovative, sustainable and attractive to operate within' and includes many qualitative objectives but no measurable targets (Regeringskansliet, 2017).

The practice of translating broad long-term policy ambitions and visions into ambitious long-, medium- and short-term targets is already occurring, although primarily in the energy domain and less in food and mobility. For example, the EU's Low-carbon Economy Roadmap (EC, 2011b) sets out the EU's long-term 2050 target of reducing GHG emissions by 80-95 %. This long-term target (2050) was supplemented with the 2020 (20 % reduction) short-term and 2030 (30 % reduction) medium-term targets. The roadmap suggested possible additional policy actions and outlined milestones 'which would show whether the EU is on course for reaching its target, policy challenges, investment needs and opportunities in different sectors' (EC, 2011b), and was later followed by supportive legislation.

Measurable targets are often set at national and local levels, but can also be set at the European level, as in the Energy Performance of Buildings Directive (EU, 2010, 2018a). Targets can be binding or non-binding and address different elements of transitions:

- first, the means through which transition is promoted (R&D spending, share of public procurement, number of EV charging points, etc.);
- second, the change desired (reduction in emissions, improvement of biodiversity, uptake of renewable energy, reduction of meat consumption, etc.).

Examples of the latter are more common. The EU Climate and Energy Framework, for example, sets change-oriented medium-term targets: at least 40 % cuts in GHG emissions (from 1990 levels), at least a 27 % share for renewable energy and at least a 27 % improvement in energy efficiency by 2030 (EC, 2014a). There are varying binding national targets for the share of renewable energy for the Member States. The EU's Low-carbon Economy Roadmap contains additional objectives, targeting a 60 % reduction in GHG emissions by 2040 and an 80 % reduction by 2050 (EC, 2011b). Sectoral, non-binding targets are suggested for buildings, transport, industry and power production.

Target setting does not need to only involve public actors. The City of London's 'zero-carbon city by 2050' vision includes commitments from the London Business Climate Leaders group to purchase 100 % renewable electricity for London-based properties by 2020 and to reduce waste generation by 50 % by 2030 (GLA, 2018).

Target setting for sustainability transitions is not a simple process. As with defining visions, collaborative target setting is desirable to get actors to commit to actions to reach the targets. The targets need also to be ambitious enough to stimulate actions to influence transitions, which are likely to face political resistance. Even when sustainability forms the backbone for the jointly agreed vision in transitions, differing views, and even disagreements, exist about the criteria to be used in target setting and performance measurement (Rauschmayer et al., 2015).

Periodic review (and eventual revision) of targets is crucial. Policy strategies, programmes and instrument mixes require continuous monitoring and periodic evaluation to see what revisions are required in the overall policy approach, target setting, instrument mix or implementation process. The multifaceted nature of transitions means that commonly used evaluation frameworks and methods may not be sufficient, and a combination of evaluation approaches is needed. These include using a combination of both quantitative measurement and qualitative or semi-qualitative stakeholder-based evaluations, using reflexive and realistic evaluations of transition experiments, and the formulation of new evaluation frameworks based on perspectives from sustainability transition frameworks (Kivimaa et al., 2017; Luederitz et al., 2017). In addition to policy evaluation, open evaluations concerning pathways, directions and system change are needed (Turnheim et al., 2015). Such pathway evaluations can support further revision or tightening of targets and the fine-tuning of policy mixes to effectively drive transformative change.

This breakdown and translation of overarching policy strategies, visions and targets to specific sectors is important as a signpost for actors in those sectors. It can help identify suitable sector strategies and policies needed. It is crucially important that the EU sets targets over different time horizons, critically assesses current performance against them and proposes additional policy actions to address any shortcomings or gaps. However, the extent to which this can be effective in steering actors' behaviour partly depends on the implementation of the proposed instruments by Member States. The potential success of proposed policies also depends on their specific design and the synergies with other policies in the policy mix influencing target group actors' behaviour and actions (see Chapters 9 and 10). Box 8.3 illustrates how national and sector-specific target setting, policy mix development, periodic review, evaluation and gradual tightening can support transformative change.

Box 8.3 Target setting and revision to support transition: development of the Finnish policy mix for buildings' energy efficiency

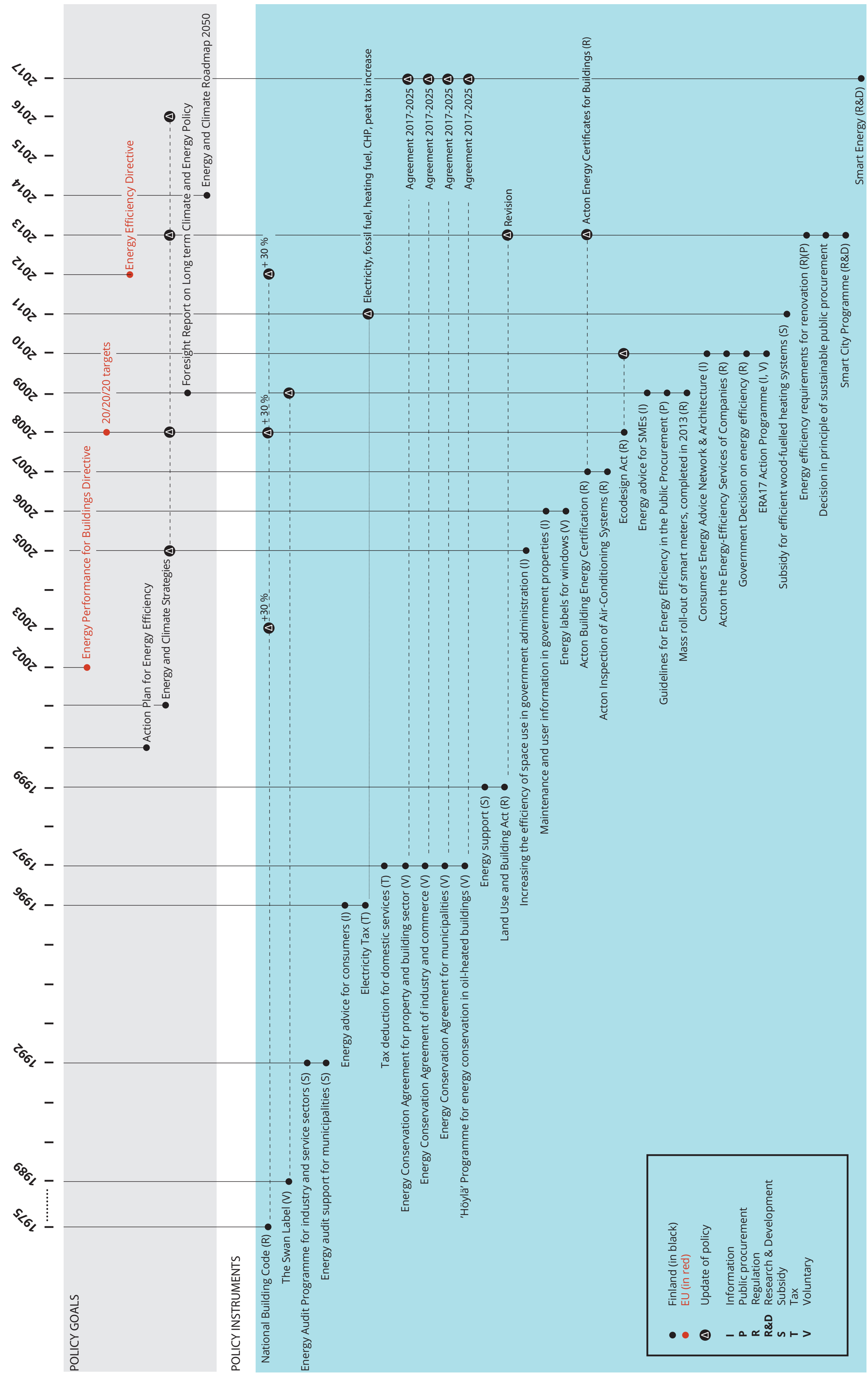
By international standards, Finland's building stock is relatively energy efficient. As an EU Member State since 1992, Finland has been guided by EU vision and target setting for buildings and relevant legislation, such as the Energy Performance of Buildings Directive (EU, 2010) and the target of new NZEBs by 2020. This vision has later been extended to decarbonise the building stock by 2050 and to have a requirement for energy renovation strategies to achieve existing NZEBs, as outlined in the revised Energy Performance of Building Directive (EU, 2018a).

The shift towards low-energy buildings in Finland has particularly advanced since the early-2000s, with measurable improvements in the energy consumption of both new and existing buildings (Lemström, 2015). Although policy for reducing the energy demand for buildings dates back to the 1970s, when energy efficiency requirements were added to building regulations, more significant advances have been made since 2000. This progress was enabled by consistent policymaking over time, setting gradually tightening energy efficiency requirements to meet the EU vision, and achieving a relatively coherent policy mix (Kern et al., 2017).

The gradually tightening energy efficiency requirements for new buildings set a trajectory for considerable improvement (Kivimaa et al., 2017), notably through periodic tightening of targets in 2003, 2008, 2010 and 2012 (Kern et al., 2017). This process was supported by a national vision for the energy efficiency of buildings, the involvement of a broad coalition of actors, and the combination of 31 different policy instruments (Figure 8.2, page 115) (Kern et al., 2017). This process also improved the coherence of the policy mix, enabling more consistent signalling to stakeholders.

The presented Figure 8.2 illustrates the importance of long-term directionality, vision setting and translating visions into concrete policies to advance transitions. It further shows how shaping the direction of transitions can partly be achieved through incrementally improving coherent policy mixes that are influenced by gradually progressing target setting and joint visioning processes with stakeholders. It indicates how visions, strategies and instrument mixes may not be enough to fundamentally transform existing regimes but need to be complemented with supporting policy implementation processes and organisational changes (Kivimaa et al., 2017).

Figure 8.2 Finnish policy mix for buildings' energy efficiency in 2017



Source: Kivimaa et al., 2019.

9 Horizontal coordination of policies

Message 7: Align policies between different domains to improve policy coherence for transitions

- Governing sustainability transitions requires horizontal policy coordination, aligning both sectoral and cross-cutting policies. This means reconciling contrasting objectives across policy areas and actors.
- Policymakers should actively seek to identify and correct existing policy misalignments. This involves a political choice between patching of existing policy mixes and more fundamental redesign.
- Policy coordination and policy integration are two key strategies for achieving coherence. They can be promoted using macro-level policy strategies, (policy) processes and organisational changes.

9.1 Transitions require coherence across policy areas

The multidimensional nature of transition processes means that they are not only influenced by sustainability, environment or innovation-related policies. Diverse sectoral policies and cross-cutting policies influence transitions, positively or negatively. Therefore horizontal policy coordination across different policy areas is crucial to advance sustainability transitions (Weber and Rohracher, 2012).

9.1.1 Sectoral and cross-cutting policies

In the sustainability transitions literature, attention is increasingly paid to policy mixes crossing policy areas (Kivimaa and Kern, 2016; Rogge and Reichardt, 2016; Uyarra et al., 2016), to influence specific transitions, such as zero-energy buildings or low-carbon mobility.

Clearly, sectoral policies have an important role to play in achieving transitions towards more sustainable configurations of energy, mobility or food systems. For example, much of the attention in the context of energy transitions focuses on energy policy decisions such as the design of subsidy schemes for the deployment of RETs or redesigning electricity market rules (e.g. about how actors can self-generate electricity and sell it to the grid, and the introduction of capacity markets to incentivise back-up capacity).

In addition to sectoral policies in relevant domains, such as energy, mobility and food, cross-cutting policies such as innovation policy, tax policy, competition policy, fiscal policy, bioeconomy policy or circular economy policy exert influence across sectors and need to be taken into account in advancing transitions. Important cross-cutting policy areas include:

- **Innovation policy:** As discussed in Chapter 3, policies on science, technology and innovation are important in terms of directing public resources into future developments and problem solving in multiple sectors. While in the past innovation policy has focused on spurring the speed and growth of innovation, it is increasingly argued that it should be principally used for solving societal problems through joint missions (Mazzucato, 2018) and transformative innovation policy (Schot and Steinmueller, 2018a). For example, science or R&D funding criteria can include sustainability objectives; new funding calls can be directed to address the advancement of innovation in non-meat diets or sustainable mobility; and completely new kinds of innovation policies can be designed that account for sustainability transition challenges through coordination with environmental policy.
- **Fiscal policy:** Rules on what is being taxed and how taxation is organised can illustrate how cross-cutting policies can impact transitions. For example, it has been argued that a change in the United Kingdom tax rules regarding tax relief for investments in community energy projects has undermined incentives to invest in such projects (Curtin et al., 2018). The introduction of green taxes (e.g. targeting emissions or energy use) has sometimes achieved limited results because of the relatively low levels of

such taxes. For example, there is a concern that the EU emissions-trading scheme has had consistently low allowance prices, which will 'fail to incentivise the investments in low-carbon capital stock and technology R&D required to achieve long-term European decarbonisation targets' (Edenhofer et al., 2017). One suggested solution is to introduce a carbon price floor. In addition, direct and indirect subsidies (e.g. tax exemptions) influence the progress of transitions either by stimulating new technology take-up (e.g. a lower value added tax rate for specified energy-saving materials as introduced in the United Kingdom) or by giving excessive advantage to old technologies, such as fossil fuels or energy-intensive production (e.g. tax exemptions for energy-intensive industry).

- **Educational policy:** Skills and education policies play an important role in helping actors to find qualified staff to upscale their activities, and for firms to expand into new sustainability areas. Skills shortages or bottlenecks can reduce the speed with which transitions progress. Education is also important in facilitating structural economic change and facilitating a just transition (Section 5.3). In the energy sector, for example, increasing attention is paid to how to retrain employees for green energy jobs. Educational policy is also important in terms of giving knowledge and information about sustainability to future generations. For example, cultural meanings alongside material infrastructures have normalised meat eating in schools, hindering transitions to non-meat diets (Kaljonen et al., 2019). For future generations, schools play an important role in educating children about what practices support sustainable diets, mobility and energy use.

- **Regional/industrial policy:** EU regional and cohesion policies have an important role in spatial planning. They are also key to transforming local economies into more forms, for example in supporting structural change in coal regions within the EU (connecting to educational policy). Again, this links to the issue of the just transition (Section 5.3). In the context of clean energy transitions, the European Commission argues that many 'European regions are well positioned to take advantage of new opportunities arising from these technological and industrial changes, while others face deindustrialisation and job losses. In this shift to a modern and clean economy, the goal of the Commission is to ensure that no region is left behind when moving away from an economy driven by fossil fuels' (EC, 2018c). National and regional industrial strategies and the supportive measures for innovation and education can also play a role in supporting transitions.

> 'A key obstacle to the effectiveness and acceptability of core climate policies is the number of regulatory and policy frameworks outside the climate policy portfolio that are not aligned with climate objectives.' (OECD, 2015)

9.1.2 Incoherence and inconsistency

Since coordination is important for many dimensions of sustainability transitions, new organisational structures and procedures may be needed to formalise channels for various kinds of interactions. Because sectoral policies are often prepared in departmental silos and different departments have different objectives and specialised expertise, misalignments between policies are common. Even within departments, new structures may be needed to overcome 'the divide between those who develop policy, and those who oversee its implementation and manage long-term relationships' (Hallsworth et al., 2011).

Policy misalignments can arise at the level of policy goals, instruments or their implementation. Within and across policy areas, policymakers may be pursuing inherently incoherent policy goals (Rogge and Reichardt, 2016; Kern et al., 2017). Goals can be seen as coherent:

> if they can be achieved simultaneously without any significant trade-offs. They are incoherent if they contain major contradictions, i.e. goals that cannot be achieved simultaneously and lead to the attainment of only some or none of the original objectives; for example, simultaneously promoting both large vehicle sales to encourage employment and fuel efficiency standards to enhance energy conservation (Kern and Howlett, 2009).

The attainment of policy goals may be undermined by inconsistent policy instruments. Instruments can be seen as consistent 'when they work together to support a policy goal. They are inconsistent when they work against each other and are counterproductive, for example, providing simultaneous incentives and disincentives towards the attainment of stated policy goals' (Kern and Howlett, 2009).

As part of the low-carbon agenda, for example, policymakers may aim to reduce the need to travel, to reduce emissions, while tax policies can incentivise alternative modes for commuting, for example by subsidising public transport and providing vouchers or tax deductions for bike purchases, in effect subsidising travel (Harding, 2014; Temmes et al., 2014). Another example is policy goals to promote renewables to replace fossil fuel generation to reduce emissions, while at the same time providing subsidies to the fossil fuel industry to protect employment in these sectors, which delays the low-carbon transition (Coady et al., 2017; Rentschler and Bazilian, 2017). Similarly, subsidies for animal farming to support the economy in rural areas are likely to slow down the introduction of non-meat diets, even if the alternatives receive subsidies as well.

Achieving aligned, horizontally coordinated policy mixes is challenging in practice because of messy policy implementation processes, in the context of multiple policy goals, priorities and actors (Kern et al., 2017; Persson and Runhaar, 2018).

The example of Finnish biogas (Box 9.1) shows that, even when policy goals in multiple policy areas are horizontally aligned, the ways in which policy instruments work or are implemented can reduce coherence, slowing down transitions (Huttunen et al., 2014). Incoherence at the implementation stage was related to the environmental permitting process required for biogas installations. In line with the EU's Waste Framework Directive (EU, 2008), Finnish waste legislation is based on the principle of a waste hierarchy, which means that if waste cannot be prevented or recycled it should be used first as a material, and then as energy, with landfill disposal being the least desirable solution. Even though government policy was to support biogas, the environmental administration was seen to prefer composting solutions and did not guide municipalities towards biogas treatment in the environmental impact assessment statements or in environmental permits. Weber and Rohracher (2012) also point to a lack of coordination between ministries and implementing agencies that can lead to a difference between strategic intentions and the operational implementation of policies.

These challenges of policy coordination are, of course, not unique to sustainability transitions. They are, however, particularly important in this context, given the complexity of transition processes and the number of aspects that will have to change in current systems, including not only technologies but also social practices, infrastructures, institutions and rules. In addition, given the long-term nature of transitions, it is particularly important not to send confusing policy messages to policy target groups (such as innovators, investors, firms and consumers) because transitions often require persistent, long-term efforts, as described in Part 2 of this report.

Resolving policy misalignments is difficult. Improving horizontal policy coordination to facilitate transitions is not just about adjustment of policy goals and instruments. It is dependent on how willing and able different sectoral and high-level policymakers are to engage in coordination. Alignment is also difficult because the capability of policymakers to design policies is limited by uncertainty and information asymmetries (Mytelka et al., 2012) and because they are dealing with competing priorities. Misalignments between policy instruments aiming to contribute to the same policy goal or trying to promote the same

Box 9.1 Influence of horizontal policy coherence and misalignments on Finnish biogas transition

Biogas production in anaerobic co-digestion systems is an innovation involving several socio-technical regimes, including energy production, waste management, agriculture and transport. The materials used include municipal biowastes, industrial wastes, sludge from waste water treatment plants and manure or sludge from farms. Biogas is a renewable fuel that can be used for heat and/or electricity production, or as a transport fuel (Huttunen et al., 2014). Despite these potential benefits, co-digestion plants for biogas in Finland produced only 0.1 % of renewable energy in 2012, compared with the EU average of 5 % that year. The small percentage is at least partly explained by uncoordinated and sometimes contradictory signals between waste, agricultural, energy and transport policy areas.

Waste legislation set by the EU and nationally has aimed to develop capacity for organic waste treatment (positive influence). In addition, there has been a national requirement to separate household-based biowaste, potentially creating material for biogas plants (positive influence). EU and Finnish agricultural policies have encouraged nutrient recycling (positive influence) but the regulation on fertiliser products (the Finnish Fertiliser Product Act (539/2006) and the European regulation on the utilisation of animal by-products (EC1069/2009)) has been unnecessarily strict and difficult to understand for many biogas actors (negative influence). Finnish energy policy has paid little attention explicitly to biogas (negative influence), but has supported bioenergy extensively, setting high hopes for biogas actors (positive influence). The feed-in tariff was designed in a way that it was either not available or not perceived as attractive by biogas actors. While potential biogas producers saw the production of transport fuels as an option, the lack of policy incentives for biofuels made it an unattractive option (negative influence) (Huttunen et al., 2014).

innovation can potentially be resolved relatively easily once identified. However, the alignment of incoherent policy goals is politically more challenging. Such misalignments are often well known but have been difficult to solve, as environmental goals seldom command enough support in political settings to trump other policy priorities.

One strategy for dealing with this issue is to focus on win-win situations, such as promoting employment and environmental concerns through green growth strategies. This is more politically appealing than, for example, promoting environmental protection through de-growth strategies.

9.2 Strategies for promoting policy alignment: coordination and integration

There are two overarching and partly overlapping strategies for promoting horizontal policy alignment and coherence: coordination and integration. The first is horizontal communication across policy areas. The second aims for coherence by integrating specific objectives (such as environmental sustainability) into other domains. Each can be promoted in different ways, notably through the use of overarching policy strategies, dedicated governance mechanisms or organisational changes.

9.2.1 Policy coordination

Coordinated policymaking between different administrative actors has long been a general concern for public administration (e.g. Bouckaert et al., 2010). It aims to avoid policy overlap and inconsistencies, minimise administrative and political conflict, seek coherence, agree on priorities and promote a comprehensive perspective (Magro et al., 2014). From the perspective of sustainability transitions, such coordination would require environmental sustainability and long-term systemic change to inform other policy goals.

There are different political and policy strategies to explicitly enforce such policy coordination to support sustainability transitions. Traditionally, at the national level, coordination across different policy areas at the highest and most abstract level has taken place at the cabinet level, often guided by overarching strategies or programmes by the elected government. Examples include sustainability transition-oriented statements and objectives in cross-cutting government strategies, and specific transition strategies. For example, the inclusion of an experimental culture in the Finnish government programme in 2015 has been very effective in advancing policymaking that supports experiments in practice (Antikainen et al., 2017).

The long time-horizons of transitions imply that other mechanisms of coordination that exceed election cycles and/or create bodies with powers independent of elected governments are useful. Ideally, in the governance of transitions at the national level, a policy coordination approach to advance transitions could include some of the following elements (OECD, 2015):

- establishing super ministries (or dedicated units with interministerial roles) that can bring together different policy areas (e.g. energy and climate policy);
- policy 'tsars' who are directly appointed by ministers and have direct access to them and senior officials to influence policymaking (Levitt and Solesbury, 2012);
- interministerial committees that facilitate dialogue and more informed policymaking to avoid misalignments;
- independent policy units, for example, a transitions unit working directly with the executive branch of national government (e.g. prime minister's office);
- appointing individual civil servants at the cross-section of two (or more) ministries to help in information exchange and identifying misalignments.

The United Kingdom's Climate Change Act (CCA) is a good example of a high-level policy for low-carbon transition that promotes coordination and directionality by creating long-term, binding obligations across the whole of government (Box 9.2). It also included an institutional innovation in establishing the Climate Change Committee, which has promoted decarbonisation and highlighted lagging sectors. The significance of the CCA may lie in its 'hugely symbolic diplomatic and political commitment, as well as leadership (at national and international levels), supported by joined-up action within government' (Benson and Lorenzoni, 2014). As such, the CCA is also relevant in providing directionality (Gillard, 2016) and vertical coordination across scales of governance (see Chapter 10).

Dedicated processes for policy coordination are important. They include, for example, processes to take transitions into account in a budgeting and financial instrument setting, and ex ante and regular *ex post* evaluation of how policy mixes impact the direction and speed of transition dynamics. In addition, formalised consultation processes, issue-specific

Box 9.2 The United Kingdom Climate Change Act as a tool for improving horizontal coordination

The United Kingdom CCA of 2008 was a pioneering long-term policy framework for emissions reduction, which legally committed the United Kingdom to an 80 % reduction in GHG emissions by 2050 (UK Government, 2008). The CCA requires the government to set legally binding emissions targets, called carbon budgets, every five years. It also made an institutional innovation in establishing an independent statutory advisor, the Committee on Climate Change (CCC), to advise the government on the level of these emissions targets and to report to Parliament on progress made in reducing emissions (Lockwood, 2013).

In parallel, in 2008, the Department of Energy and Climate Change (DECC) was founded. This addressed the earlier lack of ownership of climate change targets in the departments required to deliver them (business and transport). The creation of DECC ensured that there would be ministers and policy teams dedicated to achieving a low-carbon transition. The Department for Environment, Food and Rural Affairs (DEFRA) remained responsible for climate risk assessments and adaptation, and was given new powers to demand reports on progress from certain sectors (Gillard et al., 2017).

Despite this division of responsibility between DECC and DEFRA, Lockwood (2013) stresses that the CCA imposed legally binding carbon budgets on the whole of government. The CCA thus brought climate change objectives into emissions-related policies across various United Kingdom government departments. For example, the CCA required that the Secretary of State responsible for climate policy report to parliament about performance according to a stated schedule. This includes an annual statement of the United Kingdom's emissions and the net carbon account, a five-yearly statement covering the budget period, and production of five-yearly reports assessing the United Kingdom's climate change risks and proposed responses (Stallworthy, 2009).

In 2019, the government departments that set climate policy are the Department for Business, Energy and Industrial Strategy and DEFRA. However, the CCA continues to affect all departments, as climate change concerns all sectors. Indeed, the United Kingdom government has introduced emissions-reduction policies across various sectors, including energy production and consumption, construction and transport (Benson and Lorenzoni, 2014; Geels et al., 2016). This required that the Treasury (the economic and finance ministry) support measures addressing topics such as decarbonising heat, introducing low-carbon vehicles, promoting agricultural emissions reductions and increasing public sector energy efficiency.

The establishment of the CCC has also been influential in advancing decarbonisation, especially in the power sector, and in calling attention to lagging sectors (housing, mobility, agriculture) (CCC, 2018). Many high-level climate and energy policy publications cite the United Kingdom's 2050 target and the advice of the CCC as part of the overarching rationale for proposing policies. As CCC advice extends across all sectors, it is of relevance to various government departments. The CCC's watchdog role ensures that the government remains focused on implementing policies to meet the carbon budgets.

Developments since the financial-economic crisis highlight limitations to the effectiveness of strategic policies such as the CCA. Since 2013, cost concerns have led to downscaling of policy action, with the Treasury regaining influence over climate policy (Carter and Jacobs, 2014; Geels et al., 2016). This trend suggests that the key department for implementing the CCA is in fact the Treasury, as it retains control over taxation and subsidies, including the Levy Control Framework for energy bills (Lockwood, 2013). The waning influence of, and interest in and commitment to climate policy objectives (Carter and Jacobs, 2014) likewise signal that strategic policies such as the CCA are not sufficient. They need to be followed up with consistent instrument mixes in multiple sectors to deliver the required emissions reductions (Gillard et al., 2017). The case also highlights the political nature of transitions, which manifests in discrepancies between departments that support mitigation action and those that are more reluctant (Benson and Lorenzoni, 2014).

working groups and ministerial councils working across policy areas have been proposed (Warren et al., 2016).

9.2.2 Policy integration

Two main strategies of policy integration exist: first, the integration of cross-cutting objectives (e.g. environmental or transition related) into the strategies, policy instruments and organisational processes of specialised and sectoral policy areas; and, second, more formalised policy coordination across sectoral policies.

In the case of sustainability transitions, a strategy of policy integration (e.g. Nilsson and Persson, 2003; Jordan and Lenschow, 2010; Nilsson and Persson, 2017) means integrating the perspective of sustainability transitions into other policy areas (e.g. industry, innovation, education, transport, energy, food). This is what the Dutch government did after identifying the need for transitions in its fourth National Environmental Policy Plan. Different ministries were in charge of implementing their transition of energy, mobility, agriculture and health, with the environment ministry playing an overall coordinating role (Smith and Kern, 2009). This is therefore an example of a process in which both strategies (integrating environmental concerns into sectoral policies and policy coordination across sectoral policies) were pursued simultaneously. This has the benefit of there being potential interactions between transition pathways in energy (e.g. increased use of biomass) and agriculture, and between energy transitions (e.g. increased use of e-mobility) and mobility transitions.

Much more often attempts have been made with respect to environmental policy integration (EPI) (Box 9.3) or climate policy integration (CPI) into sectoral policies (energy, transport, agriculture and development policies). Existing examples of EPI or CPI are relevant to transition goals but can be more limited in scope. For example, the incorporation of environmental impact assessment into R&D funding assessments is an element of EPI but may not advance broader system transitions. The relevance of EPI to transitions depends on its scale and perspective.

Integrating environmental commitment across sectoral policies is likely to help achieve transformative outcomes and increase cross-domain collaboration. For example, creating overarching legislation (such as the CCA in the United Kingdom) and implementing it (in this case through carbon budgets) impinges on a range

Box 9.3 What is environmental policy integration?

EPI refers to the incorporation of environmental objectives into non-environmental policy sectors (Runhaar et al., 2014). There are different interpretations of EPI, but its common features include the following (Persson et al., 2018):

- All policy sectors share responsibility for environmental protection. In the European Commission, this means that all directorates-general (DGs) are responsible for the environment, not just the DG for Climate Action and the DG for Environment.
- There is a proactive and preventative role for environmental protection by early integration of environmental objectives in policy processes.
- The minimum standards prescribed in environmental regulations should be exceeded.

In practice, EPI has been advanced by multiple strategies and programmes (Mickwitz et al., 2009; Runhaar et al., 2014), such as national environmental plans, sustainable development strategies, green taxes or environmental impact assessment, and sectoral climate policy strategies and programmes.

Achieving EPI in policy implementation, outputs and outcomes is difficult and needs to be assessed. Successful EPI requires (i) the extensive inclusion of environmental objectives in sectoral policy, (ii) the consistent integration of such objectives in policy goals, instruments and their implementation, (iii) attention to coordination issues (e.g. generating alignments and avoiding misalignments), (iv) the harmonisation of policy goals in search of synergies, (v) appropriate dedicated resources and (vi) evaluation, monitoring and reporting of integration impacts (Lafferty and Hovden, 2003; Kivimaa and Mickwitz, 2006; Mickwitz et al., 2009).

of sectoral policies. Such policy integration can partly contribute to policy coherence, but only if it receives a relatively high or even the highest priority against other policy goals (cf. Lafferty and Hovden, 2003). This is often challenging as different broader policy aims, such as the need for economic growth, compete for primacy, as illustrated in the case of the EU Bioeconomy Strategy (Box 9.4). In general, departments in charge of finance and industry have a much stronger role and voice than those in charge of the environment.

EPI has gained broad political support in the EU and has a quasi-constitutional status. Article 6 of the Treaty on European Union states: 'Environmental protection requirements must be integrated into the definition and implementation of the Community' (EU, 2016a). Recent studies have observed generally improving CPI across different sectors, with less progress in the area of EPI more broadly (Persson and Runhaar, 2018). Prioritisation of environmental objectives would be important for policy to advance sustainability transitions. Warren et al. (2016) note that 'while on one level EPI appears a logical step in realising transition goals, in practice, the integration of environmental concerns into non-environmental policy areas has been and remains an ongoing challenge'.

The development of cross-cutting transition objectives is an important area of development in EU policymaking. For example, the Roadmap for moving to a competitive low-carbon economy in 2050 (EC, 2011b) includes a series of long-term policy plans in areas such as transport, energy and climate change and extends to electricity, mobility, built environment, industrial sectors and land use. The European Strategy for low-emission mobility likewise articulates objectives crossing the domains of transport and environmental policy: 'by mid-century, greenhouse gas emissions from transport will need to be at least 60 % lower than in 1990 and be firmly on the path towards zero. Emissions of air pollutants from transport that harm our health need to be drastically reduced without delay' (EC, 2016c). It also refers to an Integrated Research, Innovation and Competitiveness Strategy for the Energy Union, combining three interconnected strands: energy technologies, transport and industry. It recognises that low-carbon mobility contributes essentially to both low-carbon and circular economy transitions in Europe (EC, 2016c).

While horizontal coordination of objectives is receiving more attention in some areas, more could be done in others. For example, there are important synergies and trade-offs between the EU's low-carbon and circular economy strategies (EEA, forthcoming). The Bioeconomy Strategy would likewise benefit from more explicit (strong) sustainability transition objectives, especially linked to the circular bioeconomy (Hetemäki et al., 2017). Horizontal coordination could also be improved at the level of actual policies. The Energy Performance of Buildings Directives, for example, provide strong objectives for change, but more can be done to ensure that cross-cutting policies

Box 9.4 The EU Bioeconomy Strategy

The EU's Bioeconomy Strategy (EC, 2012, 2018e) is a good example of policy coordination and EPI at the strategic level. The Strategy connects multiple societal challenges, including food security, natural resources, dependence on non-renewable sources, climate change and creating jobs. It aims for horizontal policy coherence between policy areas, including EU R&I funding and bioeconomy policies. Together, the Bioeconomy Strategy and its Action Plan 'will inform research and innovation agendas in bioeconomy sectors and contribute to a more coherent policy environment, better interrelations between national, EU and global bioeconomy policies and a more engaged public dialogue' (EC, 2012).

The original Bioeconomy Strategy (2012) was criticised, however, for orienting towards weak sustainability and allowing economic dimensions to prevail over environmental and social ones (Ramcilovic-Suominen and Pülzl, 2018). Moreover, no real link was constructed between the Bioeconomy Strategy and the EU's established body of legislation aimed at conserving and maintaining biodiversity (Hetemäki et al., 2017). As such, the Bioeconomy Strategy illustrated some of the challenges in implementing horizontal policy coordination.

The updated Strategy (2018) addresses some of these issues, for example in responding to new European policy priorities such as the Renewed Industrial Strategy, the Circular Economy Action Plan and the Clean Energy Package (EC, 2015a; EC, 2016b; EC, 2017c). All of these instruments highlight the importance of a sustainable, circular bioeconomy to achieve their objectives. The updated Bioeconomy Strategy also integrates a more ambitious transitions agenda. It aims to accelerate the deployment of a sustainable European bioeconomy to maximise its contribution to the SDGs and the Paris Agreement.

(e.g. energy research funding and innovation funding) work in the same direction.

9.3 Identifying and correcting misalignments

Coordination and integration can help promote coherent policymaking. Yet misalignments in existing policy mixes are inevitable. There is therefore an important role for identifying such misalignments in policy mixes, evaluating whether they are detrimental for a specific transition process and correcting them where possible (Flanagan et al., 2011). In practice, this is not straightforward because the potential number of policies relevant to a specific transition may be large. For example, research on the low-energy building transition in the United Kingdom identified 38 relevant instruments at the national level alone; in Finland the equivalent number was 36 (Kern et al., 2017). If the scope is extended to EU- and local-level instruments, the number of policies is multiplied.

9.3.1 Tools for identifying misalignments and assessing policy coherence

Since transitions are non-linear processes, it is problematic to apply simplistic goal-attainment ex post policy evaluation models at a single point in time. Instead it is important to trace policy developments over longer periods and base analysis on frameworks that are specifically developed to understand sustainability transition processes. One such framework, which is often used in academic empirical analysis of policy coherence in transitions, is the technological innovation system (TIS) functions approach (Box 9.5). This approach has been used to examine how well policy goals and instruments crossing administrative domains are likely to stimulate relevant functions from the perspective of transitions (e.g. Huttunen et al., 2014 on biogas development; Kivimaa and Virkamäki, 2014 on the transport system; Kivimaa and Kern, 2016 on energy efficiency; and Raven and Walrave, 2018 from a modelling perspective).

Box 9.5 The Technological Innovation Systems approach

The TIS approach was created to study how new technologies emerge and how technology-specific innovation systems form around them. One of the specific aims was to identify 'system weaknesses that should be tackled by public policy' (Jacobsson and Bergek, 2011). The TIS approach proposes a list of seven system functions, defined as processes influencing the development of a TIS (Bergek et al., 2008):

- **knowledge development and diffusion:** breadth and depth of knowledge and how knowledge diffuses; academic and firm-level R&D; learning-by-doing and learning-by-using;
- **influence on the direction of search:** strength of factors incentivising and pressuring organisations to act; mechanisms having an influence on the direction (visions, actors' perceptions, policy and regulation, articulation of demand);
- **entrepreneurial experimentation:** connecting new knowledge, networks and markets into concrete actions;
- **market formation:** for an emerging TIS, markets do not exist or are underdeveloped, so niche markets are needed, involving, for example, identification of market segments, creation of markets through regulation, and other ways of creating a protective space;
- **resource mobilisation:** mobilisation of human capital (through education, entrepreneurship, management and finance), financial resources (through seed and venture capital funding, government funds) and complementary assets;
- **legitimisation:** gaining acceptability for a new technology among actors, and political backing; will influence, for example, resource mobilisation;
- **development of positive externalities:** free spillovers from knowledge development; outcomes of the development benefiting more than just the investors.

The TIS functions are combined with components of innovation systems (knowledge, actor networks, and institutions) that reinforce the impact of the functions. Through cumulative causation, the seven functions reinforce one another in an ideal case, resulting in a positive, self-reinforcing dynamic (motors of innovation); this permits the development of a technology-specific innovation system (Suurs and Hekkert, 2009). Empirical research indicates that national policy tends to support the science and technology push motor and to hamper the market and entrepreneurial motors (Suurs and Hekkert, 2009).

The technological innovations system approach can guide the analysis of policy coherence by providing a list of system functions necessary for the successful development and deployment of sustainability innovations. It is therefore particularly useful in revealing gaps and contradictions in policy mixes from an innovation and transitions perspective, assuming that all the functions are necessary for new sustainable socio-technical systems to develop. Studies have used the TIS framework to highlight particular gaps in the overall policy mix (e.g. Kivimaa and Virkamäki, 2014), instead of a specific TIS. They have also used it to show how policies from different administrative domains come together to influence a particular transition (e.g. Kivimaa and Kern, 2016).

Another framework that has been used for analysing policy coherence in relation to sustainability transitions is the multilevel perspective (see Chapter 2). For example, in a study of German and United Kingdom transport policy for EVs, Mazur et al. (2015) propose a qualitative ex ante assessment of policies, which enables policymakers to assess whether or not policies are supporting transitions coherently. Their approach utilises transition pathway thinking and involves four steps:

- analysing the current system and regime;
- identifying a future regime based upon policy targets;
- identifying a compatible transition pathway;
- assessing whether current policymaking supports the proposed transition pathway.

The assessment shows that, in the case of transport policy for EVs in Germany and the United Kingdom, policymakers were applying policies supporting pathways leading to transition outcomes and that they are likely to meet the set policy targets. No issues with policy coherence were detected.

The literature on transition management also addresses policy coherence. Rotmans et al. (2001) define transition management as complementing existing policy with a long-term vision, ensuring coherence and developing short-term actions to explore more sustainable options combined with process management (for details on transition management see Box 11.3). However, empirical analysis of the use of the transition management approach in Dutch energy policy showed that while it led to some innovative steps and engaged a variety of actors in the process, it was hard to achieve coherence of policy goals and consistency of instruments. Kern and Howlett (2009) found that the already complex energy policy mix became more complicated by the addition of transition management reforms. Transition management created new inconsistencies and made it more difficult to achieve coordinated policy, partly due to clashes between long-term sustainability goals and more short-term economic efficiency goals. The case therefore shows the difficulties in managing transitions if existing policy regimes have not been replaced or reorganised in line with long-term sustainability goals (Kern and Howlett, 2009).

9.3.2 Correcting misalignments

When significant policy misalignments or policy gaps hindering the transition in focus have been identified, the second step is to correct such misalignments. Policy studies suggest two ways to improve the coherence of policy mixes (Howlett and Rayner, 2013):

1. **Replacing the existing mix** with a carefully aligned package of instruments in support of policy objectives (policy packaging). Much policy analysis focuses on developing such optimal mixes and how they might be designed (e.g. Bertram et al., 2015; Kalkuhl et al., 2012). Empirically speaking, however, this is possible only in exceptional circumstances, as it is often politically difficult to remove instruments, particularly when they benefit from the strong backing of incumbents who benefit from maintaining the status quo (see Section 2.1). Policy development is therefore path dependent (Pierson, 2000).

2. **Patching the existing mix:** Processes of policy mix development 'can also be 'intentionally' designed — much in the same way as software designers issue 'patches' for their operating systems and programmes in order to correct flaws or allow them to adapt to changing circumstances' (Howlett and Rayner, 2013).

Acknowledging that policy cannot be completely redesigned all the time, and that significant investments have often been made in already existing policy frameworks, the policy 'patching' strategy is useful and often more realistic than complete policy redesign. An empirical analysis of policy mix developments regarding buildings' energy efficiency in Finland and the United Kingdom (Kern et al., 2017) provides support for this claim. The analysis identified cases where such patching was strategically used by policymakers in both countries to increase the chances of significant improvements in building energy efficiency. Finland has achieved coherence through policy patching by not only improving interdepartmental coordination but creating a dialogue between a range of stakeholders regarding policy mix design, with particular attention to aligning new policies with existing policies. In the United Kingdom, policymakers have started to work on policy patching through the national energy efficiency action plans and by considering the portfolio of goals and instruments in the context of the 'D3' strategy (addressing demand reductions, demand-side response and distributed energy).

The concept of patching is useful for policymakers, as it fits better with the reality of messy, real-world policymaking. Nevertheless, correcting policy misalignments is essentially a political endeavour rather than a technical exercise. While patching strategies may be more politically realistic than complete policy redesign, it requires the kind of political commitment exemplified in the case of Finnish energy-efficient building policy (Box 8.3).

10 Vertical coordination across levels of governance

Message 8: Promote coherence of actions across EU, national, regional and local governance levels

- Transitions require policy action at all levels of governance. Ensuring that they reinforce each other requires vertical coordination and mapping of responsibilities, inconsistencies and barriers.
- Promoting both top-down and bottom-up processes of governance requires new mechanisms to promote dialogue between different levels and increased flows of information and resources.
- Thematic working groups crossing different governance levels and including industry and civil society actors could be used as a tool for facilitating coordination in polycentric systems of governance.

10.1 Vertical coordination and mapping of responsibilities, inconsistencies and barriers

Sustainability transitions necessarily involve actions at multiple scales of governance, as they are multi-actor processes that cannot be steered by any one actor or level of governance on its own. International action is needed to coordinate responses to increasingly globalised sustainability challenges such as climate change, which are often associated with difficult collective action problems and global equity considerations. National governments and supranational institutions such as the EU have unique powers to drive forward the needed transitions — defining visions, missions and targets for whole socio-technical systems and using their broad powers to promote innovation and reconfiguration.

At the same time, much of the innovation and learning that is essential for transitions occur at regional and local scales, implying a critical role for regional, local and city administrations (see also Chapter 6), which are likely to have a much better understanding of local needs, skills, knowledge and capacities. Indeed, the assumption that issues should be addressed at local scales where possible is strongly embedded in EU governance via the principle of subsidiarity (Article 5 of the Treaty on European Union).

Policymakers at different scales of governance therefore have differing roles and opportunities to support sustainability transitions, as well as facing contrasting barriers (Table 10.1). Ensuring that the governance approaches and policy choices of these different actors operate to reinforce each other is the challenge of multilevel governance. In the EU context, the Committee of the Regions has defined multilevel governance as 'coordinated action by the European Union, the Member States and local and regional authorities, based on partnership and aimed at drawing up and implementing EU policies' (COR, 2009). While multilevel governance is difficult in all policy areas, the complexity of transition processes — involving myriad activities across policy areas and scales of governance — presents a particularly acute challenge.

Table 10.1 Multilevel governance of sustainability transitions: a summary of opportunities and barriers at different levels

	Opportunities for sustainability transitions policy	Barriers to sustainability transitions policy
Global level	• Enabling a coordinated response to global collective action problems, arising from, for example, distributed impacts on the environmental commons (e.g. climate change) or globalisation (of trade, financial flows, etc.). • Tackling equity and redistribution issues (e.g. climate funds, capacity-building).	• Slow negotiation processes, often resulting in weak levels of ambition, ill matched to urgent sustainability challenges. • Enforcement mechanisms are often weak or absent.
EU level	• Setting ambitious visions and targets. • Developing legally binding regulations and directives directly applicable in Member States. • Setting reporting responsibilities in Member States to follow progress with transitions. • EU investments in infrastructure, skills, innovation, innovation deployment, etc., which can shape transitions.	• Relatively limited resources available beyond R&D, regional policy, the European Investment Bank, CAP and pan-European infrastructure project funding. • Limited to policy areas where it has formal competence.
National level	• Potential for funding sustainability activities significant. • Large toolbox of potential policy instruments to foster transitions available. • Ability to coordinate between sectors and across the local-national division through influence over local decision-making, e.g. getting 'laggard' regions aboard (depending on national governance structures). • Setting regulatory and market rules for many transition-relevant sectors (such as transport or energy), in line with European rules. • Possibility of shaping transitions through national infrastructure investments..	• Incumbents often in powerful position *vis-à-vis* sectoral policymakers that can reduce ambitions in sectoral strategies. • Lack of knowledge of local realities. • Difficulty tailoring policy interventions to local realities. • Difficulties in aligning national policy and priorities across departments/ministries.
Local level	• Space for experimentation and close collaboration with local stakeholders and citizens. • Can build local political momentum. • Governance of key systems and issues implemented at local levels, e.g. spatial planning (affecting habitats, industrial symbiosis, travel), buildings, public spaces, transport, waste.	• Often very little funding available for scaling up sustainability experiments. • Regulatory obstacles often derived from national or EU context (e.g. energy market rules, state aid rules). • Action dependent on local political conditions and geographical and economic structures.

10.1.1 Barriers to multilevel governance

Multilevel governance relies on vertical coordination between different levels of policymaking. It is crucial to orient sustainability transitions in desirable directions and to enable faster transitions (Kern and Rogge, 2016; Ehnert et al., 2018). Ideally, it means designing policy actions at different levels and in ways that reinforce each other. For example:

- ambitious EU-level targets and supporting policies (e.g. directives, research and innovation funding) signal directionality to national and local actors;
- national governments implement EU policy frameworks and targets through strong domestic policies, and support related experimentation in cities and company innovation activities;
- local governments initiate their own change agendas linking to (and possibly exceeding) EU and national-level targets and policies; they acquire resources from the EU and national governments and contribute to implementing EU and national policies.

The importance of vertical coordination between different levels of governance is acknowledged in EU policies and increasingly recognised as an important mechanism for achieving policy objectives. As Gollata and Newig (2017) note, 'recent European Union environmental policies have increasingly advanced multilevel governance approaches to improve policy implementation'. For example, the EU's Strategy for Low-Emission Mobility emphasises that regions and cities will be major actors in delivering low-emission mobility solutions (EC, 2016c): 'Cities and local authorities are crucial for the delivery of this strategy. They are already implementing incentives for low-emission alternative energies and vehicles, encouraging modal shift to active travel (cycling and walking), public transport and/or shared mobility schemes, such as bike, car-sharing and car-pooling, to reduce congestion and pollution.'

There are positive examples of European multilevel governance processes contributing to achieving policy outcomes. For example, Jänicke and Quitzow (2017) concluded, regarding the EU's global leadership in climate policy, that 'Rather than the result of one strong, centralized instrument, it is more likely to be the outcome of mutually reinforcing dynamics at different levels of governance' (see Box 10.1). They argue that leading climate policy countries, such as Denmark, Germany and the United Kingdom in particular, 'are exhibiting strong local initiatives, which are further bolstering national leadership and in some cases even surpassing national ambition' (Jänicke and Quitzow, 2017).

Other cases are less positive. Gollata and Newig (2017), for example, analyse German air quality plans in response to EU air quality directives, concluding that implementing air quality policy through multilevel governance achieved limited success. As they note:

> the introduction of new functional governance layers and mandated planning has not led to more effective implementation of EU environmental legislation overall … This is owing to local administrations' ambiguous role in implementing EU air quality directives. On the one hand, local authorities are given more executive implementation power; on the other hand, they lack substantial enforcement capabilities (e.g. legal and financial backing) and are unable to obligate higher levels.

They argue that their results mirror experiences in other policy areas such as water management.

In some instances, Member States can hinder the spread of local initiatives by withdrawing crucial national-level funding, as occurred in the United Kingdom when it significantly cut government subsidies for community energy installations. In other cases, Member States may block progress or water down international or EU regulations. Germany, for instance, has repeatedly sought to weaken EU car emission standards to protect its vehicle-manufacturing industry, which specialises in premium, heavy vehicles. This issue presents obvious difficulties for the German government because the country's automotive sector is the largest manufacturing sector by employment (Meckling and Nahm, 2017).

Such influences are dynamic and positions can change over time. For example, whereas Finland initially opposed the EU Biofuels Directive (EU, 2003) and delayed its enforcement, it was later successful in its efforts to exceed the EU target (Lovio and Kivimaa, 2012). Research has shown empirically how policy mixes, interactions between policy goals and instruments, and implementation influence the contribution of policy to sustainability transitions (positively or negatively) in a variety of domains. These include low-carbon transport (Kivimaa and Virkamäki, 2014), renewable energy (Reichardt et al., 2017) and low-carbon innovation (Uyarra et al., 2016).

10.1.2 Mapping of actors and policy inconsistencies

These examples highlight the difficulties of achieving effective multilevel governance. A huge number of policies at different levels in various domains contribute to the configuration of existing socio-technical systems. Many are linked to established interests and investments, implying that there are often significant barriers to changing them. Beneficiaries of existing policies have strong incentives to protect such policies, which makes policymaking highly path-dependent.

Making complex policy regimes more coherent will take time and is politically challenging, but a useful starting point involves mapping responsible actors for various policy decisions and potential inconsistencies between policies at different governance levels. This includes identifying who is responsible for different parts of the policy mix at different levels, influencing a specific transition such as in energy, mobility or agriculture. Often the distribution of responsibilities partly depends on EU-level rules but also depends in part on the country-specific division of responsibilities between national, regional and local governments, and is therefore by no means straightforward. It also involves assessing whether there are policy goals or instruments at other governance levels that undermine incentives for sustainability transitions.

Like horizontal coordination (Chapter 9), this is partly a technical issue but primarily a political challenge. In many instances the relevant political powers at different governance levels may not be aligned in their political priorities or the importance that they attach to sustainability issues. While this points to the need for political solutions, mapping of actors and potential policy inconsistencies is a necessary first step in addressing these issues, providing a starting point for an open conversation across governance levels (see Section 10.2). This is important, since much of the existing research maps policy only at a single level, therefore addressing only horizontal coordination. More empirical analysis is needed on how EU policy goals and instruments interact with policies at Member State, regional and local levels and how these processes shape sustainability transition dynamics.

10.2 Strengthening multidirectional exchange between policymakers at different scales

10.2.1 Benefits and limitations of top-down processes

One obvious means to promote vertical coherence is through top-down processes of legislation and compliance. In the EU this operates through either enforcement or transposition of EU regulations and directives in Member States, backed with penalties for infringement and sometimes involving specific (often differentiated) national obligations and targets. Most multilevel governance research 'retains a strong top-down focus on member state compliance with central state decisions ... This holds especially for Europeanisation research, which is in its vast majority concerned with the question of whether EU directives are transposed into domestic law as required' (Thomann and Sager, 2017).

Studies show the importance of EU policy in shaping policy developments in Member States. For example, an analysis of the policy mixes to support energy efficiency in buildings in Finland and the United Kingdom during 2000-2014 found that much of the national policy action in both countries had been stimulated by the EU's drive towards increasing energy efficiency, particularly through the 2012 Energy Efficiency Directive, the 2002 European Building Energy Performance Directive and the recast Directive 2010/31/EU on the Energy Performance of Buildings. The EU's ambitious targets led to many new instruments being introduced in both cases, but the analysis also showed that Member States often use a varied set of policy instruments to achieve these targets, in line with national priorities and circumstances (Kern et al., 2017).

While the EU's top-down legislating processes do promote vertical coherence, they have some limitations — partly because of the political constraints on policymakers at national and intergovernmental level. As a result, transitions research places strong emphasis on the need for local innovation and experimentation in governance. Indeed, the 'Cambrian explosion' of new governance initiatives in recent years (Keohane and Victor, 2011) arguably reflects a recognition of the limitations of purely top-down approaches (Jordan et al., 2018a). As Setzer and Nachmany (2018) note, 'Especially in the area of climate governance, subnational governments often compensate for insufficient regulation at the national and international levels'.

10.2.2 Emergence and diffusion of innovations in governance

Local governments, for example, have a range of relevant competences that they can use to positively affect transition dynamics (Bulkeley et al., 2010; Vagnoni and Moradi, 2018). The heterogeneity of local contexts can enable local administrations to experiment with options that may not be politically feasible at other scales. For example, cities may be less susceptible than national governments to pressure from industry lobbying, or they may be characterised by comparatively progressive or green political cultures. Partly for these reasons, some cities and local-level actors are increasingly positioning themselves as leaders of transition efforts, setting ambitious targets for systemic change — sometimes exceeding national or EU targets (see Chapter 6).

Experiments in governance at local or regional scales can influence broader levels of public administration in different ways. First, such influence can occur because the actions of pioneering cities alter public attitudes in other localities or at a national scale, as occurred with the shift to renewables in Polish cities (Box 10.1). The fact that local actions make it easier to achieve targets at broader scales can also create space for greater ambition at national level. Second, successful experiments can be replicated or adapted at higher levels. As noted in Box 10.1, for example, policy approaches such as feed-in tariffs and emissions trading were piloted at regional or national levels before being used at broader scales.

Similarly, the case of the MARPOL Convention on the prevention of pollution from ships shows how local experimental policy processes can influence innovation in the broad international marine sector, in combination with international laws. A case study found that the development and adoption of new marine engines with low nitrogen oxides emissions by the energy-technology company Wartsila was accelerated by the expectation of new international rules regarding emissions from international shipping. However, the early piloting of the technology was more influenced by local rules. Swedish fairway and port discounts were designed to provide financial incentives for shipping companies to invest in new, less polluting technology. These discounts, for example, influenced the shipping company Silja Line to become a partner and the important first client in Wartsila's direct water injection technology development (Hyvättinen and Hildén, 2004).

Box 10.1 European climate and energy governance and multilevel reinforcement

The EU is an international frontrunner in climate policy, both in terms of targets and outcomes. The goal of reducing greenhouse gas (GHG) emissions by 40 % by 2030 compared with 1990 is the most ambitious among world regions and industrialised countries. EU GHG emissions have declined 23 % in the last 25 years, and the EU holds a leading position regarding the share of renewable energy in electricity production. In 2016, renewable energies accounted for 86 % of the newly added power generation capacity in the EU (EEA, 2017c). The strong performance of EU climate and energy policy is not simply due to policy instruments such as the EU Emissions Trading Scheme. Rather, Jänicke and Quitzow (2017) argue that it is the outcome of mutually reinforcing dynamics at different levels of governance, including the mobilisation of economic interests through low-carbon industrial policy. European low-carbon policy therefore represents a good example of the role of multilevel reinforcements between developments at EU, national and sub-national levels in the context of transitions.

Schreurs and Tiberghien (2007) first introduced the idea that dynamic processes of competitive multilevel reinforcement within the EU have made Europe a leader in the field of climate change mitigation. Building on this idea, Jänicke and Quitzow (2017) show how the interplay of dynamics at the EU, Member State and sub-national levels has contributed to ambitious energy and climate policies. Their research mainly focuses on the role of green industrial policy aimed at stimulating economic growth and achieving environmental goals such as climate mitigation. Climate-related industrial policy can be observed at all levels of the European governance system and is an important mechanism for reinforcing ambitious climate policy. This multilevel reinforcement is enabled through EU policies that stimulate local-level action, for example regional or cohesion policies or the EU's Covenant of Mayors. The latter was initiated by the European Commission in 2008 and has created a situation in which 'sub-national levels of governance are beginning to assume an increasing role in reinforcing industrial policy, initially promoted at the European and national levels' (Jänicke and Quitzow, 2017). Such sub-national activities can both reinforce low-carbon policy in frontrunner countries and fill gaps in laggard countries with weaknesses at the national level.

EU leaders in climate policy (e.g. Denmark, Germany and the United Kingdom) all exhibit strong local initiatives. In Germany, for example, the first feed-in tariffs for solar energy were pioneered at sub-national level to stimulate renewable energy technology (Jänicke and Quitzow, 2017). Later, this model was incorporated into the revision of the national Renewable Energy Act at the federal level, which led to significant market growth. Several *Länder* (federal states) used the opportunity to offer attractive investment conditions for renewable energy technology manufacturers, benefiting from financial support from EU Cohesion Policy funds. The resulting regional economic interests in support of renewable energy were important in stopping radical revisions to the Renewable Energy Act, as the *Länder* opposed proposals by the federal government. These dynamics therefore helped to stabilise renewable energy policy. In the Danish wind energy sector, local-level cooperatives played an important role in the early phase of wind energy transitions, but over the last 10 years their role has declined because of less favourable policies (Wierling et al., 2018) (see Box 4.3).

The example of Poland shows the opportunities provided by low-carbon policy reinforcement dynamics at sub-national level for countries with less ambitious policy at national level (Jänicke and Quitzow, 2017). While the national government opposes aspects of EU climate policy, there is a lot of enthusiasm in Polish municipalities for developing renewable power sources, especially solar and wind. For example, Bielsko-Biała was the first Polish local government that developed a sustainable energy action plan within the Covenant of Mayors and provided an example for others. These developments have been interpreted as 'municipalities in Poland ... showing signs of developing a progressive agenda on climate and renewable energy issues in the face of strong national-level resistance' (Jänicke and Quitzow, 2017).

Another important multilevel dynamic in EU climate governance is that the structure of the EU allows national policy innovations to either diffuse across Member States horizontally (such as the German feed-in tariffs) or be adopted at EU level. A good example is the United Kingdom emissions-trading scheme, which was introduced in 2002 to deliver first mover advantages to British companies before the introduction of an EU-wide emissions-trading scheme that could draw on the United Kingdom experience. The EU level can also function as a forum for benchmarking and learning lessons among Member States.

10.2.3 Strengthening knowledge and resource flows and dialogue between levels

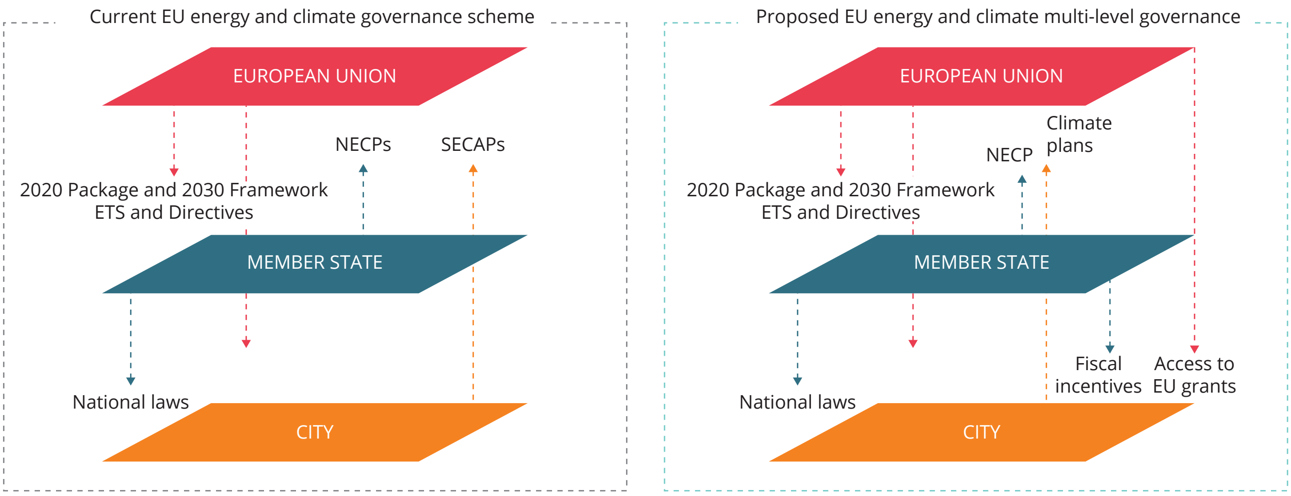
While the opportunities for learning from experiments are considerable, in practice local policymakers can find it hard to influence national or EU institutional frameworks, which may hinder the wider diffusion of alternatives beyond local experiments (Ehnert et al., 2018). Another challenge of mainstreaming or diffusing sustainability solutions more widely is the lack of public resources at the local level, which could be partly compensated for through national or EU funding to achieve upscaling or replication (Gorissen et al., 2016).

These realities point to the need to strengthen frameworks and processes to enable knowledge and resource flows and increase dialogue between policymakers at different governance levels. Empowering local and regional policymaking (including financially) is a good starting point and is in line with the EU's subsidiarity principle. But there may also be opportunities to strengthen interactions across scales, building on existing networks of towns and cities. For example, the Eurocities network specifically aims to reinforce the role of local governments in multilevel governance by enabling cities to deliver the EU's strategic priorities. As well as connecting cities directly to EU-level policymaking, it provides a platform for knowledge sharing among the local governments of more than 140 of Europe's largest cities, accounting for 130 million citizens.

Within the EU context, another particularly important network is the Covenant of Mayors for Climate and Energy. Covenant signatories commit to support the implementation of the EU's 2030 target of reducing GHG emissions by 40 % and to develop a Sustainable Energy and Climate Action Plan (SECAP) that sets out planned actions to achieve their political commitments. These plans are monitored every two years to check implementation.

This system already contributes to vertical coordination by engaging local authorities in contributing to EU goals for energy transitions, providing a platform for extracting and sharing best practices, and standardising local climate and energy policy plans in line with national and EU policies. However, it has been proposed that the approach could be strengthened by integrating the SECAPs better into the national plans prepared by Member States and by providing financial support to implement SECAPs (Tagliapietra and Zachmann, 2016). Specifically, cities should be provided with fiscal incentives and access to a range of EU grants and loans that are conditional on the fulfilment of climate plans that feed into national government progress reporting (Figure 10.1). This type of approach is to be welcomed and should be extended beyond the climate change and energy governance domain, as is already the case in the EU's regional smart specialisation strategies (Carayannis and Rakhmatullin, 2014).

Figure 10.1 Current versus proposed EU energy and climate governance schemes



Note: ETS, EU Emissions Trading System; NECP, national energy and climate plan.

Source: Tagliapietra and Zachmann, 2016.

10.3 Engaging with non-state actors and enabling polycentric governance

The proliferation of new governance initiatives during recent years has involved both state and non-state actors (see, for example, Section 3.5). Increasingly, private companies, universities, charities and faith organisations are becoming directly involved in governing climate change, for example by developing international standards and making voluntary commitments, and through business networks and grassroots initiatives and platforms.

The emergence of this polycentric form of governance — characterised by flexible, overlapping and self-organising activities — partly represents a response to the limitations of intergovernmental actions. This reality was illustrated vividly by the response to the United States' withdrawal from the Paris Agreement, when '900 American businesses, 300 mayors and numerous universities announced that they were 'still in' the Agreement and willing to do what it takes to ensure the United States delivers on its pledge' (Jordan et al., 2018a). Yet the importance of local and non-state governance is increasingly acknowledged and even embraced within intergovernmental processes. The Paris Agreement itself recognises that climate actions cannot and should not be taken by the state alone (Setzer and Nachmany, 2018), specifying that states should 'incentivise and facilitate participation by public and private entities in mitigation efforts'.

These developments are coherent with the logic of governance elaborated in sustainability transitions research. As discussed in Part 2, this emphasises the need to broaden networks and engage new types of actors to stimulate experimentation and destabilise regimes (Grin et al., 2010). While this increasingly complex landscape creates new opportunities for learning and sharing knowledge, it amplifies the challenge of coordinating governance. It highlights that, if vertical coordination is to deliver on its aims, it needs to extend beyond governments to other stakeholders (Kuhlmann and Rip, 2018).

Interactions with practitioners and stakeholders may benefit from new organisational structures, such as public-private partnerships to implement particular innovations. Business clusters and innovation agencies can play an important role as intermediaries and communicators across governance levels. Innovation hubs can act as spaces for creative thinking, visioning and exchange of learning experiences either within or outside current organisational structures. New implementation agencies can form a bridge between policymakers and practitioners. For example, energy agencies had relevant intermediary roles in the Austrian transition towards biomass district heating (see Box 4.1).

Thematic working groups that operate across different levels of governance could also help promote vertical coordination by engaging EU, national, regional and local policymakers, as well as other relevant stakeholders. Such working groups could facilitate a dialogue among actors interested in supporting a transition process, for example towards sustainable mobility. 'Putting forward explicit directionality, such as the ambition to address Grand Societal Challenges, can work as a resource and help to establish legitimacy' (Kuhlmann and Rip, 2018) for such working groups. However, it may be difficult to attract all the relevant actors to such working groups. Some new entrants and 'unusual suspects' may not be noticed by those setting up working groups, or smaller actors may not have the resources to participate.

Another potential implementation challenge is the lack of resources of local or regional actors (public and private) to participate in time-consuming activities. One way to overcome this problem is to use EU or government funding to support the participation of local actors from the public and private sectors. For example, research on how local projects can contribute to global sustainability transitions highlights the value of EU LEADER programme funding for local actors ([3]). The EU funding provided recipients not only with resources but also with legitimacy and recognition, which enabled stronger local and regional institutionalisation processes than would otherwise have been the case (Späth and Rohracher, 2012). The direct and indirect effects of EU funding awards can therefore be very positive.

(3) This programme ran until 2014 and is now continued under the name Community-Led Local Development (CLLD). Given its focus on rural developments, LEADER is implemented under the national and regional rural development programmes of each EU Member State and is co-financed from the European Agricultural Fund for Rural Development.

11 Risks, unintended consequences and adaptive governance

Message 9: Monitor risks and unintended consequences and adjust transition pathways as necessary

- Transitions have unintended consequences and trade-offs between social, economic and environmental sustainability outcomes. It is essential to continuously identify and evaluate risks associated with transitions using anticipatory governance approaches.
- Ex ante tools must be complemented with adaptive governance approaches based on iterative cycles of policymaking and planning, implementing, evaluating and learning.
- Governance of transitions should adopt a precautionary approach, recognising that it has an important role in supporting decision-making in situations of uncertainty.

From a risk management perspective, transitions present a particularly difficult governance challenge. Transitions are highly unpredictable, open-ended, complex and non-linear processes that often produce unintended consequences and surprises. For example, innovations such as novel chemicals can present direct threats to human and environmental health, while the accumulation and interaction of such substances in the environment or within organisms can amplify uncertainties. The interplay of innovations and social responses may produce counter-productive outcomes; for example, car-sharing schemes may cause people to cycle or walk less (Rademaekers et al., 2018). Interdependencies between systems can produce unexpected harms, such as the deforestation and food price increases that accompanied expanded biofuel production in the early 2000s. Structural economic change is sure to create winners and losers, potentially affecting whole regions (see also Section 5.3).

The transitions literature suggests that there are three main categories of risks and uncertainties:

1. **Uncertainty about speed and timing:** Innovations are intrinsically uncertain and often develop faster or slower than expected. The deployment of wind and photovoltaics (solar-PV), for example, has been much faster than was expected 10 years ago, whereas carbon capture and storage, heat pumps and nuclear power have diffused much slower than was assumed in many decarbonisation scenarios (Peters et al., 2017). This may lead to a change in the relative desirability of different transition pathways.

2. **Emergence of new concerns:** Innovations may have unintended environmental, social or economic consequences that require policy adjustments. For instance, the push for biofuels in the EU in the early 2000s through the Biofuels Directive (EU, 2003) had negative environmental effects (e.g. contributing to deforestation and biodiversity loss) and social impacts (contributing to increases in food prices). Transitions policies produced unintended economic costs when solar-PV diffused much faster than expected in Germany. This led to high subsidy costs and significant increases in electricity prices for consumers, which led to shifts in political support and rounds of policy adjustments (Hoppmann et al., 2014).

3. **System integration, infrastructural and institutional adjustments:** The diffusion of innovations may require adjustments in existing systems (see Chapter 5). Offshore wind diffusion in Germany, for example, experienced significant grid access delays, which required policy adjustments because it slowed down the diffusion of offshore wind parks (Reichardt et al., 2017).

11.1 Identifying and evaluating risks of transitions (anticipatory governance)

Since transitions are uncertain processes that can produce negative environmental, social or economic outcomes, there is a need for governments, businesses and other actors to identify and evaluate potential risks associated with individual innovations and entire transition pathways. A variety of structured approaches are available for identifying and assessing such potential risks.

11.1.1 Modelling strategies

Modelling approaches are particularly useful for exploring long-term challenges and prospective solution pathways. Integrated assessment models, for example, have been used to evaluate the implications of the different socio-economic scenarios employed by the Intergovernmental Panel on Climate Change. In doing so, they provide insights into the effects of delaying climate mitigation action and the importance of different technologies for achieving long-term climate or biodiversity targets.

For identifying and evaluating risks and unintended consequences, models are valuable in offering structured ways to explore potential futures and to answer 'what if' questions about policy interventions in changing societal or sectoral contexts. Integrated assessment models, for example, provide a powerful tool for exploring long-term dynamics in human-environment interactions and for highlighting potential trade-offs across multiple competing policy visions and ambitions. The quantitative outputs from these kinds of modelling exercises provide policymakers with tangible indications of how policy objectives influence physical changes (emissions, climate, land, biodiversity, etc.) and other forms of trade-offs and distributional impacts.

As noted in Chapter 2, however, quantitative modelling approaches also have important limitations, which mean that they provide only partial insights into the types of risks and unintended consequences that may arise from transitions. In particular, models struggle to integrate a variety of themes — such as the impact of external shocks, drivers of change, radical innovations and non-linearities — that are essential to understanding the dynamics of transitions and associated risks. Moreover, an additional concern in relation to models is that, by offering apparently clear and precise descriptions about how future change will occur under different assumptions, models can actually mask or downplay the likelihood of unintended outcomes.

11.1.2 Foresight

Modelling strategies provide valuable but partial insights into potential risks and unintended consequences associated with transitions. For this reason, transitions governance activities typically draw on other forward-looking approaches, in particular foresight methods. As explained by EEA and Eionet (2018):

> Foresight is a forward-looking approach that aims to help decision-makers explore and anticipate what might happen, in a participatory way, as well as prepare for a range of possible future scenarios, influence them and shape the futures. Instead of predicting the futures (see forecasting), foresight typically involves systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building processes to uncover a range of possible alternative future visions. Key foresight methods include horizon scanning and scenario building.

In the context of innovation policy, foresight is used to identify promising areas of research and technology development that can help improve competitiveness and social benefits, helping to target public resources in ways that maximise societal benefits (Martin, 1995). Most governments in industrialised countries agree that an explicit, coherent technology policy is essential for economic and social development, but, as not all areas of science and technology can be supported, some kind of foresight process is required to inform choices. For example, Japan has used a series of long-term (30-year) outlooks, prepared by the Science and Technology Agency every five years since the 1970s, to anticipate technology and innovation trends (Martin, 1995).

In the area of environmental governance, foresight approaches are used to identify potential risks associated with emerging issues and trends, including societal changes. For example, horizon-scanning approaches collect and organise a wide array of information in order to provide early indications of economic, social, technological, political and environmental changes (UBA, 2015). These approaches are increasingly being taken up in EU governance (Box 11.1).

11.1.3 Anticipatory governance

Anticipatory governance approaches provide a means of mobilising the insights from foresight, with the aim of reducing or avoiding negative outcomes ex ante, rather than seeking to mitigate effects ex post. Anticipatory governance has been developed since the early 2000s, mainly in two different strands of

Box 11.1 Identifying emerging risks and opportunities for Europe's environment and policies

The EU's 7th Environment Action Programme calls for improvements in 'the understanding of, and the ability to evaluate and manage, emerging environmental and climate risks' (EC, 2013a). One particular aim is to improve the EU's capacity to identify and act upon technological developments in a timely manner, providing reassurance to the public to foster acceptance of new technologies.

Responding to the need for better information on these themes, in 2017 the Environment Knowledge Community ([4]) established the EU foresight system for the systematic identification of emerging environmental issues (FORENV), to identify, characterise and assess emerging issues that may represent risks or opportunities to Europe's environment. FORENV adopts a systematic and participatory approach to risk management, building on methodologies, such as horizon scanning, text mining and media monitoring (EC, 2017g), and on relevant expertise. In particular, it links with the Scientific Committee on Health, Environmental and Emerging Risks and the Eionet Forward-Looking Information and Services representatives from EEA member countries. The first annual cycle, for 2018-2019, is focusing on identifying key emerging issues at the environment-social interface and communicating them to policymakers and the public at large, to encourage appropriate and timely action.

academic work: one in the public administration and management literature and one in the area of environmental studies and policy (Guston, 2014). It places strong emphasis on participatory approaches that draw on dispersed knowledge. As such, it comprises 'a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible' (Guston, 2014).

Whereas much policymaking is grounded in expectations of linear processes of change, anticipatory governance employs foresight in creating and executing public policy 'to enhance the ability of decision-makers to engage and shape events at a longer range and, therefore, to the best advantage of the citizens they serve' (Fuerth, 2009). In the field of innovation, science and technology studies, anticipatory governance through foresight has also been used to fund and govern the development of specific technologies or technology areas. It has also been applied as part of the United States National Nanotechnology Initiative. This initiative includes the Center for Nanotechnology in Society, in which social scientists work together with scientists, engineers and citizens. The Center pursues research, training and outreach on the potential societal implications of scientific and technological advances at the nanoscale (Guston, 2014).

In this context, anticipatory governance operates as a form of real-time technology assessment that is very similar to constructive technology assessment (Box 11.2). Potential negative environmental or social consequences of innovation are assessed and discussed among a wide range of stakeholders. Identified concerns then directly feed into the further development of the technology. This is not straightforward. Often the full socio-economic and environmental consequences of new technologies are extremely hard to anticipate in the lab: by the time they do become apparent, widespread diffusion and associated lock-ins may make the innovation very difficult to remove (Collingridge, 1980). Nevertheless, Guston (2014) argues that changing venues and amplifying the voices of actors that are often excluded from articulating visions of the future can help in 'bending the long arc of technoscience more toward humane ends'.

The analytical approaches outlined above provide ways to assess potential negative side-effects of transitions before they materialise. Yet these approaches have limitations. As the innovation scholar Rosenberg (1996) has observed:

> social change or economic impact is not something that can be extrapolated out of a piece of hardware. New technologies, rather, need to be conceived of as building blocks. Their eventual impact will depend on what is subsequently designed and constructed with them. New technologies are unrealized potentials that may take a very large number of eventual shapes. What shapes they actually take will depend on the ability to visualize how they might be employed in new contexts.

([4]) The Environment Knowledge Community is an informal platform of six EU actors (the Directorates-General of Environment, Climate Action and Research and Innovation; the Joint Research Centre; Eurostat; and the EEA) that was set up in 2015 with the objective of improving the generation and sharing of environmental knowledge for EU policies.

Box 11.2 Constructive technology assessment

Technology assessment (TA) has been used for several decades to assess the potential impact of emerging technologies ex ante. TA approaches aim 'to reduce the human costs of trial and error learning in society's handling of new technologies, and to do so by anticipating potential impacts and feeding these insights back into decision making, and into actors' strategies' (Schot and Rip, 1997). In the United States, for example, the Office for Technology Assessment provided independent advice on complex scientific and technological issues to Congress between 1972 and 1995 (Sadowski, 2015). Responding to criticisms that traditional TA provided inadequate scope for public participation, constructive technology assessment (CTA) was developed as a concept and used in policy practice mainly in the Netherlands and Denmark.

Schot (1992) explains that 'Whereas traditional TA focuses more on the external effects of a technology and the choice between different technological options, the new field of CTA shifts attention to the steering of the internal development of the technology.' CTA 'is based on the idea that during the course of technological development, choices are constantly being made about the form, the function, and the use of that technology and, consequently, that technological development can be steered to a certain extent'. CTA therefore promotes real-time engagement with technological developments, enabling visions and design criteria to be deliberated, with the aim of influencing the direction of change in socially desirable directions. It is not just a tool or a particular type of policy analysis but rather part of the politics of managing technology in society.

CTA processes can use a range of tools. For example, in Denmark, consensus conferences have been used to provide societal input into technology development. At such conferences, a panel of citizens spends several days discussing a specific subject or technology area with experts. The outcome is an agreed statement by the citizen panel that contains its judgments and questions for further development of the technology, on which the experts can comment. In the Netherlands, CTA was taken up by the Institute for Consumer Research, which developed a process of iterative meetings between producers and consumers to incorporate user wishes into design processes. It was also used as part of the Dutch programme on sustainable technologies, which looked at way to introduce novel protein foods as potential meat replacements (Schot and Rip, 1997).

In reality, the impacts of innovations as they emerge and diffuse in complex socio-economic and environmental systems cannot be fully anticipated. This is especially true in the context of transitions where the focus is not on individual technologies but rather on changing whole socio-technical configurations.

11.2 Experimenting and adaptive governance

Although they are essential, anticipatory approaches cannot reduce risks completely; unfolding transitions will inevitably produce unexpected consequences and surprises. The transitions literature therefore recommends complementing anticipatory governance with adaptive policies (e.g. Swanson et al., 2010), reflexive governance (Voss and Bornemann, 2011) and experimental governance (Evans and Karvonen, 2014). Like the older literature on adaptive management of complex (socio-)ecological systems (e.g. Holling, 1978), these approaches take ambivalence, uncertainty and distributed power in societal change as their point of departure. They accept that there are limits to actors' anticipatory knowledge and control over complex systems and societal change processes (Voss and Bornemann, 2011). Such governance approaches are therefore often based on collective experimentation, learning and adjustment.

Experimental and adaptive approaches are a core part of sustainability transitions. For example the literatures on Strategic Niche Management (Kemp et al., 1998; Geels and Raven, 2006; Schot and Geels, 2008b) and Transition Management (Rotmans et al., 2001; Loorbach, 2010), discussed in Box 11.3, stress that the initial exploration of transition pathways through concrete projects or experiments should be used to adjust the initial visions and/or the corresponding policy programmes (policy learning). These adjustments may involve rejecting or altering particular pathways because innovations appear to be unviable or unacceptable.

Box 11.3 Transition management and adaptive management

Transition management was developed in the Netherlands as a systematic approach for steering transitions towards sustainability using coherent sets of interventions (Rotmans et al., 2001; Kemp and Rotmans, 2004; Loorbach and Rotmans, 2006; Loorbach, 2010). Transition management was developed to tackle persistent, structural problems of unsustainability that were not solved by traditional short-term policy approaches in systems such as energy, construction, mobility and agriculture (Loorbach, 2007). Its basic rationale is that processes of change in a complex society cannot be controlled, but that it is possible to influence the speed and direction of the structural processes of change.

Since transitions are complex and long-term processes, transition management proposes a cyclical and iterative process of four main activities: (1) establishing and developing a transition arena for a specific transition theme; (2) developing a long-term vision for sustainable development and a common transition agenda; (3) initiating and executing transition experiments; and (4) monitoring and evaluating the transition process. According to early experience using this approach, one cycle can take approximately two to five years (Loorbach and Rotmans, 2006). This can be seen as a form of adaptive governance, which pursues a trial-and-error strategy and aims to learn from the real-world experiments.

Figure 11.1 The transitions management cycle

Source: Loorbach and Rotmans, 2006.

Similarly, the literature on adaptive management of socio-ecological systems also emphasises the roles of social learning and stakeholder participation, as well as acknowledging the uncertain and pluralistic nature of knowledge about ecosystems (Foxon et al., 2008). This likewise leads to an emphasis on learning through experimentation and a cyclical approach in which system boundaries, the context, problems and desired goals are identified; hypotheses are developed and tested; policy strategies are implemented; and the results are monitored and inform a revisiting of the problems and goals.

The adaptive approaches outlined here differ from anticipatory processes such as CTA (Box 11.2) in that they move beyond a focus on technological innovations in lab conditions to address novel socio-technical configurations in a real-world context.

11.2.1 Experimentation and adaptation of policy

Experimenting is important not only to explore different socio-technical configurations or different transition pathways, but also for policy and governance itself. Using policy experimentation to test novel policy interventions in a constrained timespan and geographical setting is useful for developing knowledge about policy implementation challenges and policy effectiveness. In the context of transitions, governance and policy experimentation can advance social learning (Bos and Brown, 2012), challenge dominant values and bring in new actors (Kivimaa et al., 2017), and support the accelerated diffusion of new solutions (Matschoss and Repo, 2018). For example, early experiences with fostering social innovation following the Europe 2020 strategy might provide useful learning for policy experimentation to support transitions policies.

Bos and Brown (2012) present an interesting example from Australia that illustrates the potential value of experimental governance. In this case, experimentation led to considerable changes to the governance structure in Australia's urban water sector, including the mobilisation of municipal resources and power. They describe a variety of strategic, tactical, operational and reflexive activities — drawing from transition management — that provided different initiatives with a common direction, enabled new coalitions to fulfil a visionary agenda and supported continuous reflection based on individual and policy learning. Bos and Brown (2012) conclude that:

- the design of experimentation should explicitly focus on social processes facilitating the development of innovation networks around the societal problem in question;
- policymakers need to create a context for experiments that is not dominated by engineering frameworks;
- the design of experimentation should include, in the early stages, strategies for how learning can increase an experiment's potential influence on an existing regime, drawing on transitions theory.

In summary, the complexities and uncertainties of transition processes imply that there is a need to complement the ex ante, anticipatory approaches (described in the previous section) with adaptive governance approaches. Ongoing experimentation with novel socio-technical configurations combined with iterative cycles of policymaking and planning, implementing, evaluating and learning during transition processes is an important strategy. Such ongoing analysis and evaluation may lead to a reorientation of transition pathways or policy choices because of unexpected negative consequences or changes in circumstances.

11.3 Applying a precautionary approach to transitions governance

In situations of fundamental uncertainty, where risks cannot be assessed and balanced, the precautionary principle provides a useful tool to support decision-making. Precaution is recognised as a foundational principle within EU environmental governance by its inclusion in the Treaty on European Union (EU, 2012). As defined in the Rio Declaration (UNCED, 1992), the precautionary principle stipulates that 'Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.'

The relationship of precaution and innovation has long been debated and is particularly relevant in the context of transitions research, given the strong emphasis on promoting innovation as a means to catalyse systemic change. As Stirling (2015) notes, critics of the precautionary principle (e.g. Sunstein, 2002) argue that it is 'anti-science' and 'anti-innovation', producing paralysis while providing little guidance to decision-makers about how to move forward. Such descriptions suggest that precaution is likely to hinder sustainability transition processes.

This conclusion can certainly be questioned. First, precautionary activities can actually stimulate innovation. The EEA (2013), for example, notes that 'there is now increasing evidence that precautionary measures do not stifle innovation, but can encourage it, in particular when supported by smart regulation or well-designed tax changes.' Indeed, there is robust evidence to support the Porter hypothesis that well-designed environmental regulations lead to innovation and lead markets for environmental technologies, providing an early mover advantage and therefore making a positive contribution to competitiveness (Porter and Van der Linde, 1995; Ambec et al., 2013).

Second, the implications of applying the precautionary principle are likely to depend on context. For example, the EU's BOHEMIA project final report notes that 'the challenges facing Europe and the world are substantial and not fully understood. Yet, postponing actions until we fully understand the context can have dire consequences' (EC, 2018l). According to this formulation, applying the precautionary principle would imply the need for societies to promote experimentation and innovation, notwithstanding the continuing uncertainty about the precise impacts of global environmental change.

11.3.1 Promoting diversity, avoiding path dependency

In addition to providing a stimulus for innovation, the precautionary can help decision-making by offering a set of responses in situations where risk assessment tools are inadequate. Rather than automatically requiring bans on potentially harmful innovation, it opens up a range of response strategies centred on acknowledging ignorance and uncertainty. These include the need to 'consider alternatives, explore uncertainties, maximise learning and promote adaptability in careful, reversible, step-by-step implementation' (Stirling, 2015). In this sense, transitions research embraces a precautionary approach, complementing ex ante assessments of risk with ex post adjustments of innovation pathways based on experimentation and learning.

Promoting diversity in innovation is essential to this precautionary approach because it nurtures creativity, mitigates lock-ins, hedges against surprises, enables learning and increases tolerance for failure of individual innovations. Diversity provides the foundation for shifting to alternative innovation pathways in the event of surprises or unexpected consequences. But achieving this goal requires that diversity be complemented with real-world pilots and trialling, monitoring and evaluation, learning and communication, and adaptive governance mechanisms.

Applying a precautionary approach ultimately raises questions about the purpose and direction of innovation — questions that fall outside the focus of narrow forms of risk assessment and are often brushed aside by widespread, uncritical discourses that portray all innovation as inherently desirable. For example, Genus and Stirling (2018) argue that 'Taken as a whole, EU initiatives and policies tend to characterise innovation in an undifferentiated way — as a self-evidently generally 'good thing' irrespective of the specific kind of innovation involved or the alternatives that might thereby be foreclosed.' A more precautionary approach — including open, participatory approaches to define directionality — is in tune with the EU's concept of Responsible Research and Innovation (EC, 2014b), and very much at the heart of the shift to mission-oriented and transformative innovation policy.

12 Knowledge and skills for transitions governance

Message 10: Develop knowledge and skills for transitions governance and practice

- Effectively supporting sustainability transitions requires fundamental changes in the knowledge system supporting governance, implying shifts in skills, methods, processes and cultures.
- Supporting radical innovations requires new knowledge that broadens the solution space and engages with the multiple dimensions of innovation and system change more systematically.
- Public authorities need to develop new skills and policymaking practices, embracing foresight, experimentation, evaluation and stakeholder interaction, as well as new organisational structures.

12.1 Transforming the knowledge system

During recent decades, Europe has developed an unparalleled international system of data collection and analysis to support the design and implementation of environmental policy. However, as understanding has grown about the complexity and scale of Europe's environmental challenges and resistance to change, so too has recognition of the shortcomings of existing knowledge. As summarised in *The European environment — state and outlook 2015* (EEA, 2015b), 'there is a gap between established monitoring, data and indicators and the knowledge required to support transitions'.

The knowledge systems that developed to support environmental governance during the 20th century were well adapted to the challenges and thinking of that time. Confidence in the capacities of governments to plan and steer societal development using regulations and economic instruments underpinned the widespread use of rational analytical approaches, such as quantitative modelling, grounded in mainstream economics assumptions about the way that people respond to incentives, individually and collectively. These approaches worked reasonably well during past decades, when relative stability in energy, transport, housing and food systems enabled semi-rational planning with regard to structured problems. However, they have limitations in responding to the sustainability challenges that Europe faces today.

The emergence, in recent years, of a new generation of systemic and transformational policy frameworks (see Chapter 1) creates a fundamental challenge for the knowledge system supporting policy and governance. It points to the need for evidence and skills geared towards understanding the societal systems that constrain or enable transitions — in terms of both their past and current dynamics and potential future configurations. At present, however, knowledge is primarily generated and organised in ways that support earlier generations of policy — for example in terms of monitoring ambient pollution levels and sectoral emissions. While this type of knowledge and the related policies remain essential, they are likely to be insufficient to achieve sustainability transitions.

'Too much emphasis is given in science and research to understanding the past and determining problems. Too little focus has been put on exploring visions for the future of Europe and the world and finding solutions to the problems we are facing.' EEA Scientific Committee (EEASC, 2015)

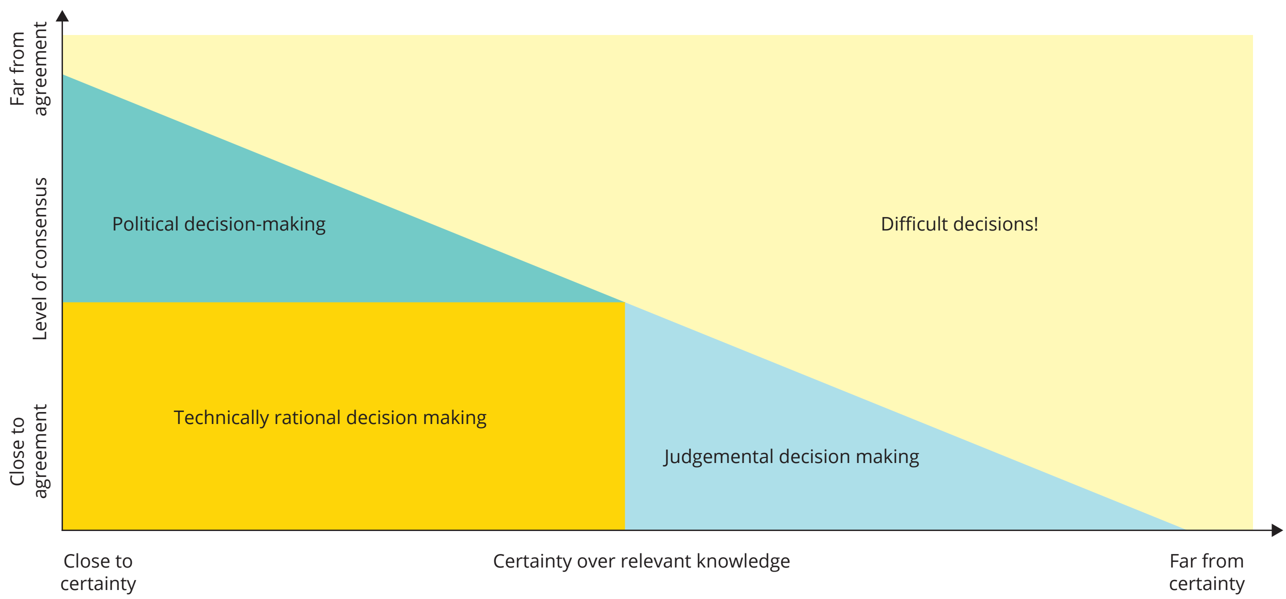
Sustainability transitions involve difficult decisions (Figure 12.1), characterised by high degrees of uncertainty (e.g. about the price, performance, acceptance, use and environmental outcomes of innovations) and disagreement and conflict among stakeholders (e.g. about desired futures, pathways and trade-offs). In addressing policy problems of this type, technically rational decision-making approaches may provide partial or misleading guidance because they struggle to integrate many of the fundamental characteristics of transitions described in this report. Such omissions include themes such as uncertainty, non-linearities, resistance, radical innovation, actors and institutions, social practices and behavioural shifts.

The inherently uncertain, exploratory and open-ended character of transitions creates the need for a much broader range of knowledge to support governance. For example:

- There is a need for a much better understanding of complex societal systems, including the interactions, lock-ins and feedbacks that influence sustainability outcomes, social acceptance and political feasibility.
- Identifying opportunities and risks associated with systemic change requires better information about the impacts of megatrends, drivers of change, unexpected consequences and cross-system interactions.
- The emphasis on innovation and experimentation necessitates a knowledge system that enables society to learn from successes and failures, to replicate and upscale promising initiatives, to identify unexpected consequences, and to avoid lock-ins to unsustainable innovation pathways.
- Identifying goals and pathways and navigating trade-offs requires information about the interests and preferences of different groups and their visions for the future.
- The viability and credibility of polycentric governance, founded on bottom-up activity by cities and other groups, hinges on the presence of robust monitoring and reporting systems.

To the extent that it is currently available, knowledge about these themes resides in multiple disciplines and with diverse actors across society. As Bourgon (2011) has argued:

Figure 12.1 Schematic representation of types of policy problems



Source: Developed on the basis of Hoppe, 2010.

> The best insight about emergent phenomena may not rest with government. It might lie in self-organized social networks and in the multiple relationships citizens have built in their local or globally dispersed communities of interest. The best means of actions may not be in government's hands. Citizens and other actors have invaluable information and capacities to offer ... Governments need to leverage the power of others. The knowledge, capabilities and loci of action are broadly dispersed.

At present, however, this dispersed knowledge makes only a limited contribution to policy and governance. Rather than providing a coherent and holistic picture of challenges and potential responses, the existing knowledge system is often **fragmented** (providing only a partial understanding of reality); **compartmentalised** (organised into disconnected disciplines or government departments and agencies); **elitist** (producing highly specialised, self-referential research with little focus on communication); **exclusive** (marginalising important voices such as the poor, women, ethnic minorities); **hegemonic** (reproducing existing structures and power dynamics); and **disconnected from action** (focusing on problems, rather than solutions and how to implement them) .

Tackling these shortcomings is an important part of the shift towards network governance approaches (see Chapter 2). In particular, it requires strategies that:

- **pluralise evaluations** — combining multiple disciplines and analytical approaches and engaging with different research communities;
- **engage with societal concerns** — recognising different viewpoints and preferences through interactions with diverse social actors and stakeholders;
- **attend to real-world complexities** — tracking developments in existing systems and abstracting lessons from (local) initiatives;
- **co-create knowledge** — ensuring the knowledge is relevant, actionable and understandable by engaging decision-makers and other stakeholders in knowledge production.

Generating knowledge of this sort requires not simply a reorientation of research priorities but rather a more fundamental change in the knowledge system, embracing changes in skills, processes, norms and organisational structures.

> 'A new system of global environmental science is required ... It will draw strongly on the existing and expanding disciplinary base of global change science; integrate across disciplines, environment and development issues and the natural and social sciences; collaborate across national boundaries on the basis of shared and secure infrastructure.' (IGBP et al., 2001)
> Amsterdam Declaration on Global Change

As with other processes of systemic change, however, efforts to transform the knowledge system face significant barriers. In part this reflects the fact that the co-evolution of different system elements (such as investments by researchers and institutions in expertise and skills) can mean that there are often strong interests in maintaining the existing system. For example, academic cultures and incentives tend to promote specialisation, rather than interdisciplinary research.

In part the difficulties in changing the knowledge system reflect practical limitations. For example, extracting, categorising and sharing information about local initiatives in ways that can inform action elsewhere is likely to be resource intensive. Similarly, stakeholder engagement can require specific skills and raises difficult questions about how to interact with large groups of people in a representative way. Responding to these needs is difficult in the context of austerity cuts, which have reduced the number of civil servants in many departments and created substantial time pressures. Moreover, in many European countries, new public management approaches and cutbacks have transformed civil servants into process managers, who rarely remain in one position for more than two or three years (King, 2015). These developments make it difficult for civil servants to build up the substantive domain expertise required for effective stakeholder interactions.

These barriers are far from trivial. However, there is evidence of change in the knowledge system supporting environmental and sustainability governance, partly enabled by new information and communication technologies. For example, the emergence of platforms of action (for example under the Paris Agreement and the EU's Circular Economy Action Plan) has provided a novel means to enable the collation and sharing of practice-based evidence among non-state and public actors. Similarly, open government and citizen science initiatives potentially offer mechanisms to deepen understanding of sustainability challenges and to devise innovative solutions. These kinds of initiative potentially provide the seeds for change in the knowledge system, although their impact so far remains limited.

'Linking knowledge with action for effective societal responses to persistent problems of unsustainability requires transformed, more open knowledge systems. ... This transformation includes inter alia: societal agenda setting, collective problem framing, a plurality of perspectives, integrative research processes, new norms for handling dissent and controversy, better treatment of uncertainty and of diversity of values, extended peer review, broader and more transparent metrics for evaluation, effective dialog processes, and stakeholder participation.' (Cornell et al., 2013)

12.2 Knowledge to support systemic innovation

As outlined in Chapters 1-11 of this report, public institutions and policies have an essential role in supporting the emergence and diffusion of radical innovations. For governments to provide such support they require a robust knowledge base. This section focuses on four areas where new evidence is particularly needed: broadening the kinds of sustainability innovations considered, monitoring progress of innovations, evaluating feasibility constraints that hinder niche development, and evaluating policy interventions in support of innovation and diffusion. The use of foresight approaches to explore visions, pathways and emerging issues is another important theme, which is discussed in Chapter 11.

12.2.1 Broadening the solution space

As outlined in Chapter 3 (e.g. Table 3.1), socio-technical transitions will require a diverse mixture of different types of innovations, extending well beyond technological fixes. In practice, however, the identification of promising innovations is often linked to narrow problem descriptions (e.g. substitutes for conventional automobility) or implicit assumptions (e.g. innovations stemming from current large industrial players). As such, there is a need to broaden the solution space to include different types of relevant niche innovations.

In the mobility sector, for example, most low-carbon scenarios address substitutes for the conventional petroleum car (i.e. battery electric vehicles, hybrid electric vehicles, hydrogen fuel cell vehicles, biofuels). Most innovation accounts and policy documents focus almost exclusively on electric vehicles, further replicating a bias for high-tech solutions with strong business backing and a cognitive bias towards private mobility. This neglects a whole spectrum of relevant solutions beyond the 'greening of cars', alternative business models (Marletto, 2014), behaviour and lifestyle changes, and public investments, e.g. public transport infrastructure (Table 12.1).

Existing knowledge also focuses too much on technical solutions. As noted in previous chapters, much less is known about non-technological forms of innovation, such as social initiatives and grassroots innovations (Section 3.5), and urban experimentation (Chapter 6). These types of initiatives could be mapped and analysed much more thoroughly. New knowledge could include:

- improved data on the experimental projects, e.g. number, scale, duration, objectives, funding, unaccounted resources;
- improved knowledge about the wider outcomes of experimental projects, e.g. sustainability impacts (individual and collective), governance influence, learning outcomes, network-building outcomes;
- improved knowledge about the appropriate means of supporting experimental projects.

Table 12.1 Contrasting approaches to sustainable mobility and some examples

Approach	Examples of innovative technologies and practices
Efficiency and substitution (greening)	Engine and fuel
Encouraging modal shift	Intermodal mobility (public transport, cycling, walking) intermodal ticketing, urban bike-hire schemes, congestion charging
Reducing trip lengths	More integrated urban and transport planning — through compact and traffic-free cities
Reducing the need to travel	Information and communications technology (ICT), teleworking, internet shopping

Source: Based on Banister, 2008.

> 'Measuring growth in consumption, observing economic activity and monitoring financial indicators are no longer enough when managing a sustainable economy. Information is also needed on environmental and social aspects. This requires businesses to develop integrated reporting (i.e. more than financial accounts) and to develop an integrated view of life cycles (of products, of business units, etc.) and value chains.' (Bontoux and Bengtsson, 2015)

12.2.2 Monitoring progress on multiple dimensions

Across all forms of sustainability innovation, there are substantial knowledge needs regarding monitoring of progress. In measuring the maturity of particular innovative niches, there is a need to move beyond metrics such as cost curves and learning rates, as they provide only limited information about niche potentials, possible development trajectories or important barriers. Evaluations of niche momentum need to take account of techno-economic dimensions (innovation, market development, investment), the kinds of actors supporting and contributing to a particular niche innovation, and contextual aspects such as changes in institutional framework conditions, such as supporting policies, public debates, shifting values and preferences.

Developing comprehensive knowledge about relevant actors is particularly challenging, as it relies largely on qualitative assessments. A useful way forward is to start mapping out the actors gravitating around particular innovations (for positive or negative reasons), to understand their motives and strategies, and to identify the kinds of influence they are able to leverage, for example power and financial resource commitments, and legitimation or delegitimation.

12.2.3 Social acceptance and political feasibility

As emphasised in Chapters 3 and 4, the issues of social acceptance and political legitimacy are important. Opposition to bioenergy with carbon capture and storage, shale gas fracking and onshore wind turbines has led to weaker deployment than initially planned, including significant delays and major disappointments in some cases. Opposition to innovation is likely to affect the direction of socio-technical change and presents serious obstacles (or even upper limits) to niche development. For this reason, it is important to develop appropriate means to anticipate potential opposition and feed such knowledge back into foresight exercises and notional assessment of likely transition pathways. Relevant forms of knowledge have to do with political dynamics (e.g. political coalitions and counter-coalitions) and societal dynamics (about citizen and user acceptance).

Assessing the political feasibility of certain pathways can be done by engaging in strategic roundtable discussions across traditional policy silos, which can reveal important bottlenecks and friction points. It may be possible to take the pulse of resistance and opposition by involving citizens and other stakeholder groups in participatory innovation assessments; mobilising knowledge about behaviours, preferences and practice changes; or employing existing survey infrastructures and consumer behaviour monitoring platforms. Small-scale and local projects also provide a useful window into concrete acceptance issues. Monitoring and reporting on these issues can help inform innovation and transition strategies at higher scales of governance.

12.2.4 Knowledge about system reconfigurations and disruption

As discussed in Chapter 5, disruption and reconfiguration of regimes involve difficult challenges because of the associated impacts on incumbent businesses and on regional economies. Increasingly, policies are being developed to manage these impacts and facilitate structural economic change. Smart Specialisation Strategies, for instance, seek to influence local transformations by supporting innovation capabilities. The German Environment Agency (UBA) has developed a dedicated programme of phase-out and 'exnovation' (David, 2017). However, there is only limited practical experience of steering such processes. Moreover, associated concerns such as increasing political resistance are likely to become more pressing as transitions on the ground gather pace (Markard, 2018; Turnheim et al., 2018a).

A growing number of detailed case studies and processual analyses identify core mechanisms, challenges and possible governance interventions to manage system disruption and reconfiguration. There are limited systematic data or comparative studies, however, and there is a particular need for new knowledge in the following areas:

- **How to govern negative consequences of transitions,** particularly in terms of the vulnerable sectors and regions that are deeply committed to non-sustainable industrial sectors and practices (i.e. the potential losers from transitions). It is important to further develop diagnostic tools that can better identify such communities and anticipate concrete challenges. It is also important to develop more systematic knowledge about the potential strategies and policy interventions to address such challenges.

- **How to govern different patterns of system reconfiguration** (Smith et al., 2005; Geels and Schot, 2007; Rosenbloom, 2017), particularly knowledge grounded in more systematic comparative data about historical and ongoing system reconfigurations. It is important that such new knowledge build on comparisons between domains (e.g. energy, mobility, food), and develop notional evaluations of how fast systems are changing and in which direction.

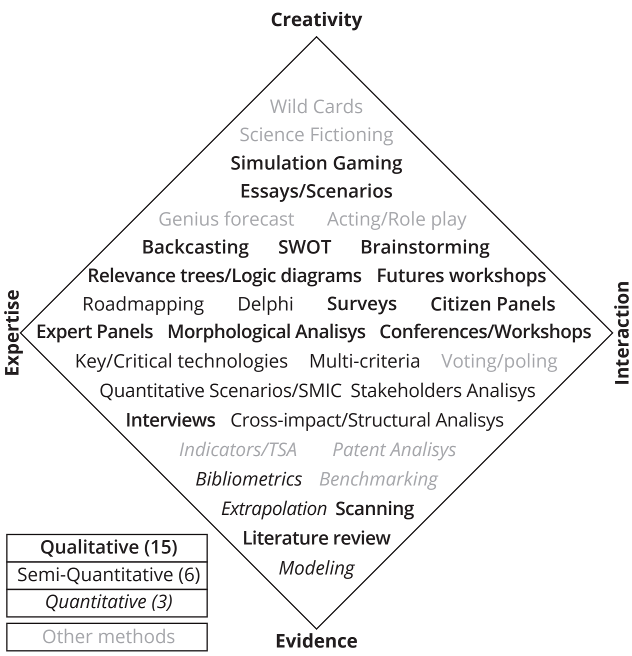
- **How to address sources of lock-in and resistance to change at system level** that is likely to slow down transition efforts. Knowledge about system lock-ins needs to take account of multiple forms and dimensions (Klitkou et al., 2015), and to mobilise such knowledge to inform evaluations of the likelihood of change, core bottlenecks and possible intervention strategies.

- **The deeper and more long-term drivers of change (landscape changes).** Monitoring of megatrends has increased substantially in recent years (EEA, 2015a; EC, 2018k). Further developments should pay more attention to the linkages between such megatrends and transition pathways, in terms of creating windows of opportunities or influencing the kinds of potential pathways and how they may be harnessed.

12.3 Competencies for governing transitions

The production and use of knowledge for transitions is tied in complex ways to existing skills, cultures, organisational structures and processes. Creating new kinds of knowledge, grounded in experimentation and evaluation, stakeholder engagement and transdisciplinarity, will therefore require changes in diverse areas of the broader knowledge system, including the development of new competencies in public institutions. Reproducing established mindsets and practices will not be enough. Although established knowledge and skills will continue to be valuable, in many cases there will be a need to develop a significantly new set of competencies that have been marginalised by prevailing educational curricula and training models.

Figure 12.2 The foresight diamond



Note: SWOT, strengths, weaknesses, opportunities, and threats; SMIC, cross-impact systems and matrices.

Source: Popper, 2008.

Being competent is this context is different from simply knowing about an issue or knowing what to do. It means actually performing and behaving in context, making sense of existing knowledge available, being aware of different values and perspectives at stake, and managing relationships with all actors. Competencies in this account are therefore a combination of knowledge, skills and attitudes, mobilised in action in a given context, towards the performance of a particular task or job (Klett, 2010). Being competent in a function (whether as a policymaker, as a researcher or in any other role) therefore requires knowing about that particular context, issue and related information or data; being able to execute certain sub-tasks and perform sub-sets of the job in an integrated manner; and being or behaving in a way that makes the job possible and successful in that particular context.

Existing formal education and training programmes are seldom designed to provide professionals at the science-policy interface with needed competencies. Curricula have mostly been designed under traditional paradigms of problem-solving, linear causality, discipline-based analysis and planning. For example, in developing forward-looking evidence, the dominant methods and skills in many public institutions, such as quantitative modelling and cost-benefit analysis, are likely to provide only partial insights. Popper (2008) argues that exploring multiple potential futures and transition pathways should draw on four different sources, which offer contrasting benefits (Figure 12.2). These comprise:

- **evidence:** rigorous data collection and analysis such as modelling;
- **creativity:** original and imaginative thinking, which can help in broadening the solution space and in expanding the understanding of potential risks and opportunities;
- **expertise:** tacit skills and accumulated knowledge, which often allow more holistic and comprehensive understandings, including insights from past failures or successes;
- **interaction:** dialogue and participation, drawing on the knowledge of diverse stakeholders, which can enrich analysis and creative visioning, improve coordination between actors and strategies, and build a sense of co-ownership and commitment to foresight outcomes.

The remainder of this section addresses three areas where new competencies and approaches are needed to promote transitions governance: experimentation and evaluation, stakeholder engagement, and combining the insights from multiple analytical perspectives.

12.3.1 Experimentation and developmental evaluation

As emphasised throughout this report, the governance of highly complex and uncertain change processes depends on experimentation, monitoring and learning. As noted in the European Commission's report, *Transitions on the Horizon*, 'Each policy attempt to solve a problem is an experiment from which lessons can be learned. Multiple policy experiments can drastically improve understanding of problems and potential solutions' (EC, 2018l).

Experimentation may deviate in some ways from standard policy skills and approaches, in which experts first identify the best option and then use mainstream project management approaches to implement it (e.g. articulate clear goals or specifications, invite proposals, select the cheapest one, monitor intermediate deliverables and milestones to ensure delivery on time and on budget). The success of experimental governance approaches depends in part on a willingness to accept that some experiments will fail and to acknowledge and learn from those failures. In many instances, therefore, the shift towards more experimental governance will require shifts in incentive structure, mentalities and organisational cultures.

Managing long-term and uncertain processes requires developmental evaluation, which aims to learn lessons

Table 12.2 Comparison between traditional and developmental evaluation

Traditional evaluation	Developmental evaluation
Render definitive judgements of success or failure	Provide feedback, generate learning, support direction, or affirm changes in direction
Measure success against predetermined goals	Develop new measures and monitoring mechanisms as goals emerge and evolve
Design the evaluation based on linear cause-effect logics	Design the evaluation to capture system dynamics, interdependencies and emerging interconnections
Aim to produce generalisable findings across time and space	Aim to produce context-specific understandings that inform ongoing innovation
Accountability focuses on and is directed to external authorities and funders	Accountability focused on learning and responding to what is unfolding
Evaluation engenders fear of failure	Evaluation feeds hunger for learning

Sources: Patton, 2010; Technopolis, 2018.

from on-the-ground projects and use these lessons to adjust visions and missions, which can then inform another round of experimentation (Geels and Raven, 2006; Loorbach, 2010). Repeated cycles of visioning, experimentation and evaluation provide a navigational strategy that is both goal-oriented (through visions and mission) and adaptive (through portfolios of experiments aimed at learning). Developmental evaluation is demanding and differs in several ways from traditional evaluations, which focus primarily on assessing whether money has been well spent and if pre-defined targets have been met (Table 12.2).

Traditional evaluation remains important for sustainability transition projects to provide financial and other forms of accountability. However, it should be complemented with developmental evaluations that:

- are repeated regularly (instead of focusing on a single funding round);
- take a wider, programmatic approach (instead of focusing on single projects);
- assess wider and more diffuse outcomes (rather than narrow technical goals), such as learning about the specific innovation, determining if visions or goals need to be adjusted, and understanding wider contexts and systems;
- communicate evaluation results back to practitioners and not only to external funders;
- aim to contribute to further development of the innovation (rather than just providing financial accounting).

While potentially powerful, developmental evaluations may be difficult to implement in real-world policy contexts (Box 12.1).

In terms of skills and competencies, developmental evaluations require in-depth knowledge of the particular innovation area and wider context; more subtle understandings of innovation processes (beyond input-output variables); and a wider awareness of how evaluations are part of knowledge development and strategy processes. Developmental evaluations also require sufficient time for data-collection, interpretation and stakeholder interaction.

12.3.2 Stakeholder interactions

Stakeholder interaction is generally important in governance approaches and especially crucial in sustainability transitions because policymakers are dependent on firms, researchers, non-governmental organisations (NGOs), cities, communities and the

Box 12.1 Real-world challenges in the United Kingdom policy evaluation, review and learning

Although policymakers agree that evaluations are important and often commission them, a study by the Institute for Government (Hallsworth et al., 2011), drawing on in-depth interviews with British senior civil servants and ministers, found that the government learns only a limited amount from evaluations. Lessons seldom feed back into policy design or problem formulation. The report identifies several reasons for this:

- **Policymakers are not very interested in the past.** Ministers tend to have limited interest in how effective their predecessors' policies were, and civil servants tend to be more geared towards looking forwards to the next big policy issue.
- **Timescales for evaluation and policymaking are out of sync**. If evaluations are published some years after the policy has been superseded, they rarely influence new policymaking. There is therefore a role for real-time evaluation of policy implementation that is more flexible.
- **Departments have incentives and opportunities to tone down unfavourable findings.** Independent evaluators may also provide lenient evaluations, especially if they depend on repeat contracts. Such curbing or softening of critical evaluation findings may, however, diminish learning opportunities.
- **Evaluations are often not built into policy design.** Early in the policy process, civil servants may show limited interest in evaluations because they are under pressure to deliver.
- **Evaluation findings are rarely collated and managed to provide a repository of knowledge.** Varying evaluation formats make it difficult to aggregate lessons and build a cohesive understanding.

wider public for knowledge, finance, innovation, social initiatives, legitimacy, social acceptance and creative foresight, as previous chapters have shown.

The need for public participation and stakeholder interactions is increasingly highlighted in policy documents. In practice, however, national and European policymaking are often rather bureaucratic (Kaiser and Schot, 2014), relying on in-house expertise and inputs from large companies. Policymakers may want to interact with stakeholders, but not give up too much control, which can lead to passive interaction processes (focused on informing or consulting) rather than active ones (based on advising and co-deciding). It can also produce a tendency to organise them in parallel to existing policy networks, which can limit their influence and create frustration as stakeholders' concerns are sidelined.

Another challenge is that citizens may be highly informed about their local contexts, but tend to have less expertise about abstract problems. Based on studies of public participation processes in Dutch infrastructure decisions at local, regional and national levels, Woltjer (2000) concludes that 'Most local and many regional parties feel that consensus building at an abstract, strategic level is too complicated and unclear ... It seems that a successful consensus process has to be concrete. It turns out that involving citizens or even interest groups in an abstract, strategic problem is very difficult'.

Correcting this institutional reality will call not only for better enabling governance conditions, but also for fine-tuned sets of professional competencies. Successful stakeholder interaction requires competence at:

- interacting with multiple stakeholders, not just large corporations and technical experts, but also citizens, small and medium-sized enterprises, NGOs and local authorities;
- acknowledging that some actors may legitimately have preferences, concerns, views or outlooks that deviate from the policy mainstream (e.g. valuing other dimensions than technical efficiency and least cost);

> 'Open innovation is about involving far more actors in the innovation process, from researchers, to entrepreneurs, to users, to governments and civil society.' (EC, 2016f)

- actively listening to concerns of all actors and not disqualifying some of them as uninformed or self-serving;
- broadening existing policy networks and providing a wider set of stakeholders with a seat at the table, to widen discussions;
- broadening analysis of problems and solutions beyond techno-economic rationalities, to accommodate multiple concerns and issues, abandoning the notion of a single best solution and instead searching for win-wins or compromise package deals that make actual implementation more likely;
- making adjustments in design parameters to alleviate stakeholder concerns (or offering other forms of compensation);
- creating multi-stakeholder networks or platforms for cooperation and coordination between local, national and European policymakers and various stakeholders on matters related to sustainability transition process;
- developing and communicating appealing narratives and missions that inspire and enthuse the wider public;
- convincing, motivating and cajoling, in order to build, maintain and expand support coalitions for missions, transition pathways or particular innovations;
- cooperating, negotiating, moderating, mediating and resolving conflicts.

12.3.3 Combining disciplines and approaches

Pluralising the knowledge base to include the insights from multiple academic disciplines and analytical perspectives will be essential to support the governance of transitions. As Hackman et al. (2014) note, for example 'It is remarkable that we keep perceiving problems that are caused by humans, that inflict harm on humans ... and that can only be solved by humans in terms of their biophysical nature, as matters of molecules, shifts in atmospheric dynamics or ecosystem interactions, imbalances in elemental cycles or merely as collapsing environmental systems.'

Another line of criticism questions if scientific research responds to the needs of policymakers and the public more broadly. Does it actually help guide choices towards solutions? Is science sufficiently engaged in transformative processes? Is science even developed and communicated in ways that are comprehensible and actionable?

These two sets of concerns explain the widespread calls in the scientific literature for research into sustainability challenges and solutions to be more transdisciplinary and developed through co-creative processes that bring together researchers, decision-makers and other stakeholders (e.g. IGBP et al., 2001; ESF and COST, 2011; Future Earth, 2014; Hackmann et al., 2014; Nature, 2015).

While the need to create a more balanced and integrated knowledge base is widely acknowledged, the barriers to achieving this goal are considerable. On the research side, they include 'disciplinary differences in language and terminology, methodologies and techniques, norms and expectations about research development and dissemination, and the criteria for prestige and self-actualisation' as well as very few career opportunities for participatory, integrative, user-engaged research (Cornell et al., 2013). More broadly, there are significant challenges in combining contrasting knowledge inputs (such as quantitative and qualitative evidence) that are based on fundamentally different assumptions and methods.

Full integration of the different approaches seems impossible, but a potentially promising strategy is bridging, based on dialogue and interaction of independent approaches (McDowall, 2014; Turnheim et al., 2015). Using contrasting but complementary approaches may enable governance strategies that accommodate multiple policy-relevant criteria. For example:

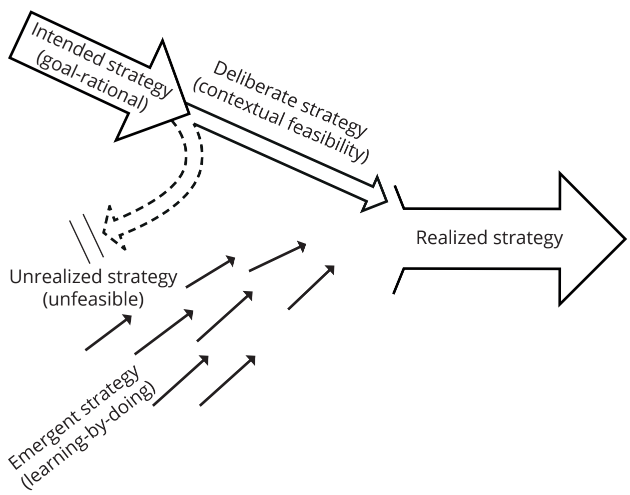
- Computer models and economic cost-benefit analyses may be used to offer goal-oriented analyses of the cost-efficiency of green options and their effectiveness in reaching environmental goals. These approaches, however, are often based on stylised assumptions with a techno-economic orientation.

- Socio-technical transitions theory may be useful in assessing the socio-political feasibility and social acceptance of green niche innovations by analysing the interpretations, strategies and resources of different social groups. Regime analysis of stability and tensions may also identify potential windows of opportunity for these niche innovations and degrees of resistance (barriers).

- Detailed action research of local projects may be useful to assess on-the-ground experiences with specific green solutions and to understand and address the concerns of specific stakeholders. Such analyses may not only inform policymakers about the social acceptance of particular transition pathways, but also identify novel bottom-up solutions, which introduce flexibility and creativity into the policy process.

This multi-approach strategy aligns with the synthesis of Mintzberg et al. (2005), who found that strategies in complex situations arise from combinations of intended, deliberate and emergent approaches (Figure 12.3). Such strategies allow decision-makers to combine goal-rational, contextual and experimental rationalities, which are arguably more suited for open-ended, non-linear and contested processes such as socio-technical transitions.

Figure 12.3 Realised strategies arising from combinations of intended, deliberate and emergent strategies



Source: Adapted from Mintzberg et al., 2005.

A more transdisciplinary approach to knowledge creation and communication would have diverse implications. For example, knowledge institutions at the science-policy interface, such as the Intergovernmental Panel on Climate Change (IPCC), could increasingly extend their focus from attribution of causes and impacts towards the evaluation and co-construction of possible solutions. Beck and Mahony (2017) argue, for example, that:

> By organizing solution-oriented assessment not just around [techno-economic pathways] but around different pathways of societal transformation, the IPCC can play a key role in facilitating dialogue about policy alternatives and their political implications. The IPCC is an incredibly powerful actor in climate politics. It is an important player in making futures, not just forecasting them — a role likely to intensify in a new solution-oriented mode.

Governance of sustainability transitions is likely to depend in part on the work of intermediary organisations, such as the IPCC, which bring together relevant solutions-oriented knowledge. Extending the focus of such organisations beyond climate change mitigation and adaptation to embrace other dimensions of sustainability would provide an important mechanism for linking the growing body of knowledge about sustainability science and transitions research to policy and action.

Glossary

Adaptive governance	Governance that aims to deal with the uncertainties and surprises inherent in transforming complex social and ecological systems. Adaptive governance relies particularly on iterative cycles of policymaking and planning, implementing, evaluating and learning.
Co-evolution	Dynamic interaction between systems or elements within a system. In the transitions context, co-evolution often refers to interactions of technologies, industries, markets, consumer behaviour, policy, infrastructure, spatial arrangements and cultural meaning.
Directionality	Deliberate orientation of social or technological change towards fulfilling particular objectives or goals.
Disruptive innovation	Innovation that significantly challenges existing systems, business models or practices — with positive and negative consequences. Disruptive innovation can lead to radically new systems and industries, but can also imply structural change, with significant socio-economic consequences.
Foresight	Foresight methods are structured techniques for exploring potential future developments and consequences in technology, society and other relevant topics. It includes a wide range of approaches that in varying degrees emphasise evidence, creativity and social interaction.
Grassroots innovation	Innovation involving local communities and civil society, which is informed by a bottom-up vision of change and reflects the interests and values of local communities. Grassroots innovation often relies on non-market processes (volunteering, civic engagement, informal economy).
Incremental Innovation	Innovation that makes small improvements in existing products or production techniques,aimed at efficiency improvement, optimisation or cost reduction.
Landscape	A landscape is an analytical category in the multilevel perspective that represents the exogenous macro-level environment of a system that cannot be directly influenced by system actors. Landscape changes include both slowly evolving megatrends and more sudden shocks (e.g. oil shocks, wars, crises).
Multilevel perspective	An analytical framework to understand the dynamics of socio-technical transitions at three levels: niche, regime and landscape. It explains systemic transitions in terms of dynamic interactions between these levels.
Niche	Socio-technical niches are protected spaces at the micro level, which provide favourable conditions for experimentation and development of radical innovations in relative isolation from mainstream market pressures.

Pathways	Pathways are alternative ways of achieving a transition, which vary in terms of actors, innovations, institutions and multilevel interactions.
Phase-out	The process and means through which existing products, practices or systems can be removed (sometimes termed 'exnovation'). Phase-out may accelerate transitions, but is challenging to implement because of resistance from vested interests (e.g. firms, employees).
Polycentric governance	In contrast to top-down, state-led coordination, polycentric governance acknowledges that power, capabilities and resources are dispersed and that change often involves bottom-up and self-organising actions, involving both state and non-state actors. Networks (formal and informal) are important sources of coordination.
Practice-based knowledge	An alternative to formal, codified knowledge. It includes the know-how, skills and tacit learning developed by practitioners. It is highly relevant to context-specific innovation processes and policy implementation.
Radical innovation	Radical innovations deviate significantly from established systems and incremental innovation trajectories in terms of the technology involved, user preferences and operational requirements (e.g. skills, infrastructure, regulations). Radical innovations therefore often face major barriers but also offer the potential to enable transformative change.
Regime	Regimes comprise the institutions (regulations, norms, values) that shape and coordinate socio-technical systems and actor networks. Regime rules are challenged and reformulated during transitions.
Scaling	A diffusion mechanism in which innovations are applied in successively bigger projects at larger scales, leading to learning, performance improvement and cost reduction (economies of scale). Social innovations often diffuse in other ways, such as 'scaling deep' (influencing values, narratives and beliefs) and 'scaling out' (replicating and adapting practices in new settings)
Socio-ecological system	Interconnections and mutual dependencies between humans and ecological systems (e.g. fisheries, forestry, agriculture, coral reefs).
Socio-technical system	The configuration of elements (technologies, markets, policies, user practices, cultural meanings, manufacturing) that underpin the fulfilment of societal functions such as mobility, heating, shelter and sustenance.
Sustainability transition	A fundamental and wide-ranging transformation of a socio-technical system towards a more sustainable configuration that helps alleviate persistent problems such as climate change, pollution, biodiversity loss or resource scarcities.
System innovation	Fundamental change in entire systems (e.g. energy, transport, agro-food), resulting from multiple radical innovations, and institutional and cultural changes. This implies a higher order of change than conventional understandings of innovation (e.g. regarding products or organisational forms). Different from 'innovation system'.
Technological Innovation Systems	The actors, networks and institutions that enable the emergence of novel technologies. Relevant activities in technological innovation systems include knowledge development and diffusion, entrepreneurial experimentation, influencing the direction of search, market formation, legitimation, resource mobilisation and developing positive externalities.

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